5.3 GEOLOGIC HAZARDS

5.3.1 Affected Environment

The Bullard Energy Center (BEC) site is located in the eastern San Joaquin Valley, which is part of the Central Valley. The Central Valley comprises about 20,000 square miles and extends from near Red Bluff on the north to near Bakersfield on the south, a distance of about 400 miles. The average width of the valley is about 50 miles. Elevations in the Central Valley range from slightly below mean sea level to 400 feet above mean sea level at its north and south ends. The Central Valley is bounded on the north by low-lying hills; on the northeast by a volcanic plateau of the Cascade Range; on the west by the Coast Ranges, which in places rise to elevations of about 4,000 feet above mean sea level; on the east by the Sierra Nevada, which in places rise to elevations of more than 14,000 feet above mean sea level; and on the south by the Coast Ranges and the Tehachapi Mountains. Roughly the northern one-third of the valley is known as the Sacramento Valley and the southern two-thirds as the San Joaquin Valley (Page 1986; Norris and Webb 1990).

The Central Valley is also referred to as the Great Valley geomorphic province. The most extensive geomorphic units in the province include dissected uplands, low alluvial plains and fans, river floodplains and channels, and overflow lands and lake bottoms. The valley represents the alluvial, flood, and delta plains of two major rivers (the Sacramento and San Joaquin rivers) and their tributaries. The region persisted as a lowland or shallow marine embayment during the entire Cenozoic and at least the later Mesozoic. In the late Cenozoic, much of the area was occupied by shallow brackish and freshwater lakes, particularly in the San Joaquin Valley which has had interior drainage in its southern third since the Pliocene (Page and LeBlanc 1969; Page 1986; Norris and Webb 1990).

5.3.1.1 Bullard Energy Center

The BEC site, including the power plant, construction laydown, electrical interconnection lines, natural gas pipelines, and access road are located south of the San Joaquin River on the high alluvial fan of the San Joaquin River. Some linears extend into the compound alluvial fan of intermittent streams north of the Kings River as defined by Page and LeBlanc (1969).

The high alluvial fans of the San Joaquin and Kings rivers are two of the largest geomorphic features in the Fresno area. These fans lie from 10 to 90 feet above the channels of the present day rivers and are not subject to inundation by the rivers (Page and Le Blanc 1969). The Fresno area alluvial fans form part of a continuum of fans along the eastern margin of the San Joaquin Valley structural trough. The sediments are derived from the Sierra Nevada to the east. The east side fans are formed by meandering or braided stream floodplain processes that contain more well-sorted, fine-grained material and have gentler slopes and a longer radial profile with greater surface area than the semiarid fans on the west side of the San Joaquin Valley. The east side fans have low relief with very gentle gradients (Cehrs et al. 1980).

The site elevation is about 300 feet above mean sea level and slopes gently with elevation decreasing to the south. The facilities are situated on a thick section of Quaternary alluvial and lacustrine sediments overlying older Quaternary and Tertiary alluvial deposits, sedimentary rocks, and minor volcanic rocks, Tertiary to Jurassic sedimentary rocks of the Great Valley sequence, and Mesozoic and Paleozoic crystalline basement complex rocks (Bartow 1991).

Regional Geology

The San Joaquin Valley is an asymmetrical basin defined by the Coast Ranges to the west, the Tehachapi Mountains to the south, the Sierra Nevada to the east, and the delta of the San Joaquin and Sacramento rivers to the north. The axis of the valley trough is closer to the Coast Ranges than to the Sierra Nevada (Belitz and Heimes 1990).

Bartow (1991) divided the San Joaquin Valley into five regions on the basis of differing structural style. Fresno is located within the northeast portion of the southern Sierran block near the arbitrary boundary with the northern Sierran block. The southern part of the block is similar in style to the northern part of the block, but has a higher degree of deformation. The southern Sierran block is the stable east limb of the valley syncline between the San Joaquin River and the Bakersfield arch. The sedimentary history of the San Joaquin basin, recorded in terms of unconformity-bounded depositional sequences, has been controlled principally by tectonism, but also by eustatic sea-level changes and, to a lesser degree, by climate. The early Cenozoic sedimentary history of the San Joaquin basin differs from that of the later Cenozoic: the former is characterized by a few long-lasting basin-wide depositional sequences, whereas the latter is characterized by shorter sequences of more local extent. Climate was an important factor in basin history only in the latest Cenozoic (late Pliocene and Pleistocene), when alpine glaciers in the Sierra Nevada and a pluvial climate influenced sedimentation. Evolution of the San Joaquin basin comprises the gradual restriction of the marine basin through uplift and emergence of the northern part in the late Paleogene, closing off of the western outlets in the Neogene, and finally the sedimentary infilling in the latest Neogene and Quaternary (Bartow 1991).

The rocks that crop out in the Fresno area or occur in the subsurface are divided into two general types, consolidated rocks and unconsolidated deposits. The consolidated rocks consist of the basement complex of pre-Tertiary age and marine and continental sedimentary rocks of Cretaceous and Tertiary age (Page and LeBlanc 1969). The oldest rocks in the area are basement complex rocks that form much of the Tehachapi Mountains, San Emigdio Mountains, and the southern Sierra Nevada which are composed of a mass of plutonic and metamorphic rocks commonly referred to as the Sierra Nevada batholith of pre-Tertiary age (Figure 5.3-1, Regional Geologic Map). Contours drawn on depth to the top of the basement complex indicate a depth to basement of about 4,000 feet below ground surface (bgs) at the BEC (Page and LeBlanc 1969), which is consistent with the basement rocks encountered at a depth of about 3,700 feet bgs in an exploration well drilled approximately 1.5-miles northwest of the site (ARCO Oil and Gas Company 1967).

Consolidated marine and continental sedimentary rocks of Cretaceous and Tertiary age consisting mainly of sandstone, sand, siltstone, and shale lie immediately over the basement complex (Page and LeBlanc 1969). Tertiary and older rocks are not well known because of the absence of Tertiary outcrops between the San Joaquin and Tule rivers, and because of the sparsity of deep wells in the area. Cross-sections prepared by Bartow (1991) indicate that a thinning to the east accumulation of Great Valley sequence rocks lie between basement complex

rocks and younger deposits underlying the BEC (Bartow 1991). The Great Valley sequence unconformably onlaps igneous and metamorphic basement complex rocks beneath the eastern San Joaquin Valley and is only exposed on the east side of the valley at the northern end (Bartow and Nilsen 1990). Based on the cross sections of Bartow (1991), Tertiary to Jurassic age Great Valley sequence rocks underlying BEC should not exceed 1,500-feet in thickness, and are probably less than 1,000 feet thick.

A series of predominantly nonmarine Tertiary clastic deposits rest on the Great Valley sequence rocks beneath the San Joaquin Valley floor. They dip gently southwestward beneath the Quaternary alluvial deposits. The oldest of these, the Eocene Ione Formation, consists primarily of quartz sandstone with interbedded kaolinitic clay, usually near the base. The sandstone becomes conglomeratic and very strongly cemented near the top, where it locally contains marine fossils. The Ione Formation is exposed along the east margin of the San Joaquin Valley and in the westernmost foothills of the Sierra Nevada. The Valley Springs Formation is an Oligocene and Miocene sequence of rhyolitic sandstone, siltstone, claystone, and conglomerate that overlies the Ione Formation. The Mehrten Formation is a Miocene to late Pliocene age conglomerate, sandstone, siltstone, and claystone derived from andesitic source material. The Valley Springs and Mehrten formations are exposed along the east side of the San Joaquin Valley from Merced County northward and north of the Fresno River, respectively. Tuffaceous silt, sand, and gravel deposits correlative with the older part of the Mehrten Formation are exposed near Friant. A regional angular unconformity separates the Mehrten Formation from the overlying Laguna Formation. The Laguna Formation is a granitic alluvium raging from gravel to fine silt. Isolated outcrops of these deposits are exposed nearly as far south as the Chowchilla River, and similar deposits occur near the mouths of the Kings and Kaweah rivers. The age of the Laguna Formation is Pliocene. Thin Pliocene or Pleistocene age lag gravels of the North Merced Gravel may be deposited on the Laguna Formation and may be traced at least as far south as the San Joaquin River (Marchand and Allwardt 1981). Based on the cross sections of Page and Leblanc (1969) and Bartow (1991), continental deposits of Quaternary and Tertiary age estimated to be about 2,400-feet thick underlie the BEC.

Local Geology – Stratigraphy

The Modesto, Riverbank, and Turlock Lake Formations, all Pleistocene in age, comprise the major surface and subsurface stratigraphic and lithologic units of the Fresno area fans (Cehrs et al. 1980). These three formations are similar because of the arkosic nature of their sand and silt fractions, a tendency toward upward coarsening sedimentation cycles, deposition as sequential overlapping alluvial terrace and fan systems, and probable glacial origin of most of the sediment (Marchand and Allwardt 1981). The base of Quaternary age deposits appears to correlate with a change in resistivity with high resistivity coarse-grained materials overlying low resistivity fine-grained materials (Page and LeBlanc 1969).

The Turlock Lake Formation is the oldest unit exposed in the Fresno fans and forms extensive subsurface deposits throughout the San Joaquin Valley (Cehrs et al. 1980). The thickness of the Turlock Lake Formation is variable and appears to increase to the west. In the Chowchilla area north of the BEC, the formation ranges in thickness up to about 500 and 230 feet thick for the lower and upper units, respectively (Marchand and Allwardt 1981). These deposits extend west to the valley axis where they interfinger with the aerially extensive Corcoran Clay. The Corcoran Clay is an important hydrologic unit in the axial and western San Joaquin Valley.

Turlock Lake Formation sediments are homogeneous, exhibiting laminated to thick bedding with gradational, abrupt, or erosional bedding planes (Cehrs et al. 1980).

The Riverbank Formation overlies the Turlock Lake Formation and is composed of heterogeneous sediments that are poorly sorted with a variety of mineralogies. In the Fresno area, the Riverbank Formation is between 15- and 30-feet thick and includes an extensive, though not pervasive, iron-silica hardpan in its upper portions which is present both subareally and subsurface. The Riverbank Formation is similar to the overlying Modesto Formation in its distinguishable features but is more massively bedded with a few gradational bedding planes (Cehrs et al. 1980).

The Modesto Formation and the associated post-depositional alluvium comprise the youngest unit of the Fresno fans. These deposits cover a large part of the central San Joaquin Valley, and include fan, axial basin, and river channel deposits. In the Fresno area, Modesto Formation sediments are a 10- to 30-feet thick veneer that shows little if any erosional modification. The Modesto Formation is a heterogeneous unit comprised of a wide spectrum of mineralogies, principally of granitic and metamorphic origins but with some volcanics. Modesto Formation bedding is typically massive, without any distinguishable gradational bedding planes (Cehrs et al. 1980).

Published geologic mapping of the site at a 1:250,00 scale indicates that geologic materials exposed within a 2-mile radius of the site are limited to Pleistocene nonmarine sediments and recent stream channel deposits (CDMG 1966) (Figures 5.3-2A and 5.3-2B, Site Geologic Map). More detailed (1:125,000 scale) mapping of Quaternary deposits of the northeastern San Joaquin Valley extended to about 4 miles north of the site but did not include the BEC or linears (Marchand and Allwardt 1978).

Figure 5.3-3, Stratigraphic Section, summarizes the local stratigraphic nomenclature. The underlying basement rocks and marine and non-marine sedimentary rocks of Tertiary age included in Figure 5.3-3 are of regional significance but are not exposed within a 2-mile radius of the site.

Local Geology – Groundwater

The Fresno area is underlain by an impermeable basement complex and poorly permeable consolidated marine and continental sedimentary rocks. The consolidated marine and continental sedimentary rocks contain water unsuitable for most uses and are not typically penetrated by water wells. These rocks are overlain by unconsolidated deposits, which are divided into lower fine-grained sediments and upper coarse-grained sediments. The principal aquifer system containing fresh groundwater is the unconsolidated coarse-grained deposits. Quaternary age deposits yield more than 90 percent of the water pumped from wells in the Fresno area (Page and Leblanc 1969; Mitten 1984). Nearly all of the fresh groundwater (less than 2,000 milligrams per liter [mg/L] of dissolved solids) in the Central Valley is contained in rocks and deposits younger than Eocene age. Marine deposits underlying large parts of the Central Valley generally contain saline water, some of which has migrated into adjacent and overlying freshwater aquifers (Bertoldi et al. 1991). Based on the cross section of Page and LeBlanc (1969) and map of Page (1973), the depth to the base of fresh groundwater underlying the BEC is estimated to be between about 1,360 feet and 1,000 feet below ground surface (bgs), respectively.

The aquifer is generally unconfined except to the southwest where clay layers including the Corcoran Clay act as confining beds. Corcoran Clay (modified E Clay) deposits are located about 18 miles west of the BEC (Page 1986). Locally, intercalated clays within the coarse-grained sediments can cause partial confinement. Very little water moves upward from the fine-grained deposits. Most wells in the area penetrate only the upper part of the coarse-grained sediments. Groundwater generally flows toward the southwest, although pumping depressions near and west of Fresno locally cause groundwater to move toward the depressions (Mitten 1984).

The alluvial Turlock Lake, Riverbank, and Modesto formations contain aquifers with increasing thickness to the west. West of Fresno, the Corcoran Clay separates the younger unconsolidated sedimentary fill into an upper and lower portion, which have differing water chemistries and hydraulic heads. Production wells in Fresno pump water from the Turlock Lake Formation (Cehrs et al. 1980). Flood basin deposits within the Modesto Formation may impede movement of water and restrict yields to wells. River deposits within the Modesto Formation are among the more permeable deposits in the valley (Page 1986).

In general, groundwater on the east side of the Central Valley is bicarbonate type and has low to moderate dissolved-solids concentrations. Groundwater chemistry in the eastern part of the San Joaquin Valley commonly resembles the chemical type of the local surface water that recharges the groundwater. Problem compounds in groundwater can include high chloride concentrations near the San Joaquin River, high concentrations of nitrate around the Fresno metropolitan area, and dibromochloropropane (DBCP) near orchards and vineyards (Bertoldi et al. 1991).

In spring 2004, the elevation of the top of groundwater within the unconfined aquifer was about 200 feet above mean sea level at the BEC, based on published California Department of Water Resources data (www.sjd.water.ca.gov/groundwater/basin_maps/maps/king_e04/).

Groundwater is also discussed in Section 5.5, Water Resources.

Local Geology – Structure

The San Joaquin Valley is synclinal structure between the tilted block of the Sierra Nevada on the east and the complexly folded and faulted Coast Ranges on the west. The Sierra Nevada is uplifted along its eastern flank and depressed along its western flank where it is overlain by sedimentary deposits of the San Joaquin Valley. Beneath the San Joaquin Valley, a westwardly thickening wedge of sediments overlies crystalline basement rocks similar to those exposed in the Sierra Nevada. Indirect evidence suggests that the Sierra Nevada block extents westward to the flanks of the Coast Ranges (Miller et al. 1971).

The large northwest-trending syncline between the Sierra Nevada and the Coast Ranges is the principal late Cenozoic structure in the San Joaquin Valley. The axial part of the syncline has subsided at a minimum rate of 0.7 to 1 foot per 1,000 years during the past 600,000 years. The structural axis 3 to 6 miles east of the western valley margin has remained stationary during the late Quaternary and governs the general location and orientation of the valley. The topographic axis (trough) of the valley, approximated by the interface of Sierran sands and Coast Range alluvium in the valley subsurface, has rarely coincided with the structural axis, suggesting that rates of sedimentation have equaled or exceeded rates of subsidence (Lettis 1982).

Buried or partially buried faults that have offset the basement rock surface have been inferred near Clovis northeast of Fresno. The presence of these inferred faults is based principally on surface lineaments and a steeply west-sloping basement surface, but no fault offsets have been convincingly demonstrated. In contrast with the northern Sierran block where the normal faulting is mostly late Cenozoic in age, faulting appears to be mostly Miocene or older in the southern part of the block (Bartow 1991).

The Diablo Range (the most easterly of the Coast Ranges) forms the western border of the San Joaquin Valley. The structure of this range is a broad anticline with an eastern monoclinal limb dipping beneath the valley. The exposed core of the range is formed by complexly folded and contorted sedimentary and igneous rocks of the Franciscan Formation. Lesser folds pass beneath the valley and trend obliquely to the range. Structural complexity along the west flank of the Coast Ranges generally increases in a southward direction. Less deformed sedimentary strata exposed along the western border of the valley and folded during the uplift of the Coast Ranges range in age from Late Cretaceous to Quaternary in age (Miller et al. 1971).

Plate Tectonic Setting

Persistent tectonic activity affected much of the Central Valley during the Cenozoic and is shown by the numerous unconformities that occur in the deposits that underlie the valley margins. At least four or five erosional events separate Cenozoic deposits from one another and indicate that deposition in the central parts of the valleys continued with little interruption during most of the Cenozoic, but deposition was frequently separated by tectonism and erosion along the margins of the bordering mountain ranges (Norris and Webb 1990).

The boundary between the North American and Pacific tectonic plates lies within 65 miles southwest of the site. The site is located on the North American tectonic plate, which is separated from the Pacific tectonic plate by the San Andreas fault. The relative motion between these two plates has been determined from paleomagnetic lineations in the Gulf of California, from global solutions to known slip rates along plate boundaries, from geology, and from geodesy (Minster and Jordan 1978; DeMets et al. 1987; Wallace 1990) to be primarily horizontal at a rate of about 50 millimeters a year (DeMets et al. 1987). On a broad scale, the North American-Pacific tectonic plate boundary in California is a transform fault that extends from the Gulf of California to Cape Mendocino. The San Andreas fault and the transform plate boundary end to the north at the Mendocino Triple Junction in northernmost California. North of Cape Mendocino, the spreading center and subduction zone of the Juan de Fuca plate lie between the North American and Pacific tectonic plates. At the southern end, another spreading center lies in the Gulf of California, creating parts of the Pacific and Rivera tectonic plates. The transform faults of that spreading center merge into the San Andreas fault system near the Imperial Valley and the Salton Sea (Hutton et al. 1991).

Seismicity and Seismotectonics

Most of Fresno County is situated within an area of relatively low seismic activity. Faults and fault systems that lie along the eastern and western boundaries of the county, as well as other regional faults, have the potential to produce high-magnitude earthquakes throughout the county. High magnitude earthquakes on these faults could cause moderate intensity ground shaking in the county (Fresno County 2000).

Significant Quaternary Faults

Quaternary faults located within about 62 miles (100 kilometers) of the BEC include the Ortigalita, San Andreas, and Nunez faults. An "active fault" is defined by the California Division of Mines and Geology (CDMG) as one that has had surface displacement within the last 11,000 years. Faults with no evidence of surface displacement with the last 11,000 years (i.e., Holocene age) are not necessarily inactive. Potentially active faults have shown displacement within the last 1.6 million years (Quaternary age). "Inactive faults" show no evidence of movement in historic or recent geologic time, suggesting that the faults are dormant (Fresno County 2000).

The Alquist-Priolo Earthquake Fault Zoning Act of 1994 (formerly known as the Alquist-Priolo Special Studies Zone Act of 1972) stipulates that no structure for human occupancy may be built within an Earthquake Fault Zone until geologic investigations demonstrate that the site is free of fault traces that are likely to rupture with surface displacement (Fresno County 2000). The Ortigalita fault zone, the San Andreas fault zone, and the Nunez fault are described because they are the closest designated Earthquake Fault Zones to the site. The Clovis fault, Foothills fault system, and Great Valley thrust faults are also described due to their proximity to the site and potential for activity. The site is not located within an Earthquake Fault Zone. Significant regional faults are shown on Figure 5.3-4, Regional Fault Map.

Ortigalita Fault Zone

The Otigalita fault zone is approximately 50-miles long, originating near Crow Creek in western Stanislaus County and extending southeast to a few miles north of Panoche in western Fresno County. Most of the fault is considered active due to displacement during Holocene time (Fresno County 2000).

The Ortigalita fault zone is a major Holocene dextral strike-slip fault in the central Coast Ranges that is an eastern part of the lager San Andreas fault system. The Ortigalita fault zone is about 54 miles from the site at its closest point. The Ortigalita fault zone extends from about 12.4 miles northwest of San Luis Reservoir southeast to the vicinity of Panoche Valley. The Ortigalita fault zone is characterized by echelon fault traces separated by pull-apart basins. The fault zone is divided into four sections. The Little Panoche Valley section is the southern most section and is closest to the site. The Little Panoche Valley section is late Holocene active. Late Quaternary slip rates and recurrence intervals are unknown, although the recurrence interval for the entire Ortigalita fault zone is about 2,000 to 5,000 years. The vertical slip rate is at least 0.01-0.04 millimeters per year. The dextral slip component is probably greater than the vertical component and is estimated to be 0.5 to 1.5 millimeters per year (USGS 2006a).

San Andreas Fault Zone

The San Andreas fault lies to the west and southwest of the site. The fault is considered active and is of primary concern in evaluating seismic hazards throughout western Fresno County (Fresno County 2000). The 684-mile-long San Andreas fault zone is the principal element of the San Andreas fault system, a network of faults with predominantly dextral strike-slip displacement that collectively accommodates the majority of relative north-south motion between the North American and Pacific plates. The San Andreas fault zone is the most extensively studied fault in California, and perhaps the world. The creeping section of the San Andreas fault is about 64 miles from the site at its closest point. The San Andreas fault zone is

considered to be the Holocene and historically active dextral strike-slip fault that extends along most of coastal California from its complex junction with the Mendocino fault zone on the north, southeast to the northern Transverse Range and inland to the Salton Sea, where a well-defined zone of seismicity transfers the slip to the Imperial fault along a right-releasing step (USGS 2006b).

Two major surface-rupturing earthquakes have occurred on the San Andreas fault in historic time: the 1857 Fort Tejon and 1906 San Francisco earthquakes. Additional historic surface rupturing earthquakes include the unnamed 1812 earthquake along the Mojave section and the northern part of the San Bernardino Mountains section, and a large earthquake in the San Francisco Bay area that occurred in 1838 that was probably on the Peninsula section. Historic fault creep rates are as high as 32 millimeters per year for the 82-mile-long creeping section in central California with creep rates gradually tapering to zero at the northwestern and southeastern ends of the section. Average slip rates for the San Andreas fault zone exceed 5.0 millimeters per year (USGS 2006b).

Nunez Fault

The Nunez fault is located approximately 6 to 7 miles northwest of Coalinga and is about 63 miles from the site at its closest point. The fault is about 2.6 miles long and is considered active based on surface rupture associated with the 1983 Coalinga earthquake. The fault is divided into two north and south trending segments. About 2.1 miles of right-reverse surface rupture occurred on the segments. Total displacement and timing of past fault movements are poorly constrained (Rymer and Ellsworth 1990; Fresno County 2000).

Clovis Fault

The northwest-trending Clovis fault is believed to be located approximately five to six miles east of the City of Clovis, extending from an area just south of the San Joaquin River to a few miles south of Francher Creek. The fault is about 13 miles from the site at its closest point. The Clovis fault is considered a pre-Quaternary fault with no recognized Quaternary displacement. The fault is not necessarily inactive (Fresno County 2000).

Foothills Fault System

The southern part of the Foothills fault system, located approximately 70 to 80 miles north of the City of Fresno, includes the Bear Mountains fault and the Melones fault zone, as well as numerous smaller, but related faults. According to CDMG data, these faults have not shown any activity during the last 1.6 million years; however, geologic investigations of the seismic safety of the Auburn Dam site suggest that these faults are potentially active. Therefore, the possibility exists that earthquakes could occur on these faults (Fresno County 2000).

Great Valley Thrust Faults

The Great Valley thrust faults have been divided into at least 14 segments extending over 300 miles in cumulative length based on geomorphic interpretation of the range front bordering the western edge of the Central Valley (USGS 2006b). The Great Valley thrust faults are not shown on Figure 5.3-4, Regional Fault Map, because their location is poorly constrained. The closest Great Valley thrust fault is about 45 miles from the site at its closest point. Recent evidence suggests that the faults located along the western boundary of the San Joaquin Valley may be more active than once believed. Asymmetrical folds identified on the eastern slopes of

the Coast Ranges can hide faults that show no surface rupture. The faults and folds along the Coast Range-Sierran Block Boundary (Great Valley thrust faults) are similar or include the faults and folds that were the source of the 1983 Coalinga earthquake. The Great Valley thrust faults are now believed to be active and capable of generating large magnitude earthquakes (Rymer and Ellsworth 1990; Fresno County 2000). The Great Valley thrust faults are not identified as Earthquake Fault Zones.

Ground Shaking

Ground shaking is the most significant geologic hazard at the site. The BEC is situated within an area of relatively low seismic activity (Fresno County 2000).

The California Energy Commission (CEC 1989) recommends that non-nuclear power plants be designed to the level of conservatism implied by the Uniform Building Code (ICBO 1997). Chapter 15.08.020 CC of the Fresno County Building Code defines the site within Seismic Zone 3 as defined in the 1998 Edition of the California Building Code. The Seismic Zone definitions of the 1998 Edition of the California Building Code are based on the 1997 Edition of the Uniform Building Code (UBC). The closest type A fault to the site is the San Andreas fault, which is about 64 miles from the site at its closest point. The closest type B fault to the site is a segment of the Great Valley thrust faults, which is about 45 miles from the site at its closest point.

The estimated peak horizontal ground acceleration at the BEC is less than 0.2g. The estimated peak horizontal ground acceleration is a fraction of acceleration due to gravity (g) based on a 10 percent probability of being exceeded in 50 years. Estimated peak horizontal ground acceleration in Fresno County ranges from 0.1g in the valley and foothills increasing outward to as high as 0.7g or greater in a small area in the southwestern part of the county (Fresno County 2000). Estimated ground motions based on interpolated values may not equal values calculated for a specific site, and should be considered preliminary.

Based on site-specific preliminary geotechnical recommendations prepared by Kleinfelder, Inc., there are no geotechnical factors at the site that are unique or necessitate special seismic considerations for design of the structure (see Appendix L, Geotechnical Report). Use of the 2001 California Building Code seismic design criteria is considered appropriate unless the structural engineer requires more specific data. The Soil Profile Type is Sd, the governing Seismic Source Type is B, the Seismic Zone is 3, and the Seismic Zone Factor (Z) is 0.3 (Kleinfelder 2006).

Ground Rupture

No faults were identified within 2 miles of the site (Bartow 1991; Fresno County 2000). The nearest Earthquake Fault Zone as defined by the Alquist-Priolo Earthquake Fault Zoning Act of 1994 is the Ortigalita fault zone, which is about 54 miles from the site at its closest point. Earthquake Fault Zones include faults considered to have been active during Holocene time and to have a relatively high potential for surface rupture (CDMG 2000). Ground rupture is not likely at the site.

Liquefaction

Liquefaction is a phenomenon whereby loose, saturated, granular soils lose their inherent shear strength due to excess pore water pressure build-up such as that generated during repeated cyclic loading from an earthquake. A low relative density of the granular materials, shallow groundwater table, long duration, and high acceleration of seismic shaking are some of the factors favorable to cause liquefaction. Presence of predominantly cohesive or fine-grained materials and/or absence of saturated conditions can preclude liquefaction. Liquefaction hazards are usually manifested in the form of buoyancy forces during liquefaction, increase in lateral earth pressures due to liquefaction, horizontal and vertical movements resulting from lateral spreading, and post-earthquake settlement of the liquefied materials.

No specific countywide assessments to identify liquefaction hazards have been performed. Ground accelerations must approach 0.3g before liquefaction occurs in a sandy soil with relative densities typical of San Joaquin alluvial deposits (Fresno County 2000). Recent soil borings drilled at the site did not encounter groundwater to the maximum depths explored of 101.5 feet bgs (Kleinfelder 2006). The depth to groundwater is expected to be around 100 feet bgs. The depth to groundwater makes liquefaction at the site unlikely.

Erosion and Sedimentation

The primary causes of erosion at the site are wind and water. Although considered to be a secondary hazard, wind erosion is a possibility due to windy conditions combined with fine windborne silt particles. Water erosion is also a secondary hazard due to the relatively flat topography and paving at the site.

The soils exposed at the site consist of Exeter sandy loam and Exeter loam (see Section 5.4, Agriculture/Soils). Within the valley, erosion is generally not problematic except for areas containing Rossi soil near the Fresno Slough west of the site. Severe erosion potential has been identified along the San Joaquin River Bluff north of the site (Fresno County 2000). The erosion hazard of the Exeter sandy loam and Exeter loam present at the site is slight (USDA 1971).

The City of Fresno grading and erosion control ordinance (Fresno Building Code Section 12-1210 – Grading and Erosion Control) stipulates that approved parcel maps shall be conditioned on compliance with the requirements for grading and erosion control, including the prevention of sedimentation or damage to off-site property, set forth in Appendix Chapter 70 of the Uniform Building Code, 1973 Edition, Volume I, as adopted and amended by the city as part of the Code.

Grading and site plans would consider the slight hazard of potential erosion and sedimentation at the site. The site-specific geotechnical report (see Appendix L, Geotechnical Report) indicates that drainage away from the improvements should be provided to prevent ponding or saturation of the soils in the vicinity of foundations, concrete slabs-on-grade, or pavements. Poor surface drainage could cause reduced subgrade support. The site should be graded to carry surface water away from the improvements and convey it to proper discharge points (Kleinfelder 2006).

Landslides

The CDMG has not developed landslide hazard maps for Fresno County. There is no risk of large landslides in the valley area due to its relatively flat topography. There is potential for small slides and slumping along the steep banks of rivers or creeks (Fresno County 2000).

The existing topography at the site does not provide sufficient relief that would cause concern due to potential landslides. There are no topographic features of significant relief that could present a landslide hazard to the facility within 2 miles of the site. The south bank of the San Joaquin River is located approximately 1.7 miles north of the site but is too distant to pose a landslide hazard to the site. Various canals and ditches surrounding the site are too shallow to pose a landslide hazard.

Based on general screening criteria, the site topography does not meet the categories for geologic environments likely to produce earthquake-induced landslides. Cut slopes and fills constructed for the planned site facilities would consider stability against landslides.

Subsidence and Settlement

Subsidence occurs when a large portion of land is displaced vertically, usually due to the withdrawal of groundwater, oil, or natural gas. Soils that are particularly susceptible to subsidence include those with high silt or clay contents. Subsidence caused by groundwater withdrawal can affect large areas (Fresno County 2000).

About one half of the San Joaquin Valley has been affected by subsidence (Poland, et al. 1975). Most of the subsiding area in the San Joaquin Valley is underlain by a continuous and extensive confining bed, and most of the pumping overdraft and compaction due to head decline occurs in the confined aquifer system beneath this bed. North of Wasco, the confining bed is the Pleistocene Corcoran Clay Member (E-Clay) of the Tulare Formation (Ireland, et al. 1984); these deposits are located about 18 miles west of the BEC (Page 1986). The BEC and linears are located in an area with little or no subsidence (Poland, et al., 1975, Ireland, et al., 1984, Ireland, 1986, Fresno County, 2000).

Settlement can occur in poorly consolidated soils during groundshaking. Earthquake induced settlement can cause distress to structures supported on shallow foundations, damage to utilities that serve pile-supported structures, and damage to lifelines that are commonly buried at shallow depths (Kramer 1996). During settlement, the soil materials are physically rearranged by the shaking to result in a less stable alignment of the individual minerals. Settlement of sufficient magnitude to cause significant structural damage is normally associated with rapidly deposited alluvial soils, or improperly founded or poorly compacted fill (Fresno County 2000). Some soils encountered during the geotechnical investigation of the site were relatively loose; however, peak site accelerations at the site are unlikely to be high enough to produce settlement (Kleinfelder 2006).

Expansive Soils

Expansive soils are those that greatly increase in volume when they absorb water and shrink when they dry out. Expansion is measured by shrink-swell potential, which is relative volume change in soil with a gain in moisture. Soils with moderate to high shrink-swell potential may damage buildings, roads, and other structures built on them. The BEC is not located within an area of soils exhibiting moderately high-to-high expansion potential (Fresno County 2000). Based on geotechnical assessment, foundation soil is expected to have a low expansive potential (Kleinfelder 2006).

Soils are discussed more completely in Section 5.4, Agriculture/Soils.

Flooding

The east side of Fresno County is drained primarily by the San Joaquin and Kings rivers (Fresno County 2000). Other than the San Joaquin River north of the site, all streams in the mapped area are intermittent or ephemeral, flowing only during stormwater runoff events. The drainage of the site is toward the northwest and consists of overland sheet flow. The topography slopes northwest at less than 1 percent grade (USGS 1978). The site is ultimately drained by the San Joaquin River into the Sacramento River delta. Major flooding is not expected at the site but sheet overland flow and pooling in low areas is probable during heavy or prolonged storms.

The site is located outside the 500-yr floodplain determined on the FEMA Flood Insurance Rate Map (Zone X) (FEMA 2005). The boundaries of the 100-yr floodplain are delineated by FEMA on the basis of hydrology, topography, and modeling of flow during predicted rainstorms. The analysis of predicted flooding does not account for the effects of continued land subsidence or increases in sea level (Fresno County 2000).

Seiches are standing waves produced in a body of water such as a reservoir, lake, or harbor by wind, atmospheric changes, or earthquakes. No large bodies of water have been identified within 2 miles of BEC or linears. Earthquake induced seiches are not considered a risk in Fresno County. The effects from a seiche would be similar to the flood hazard for a particular area, and the risk of occurrence is perceived as considerably less than that risk of flooding (Fresno County 2000).

5.3.2 Environmental Consequences

No adverse effect on geological resources is expected from construction or operation of BEC and associated linear components. The project site is relatively flat and incorporates recent alluvial sediments of little recreational value. There are no known geologic resources that provide a significant scientific value in the vicinity of the site. Aggregate and petroleum are considered the county's most significant extractive mineral resources (Fresno County 2000).

There are no known mines or aggregate borrow operations in the immediate vicinity of the plant site. The site is located within the Fresno aggregate materials production-consumption region but is outside of areas where adequate information indicates that significant mineral deposits are present, or where it is judged that there is a high likelihood of their presence (i.e., MRZ-2) (CDMG 1988, Fresno County 2000). The Fresno production-consumption region includes urban and urbanizing parts of Fresno and Madera counties. The closest permitted mine producing

portland cement concrete aggregate is Calaveras Materials, Inc. located approximately 4 miles northeast of the site. All of the aggregate produced within the Fresno production consumption region is consumed within the region (CDMG 1999, Fresno County 2000).

The Raisin City oil field is located about 17 miles southwest of BEC. Peak oil and gas production from the field occurred in 1956 and 1959, respectively (DOGGR 1985 and 2006). An exploratory well was drilled approximately 1.5 miles northeast of the site and an electric log of the hole encountered "basement" at a depth of about 3,700 feet bgs (ARCO Oil and Gas Company 1967). The site is not located within a known oil or gas field.

Fresno County has been a leading producer of minerals because of the abundance and wide variety of mineral resources that are present in the county. However, no collectable or marketable minerals are known to be present within 2 miles of the site (Fresno County 2000). The BEC is not expected to impact geologic resources of commercial value.

5.3.3 Laws, Ordinances, Regulations, and Standards Compliance

The Fresno Building Code (FBC) indicates building codes that are currently in use for an "industrial facility" constructed at the site.

The City of Fresno has adopted the "2001 California Building Standards Code" (this part known as the California Building Code (CBC), as promulgated by the California Building Standards Commission, which incorporates the adoption of the 1997 edition of the Uniform Building Code as amended with necessary California amendments and the 1997 Uniform Building Code, volumes 1 and 2, of the International Conference of Building Officials, except as otherwise provided by the FBC.

The BEC will conform to all applicable LORS related to geological resources. At least 30 days (or a lesser number of days mutually agreed to by the BEC and the Chief Building Official [CBO]) prior to the start of construction, the BEC will submit to the Compliance Project Manager (CPM) for approval the name(s) and license number(s) of the certified engineering geologist(s) assigned to the project. The submittal will include a statement that the CPM's approval is needed. The CPM will approve or disapprove of the engineering geologist(s) and will notify the BEC of its findings within 15 days of receipt of the submittal. If the engineering geologist(s) is subsequently replaced, the BEC will submit for approval the name(s) and license number(s) of the newly assigned individual(s) to the CPM. The CPM will approve or disapprove of the engineering geologist(s) and will notify the BEC of the findings within 15 days of receipt of the notice of personnel change.

The BEC shall include in the application for a grading permit a report of the liquefaction analysis, and a summary of how the results of this analysis were incorporated into the project grading plan, for the CBO's review and comment.

1. Within 15 days after submittal of the application(s) for grading permit(s) to the CBO, the BEC will submit a signed statement to the CPM stating that the Engineering Geology Report has been submitted to the CBO as a supplement to the plans and specifications and that the recommendations contained in the report are incorporated into the plans and specifications.
2. Within 90 days following completion of the final grading, the BEC will submit copies of the Final Engineering Geology Report to the CBO, and to the CPM on request.

Applicable laws, ordinances, regulations, and standards (LORS) are discussed below and are summarized in Table 5.3-1, LORS Applicable to Geologic Hazards and Resources.

TABLE 5.3-1
LORS APPLICABLE TO GEOLOGIC HAZARDS AND RESOURCES

LORS	Applicability	Conformance (Section)
Federal	No Federal LORS are applicable	See Section 3.12
State		
Cal PRC S25523(a), Alquist-Priolo Earthquake Fault Zoning Act of 1994	Act addresses the seismic hazard of surface rupture – Not Applicable because site is not located in an Earthquake Fault Zone	5.3.1.1.9
California Building Code, Chapters 16 and 33	Codes address excavation, grading, and earthwork construction, including construction applicable to earthquake safety and seismic activity hazards	5.3.3
Local		
FBC Section 12-1210, Grading and Erosion Control	Stipulates that approved parcel maps shall be conditioned on compliance with the requirements for grading and erosion control	5.3.3
FBC Section 13-100, Seismic Zone 4 Near-Source Factor	Amends CBC Section 1629.4.2.1 – Not applicable because site is in Seismic Zone 3	5.3.1.1

Notes:
FBC = Fresno Building Code
LORS = laws, ordinances, regulations, and standards
PRC = Public Resources Code

5.3.3.1 Federal

No federal LORS are applicable.

5.3.3.2 State

California Public Resources Code Section 25523(a): 20 California Code of Regulations (CCR) Section 1752(b) and (c)

The project site is not within an Earthquake Fault Zone as defined by the Alquist-Priolo Earthquake Fault Zone Act.

5.3.3.3 Local

California Building Code, Appendix Chapter 33

This element sets forth rules and regulations to control excavation, grading, and earthwork construction, including fills and embankments. It establishes basic policies to safeguard life, limb, property, and public welfare by regulating grading on private property.

The geotechnical engineer and engineering geologist will certify the placement of fills and adequacy of the site for structural improvements in accordance with the CBC, Appendix Chapter 33.

The geotechnical engineer will address Sections 3309 (Grading Permit Requirements), 3312 (Cuts), 3315 (Drainage and Terracing), 3316 (Erosion Control), 3317 (Grading Inspection), and 3318 (Completion of Work) of the CBC, Appendix Chapter 33.

5.3.3.4 Agencies and Agency Contacts

Agencies with jurisdiction to issue applicable permits and/or enforce LORS related to geologic hazards and resources, and the appropriate contact person are shown in Table 5.3-2, Applicable Agencies and Agency Contacts.

TABLE 5.3-2
APPLICABLE AGENCIES AND AGENCY CONTACTS

Agency	Contact/Title	Telephone
California Energy Commission	Michael Stephens, Geologist	916-651-0315
State of California, Division of Mines and Geology	Library, Dale Stickney	916-327-1850
County of Fresno, Planning Department	Phil Desatoff	559-443-5346
City of Fresno, Planning and Development Department	Arnoldo Rodriguez	559-621-8633

5.3.3.5 Applicable Permits

A grading permits may be issued by the City of Fresno based on a review of the grading plan and the Geotechnical Investigation Report (see Appendix L, Geotechnical Report).

Compliance with UBC standards will be addressed by engineering and construction permits to be issued for the BEC. No other permit requirements that specifically address geologic resources and hazards have been identified.

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Adequacy Issue: Adequate ____ Inadequate ____

DATA ADEQUACY WORKSHEET

Revision No. 0 Date ____

Technical Area: **Geological Hazards** Project: ____ Technical Staff: ____

Project Manager: ____ Docket: ____ Technical Senior: ____

SITING REGULATIONS	INFORMATION	AFC PAGE NUMBER AND SECTION NUMBER	ADEQUATE YES OR NO	INFORMATION REQUIRED TO MAKE AFC CONFORM WITH REGULATIONS
Appendix B (g) (1)	...provide a discussion of the existing site conditions, the expected direct, indirect and cumulative impacts due to the construction, operation and maintenance of the project, the measures proposed to mitigate adverse environmental impacts of the project, the effectiveness of the proposed measures, and any monitoring plans proposed to verify the effectiveness of the mitigation.	5.3		
Appendix B (g) (17) (A)	A summary of the geology, seismicity, and geologic resources of the project site and related facilities;	5.3.1, 5.3.2		
Appendix B (g) (17) (B)	A map at a scale of 1:24,000 and description of all recognized stratigraphic units, geologic structures, and geomorphic features within 2 miles of the project site. Include an analysis of the likelihood of ground rupture, seismic shaking, mass wasting and slope stability, liquefaction, subsidence, and expansion or collapse of soil structures.	5.3.1		
Appendix B (g) (17) (C)	A map and description of geologic resources of recreational, commercial, or scientific value which may be affected by the project. Include a discussion of the techniques used to identify and evaluate these resources.	5.3.1, 5.3.2		

Adequacy Issue: Adequate _____ Inadequate _____

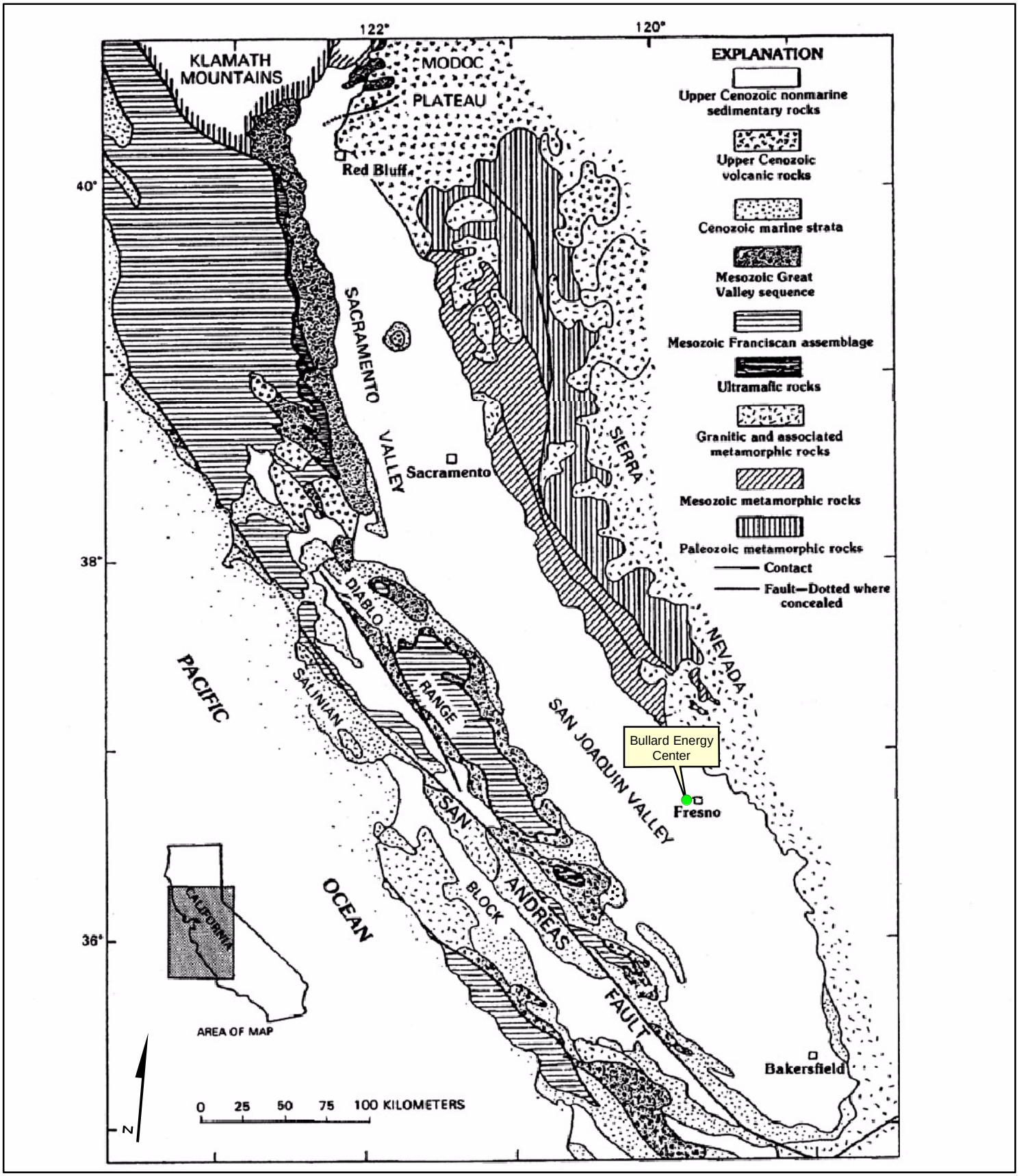
DATA ADEQUACY WORKSHEET

Revision No. 0 Date _____

Technical Area: **Geological Hazards** Project: _____ Technical Staff: _____

Project Manager: _____ Docket: _____ Technical Senior: _____

SITING REGULATIONS	INFORMATION	AFC PAGE NUMBER AND SECTION NUMBER	ADEQUATE YES OR NO	INFORMATION REQUIRED TO MAKE AFC CONFORM WITH REGULATIONS
Appendix B (h) (1) (A)	Tables which identify laws, regulations, ordinances, standards, adopted local, regional, state, and federal land use plans, and permits applicable to the proposed project, and a discussion of the applicability of each. The table or matrix shall explicitly reference pages in the application wherein conformance, with each law or standard during both construction and operation of the facility is discussed;	5.3.3		
Appendix B (h) (1) (B)	Tables which identify each agency with jurisdiction to issue applicable permits and approvals or to enforce identified laws, regulations, standards, and adopted local, regional, state and federal land use plans, and agencies which would have permit approval or enforcement authority, but for the exclusive authority of the commission to certify sites and related facilities.	5.3.3		
Appendix B (h) (2)	A discussion of the conformity of the project with the requirements listed in subsection (h)(1)(A).	5.3.3		
Appendix B (h) (3)	The name, title, phone number, and address, if known, of an official within each agency who will serve as a contact person for the agency.	5.3.3		



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Regional Geologic Map

Bullard Energy Center

URS

FIGURE 5.3-1

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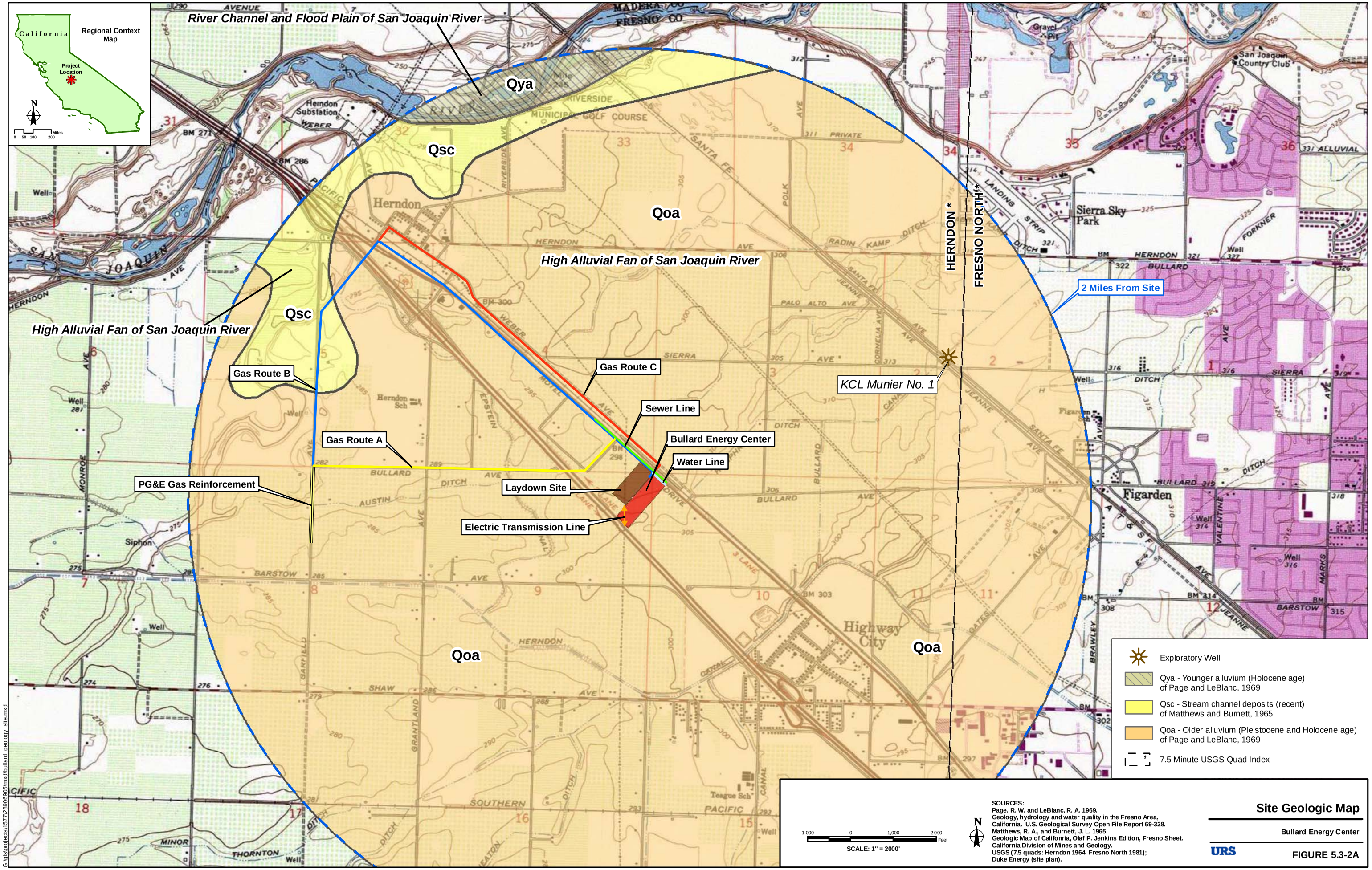
Regional Context Map
California
Project Location
N
0 50 100 200 Miles
River Channel and Flood Plain of San Joaquin River
Qya
Qsc
Qoa
High Alluvial Fan of San Joaquin River
High Alluvial Fan of San Joaquin River
Qsc
Qoa
Qoa
HERNDON *
FRESNO NORTH *
2 Miles From Site
KCL Munier No. 1
Gas Route B
Gas Route C
Sewer Line
Gas Route A
Bullard Energy Center
Water Line
PG&E Gas Reinforcement
Laydown Site
Electric Transmission Line
Herndon
Herndon Substation
Sierra Sky Park
San Joaquin Country Club
Figarden
Highway City
Exploratory Well
Qya - Younger alluvium (Holocene age) of Page and LeBlanc, 1969
Qsc - Stream channel deposits (recent) of Matthews and Burnett, 1965
Qoa - Older alluvium (Pleistocene and Holocene age) of Page and LeBlanc, 1969
7.5 Minute USGS Quad Index
1,000 0 1,000 2,000 Feet
SCALE: 1" = 2000'
N
SOURCES:
Page, R. W. and LeBlanc, R. A. 1969.
Geology, hydrology and water quality in the Fresno Area, California. U.S. Geological Survey Open File Report 69-328.
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USGS (7.5 quads: Herndon 1964, Fresno North 1981);
Duke Energy (site plan).
Site Geologic Map
Bullard Energy Center
URS
FIGURE 5.3-2A
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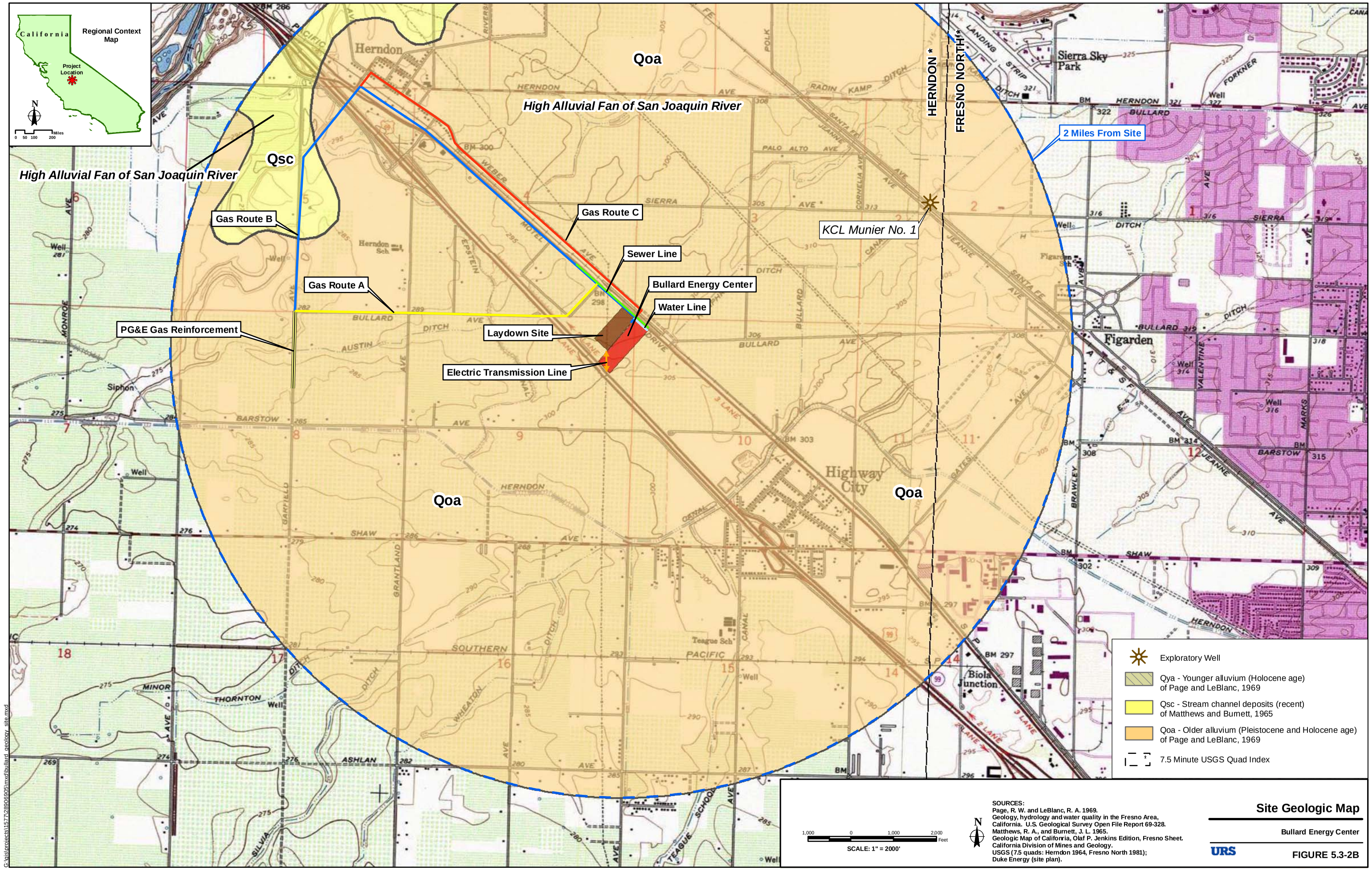

SOURCES:
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USGS (7.5 quads: Herndon 1964, Fresno North 1981);
Duke Energy (site plan).

Site Geologic Map

Bullard Energy Center

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FIGURE 5.3-2B

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AGE	FORMATION / UNIT	MAP SYMBOL	APPROXIMATE THICKNESS (FT)		LITHOLOGY	GRAPHIC COLUMN
Recent-Holocene	Younger Alluvium	Qya	-	4,000	Map units of CDMG (1965) and Page and LeBlanc (1969) comprised of Modesto, Riverbank, or Turlock Lake Formation sediments	
	Stream Channel Deposits	Qsc				
Holocene-Pleistocene	Older Alluvium	Qps				
Pleistocene	Modesto Formation	mle / mlb / ml / m2e / m2b / m2	10 - 30		Alluvial sand and silt of probable glacial origin	
	Riverbank Formation	r1 / r2 / rg / r3	15 - 30			
	Turlock Lake Formation	t2 / t2f / t1	< 730			
Pleistocene-Pliocene	North Merced Gravel	QTnm	< 2,400		Lag gravels	
Pliocene	Laguna Formation	Tl			Granitic alluvium	
Pliocene-Miocene	Mehrten Formation	Tm			Conglomerate, sandstone, siltstone, claystone	
Miocene-Oligocene	Valley Springs Formation	Tvs			Rhyolitic sandstone, siltstone, claystone, conglomerate	
Eocene	Ione Formation	Ti			Quartz sandstone with interbedded kaolinitic clay	
Tertiary-Jurrassic	Great Valley Sequence	TJgv	< 1,500		Sandstone, sand, siltstone, and shale	
Pre-Tertiary	Sierra Nevada Batholith	gr	-	-	Granitic rocks	

NO SCALE

N

SOURCES:
Lithologies simplified from
Page and LeBlanc, 1969; Cehrs et al., 1980;
Marchand and Allwardt, 1981; Bartow, 1991.

Stratigraphic Section

Bullard Energy Center

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FIGURE 5.3-3

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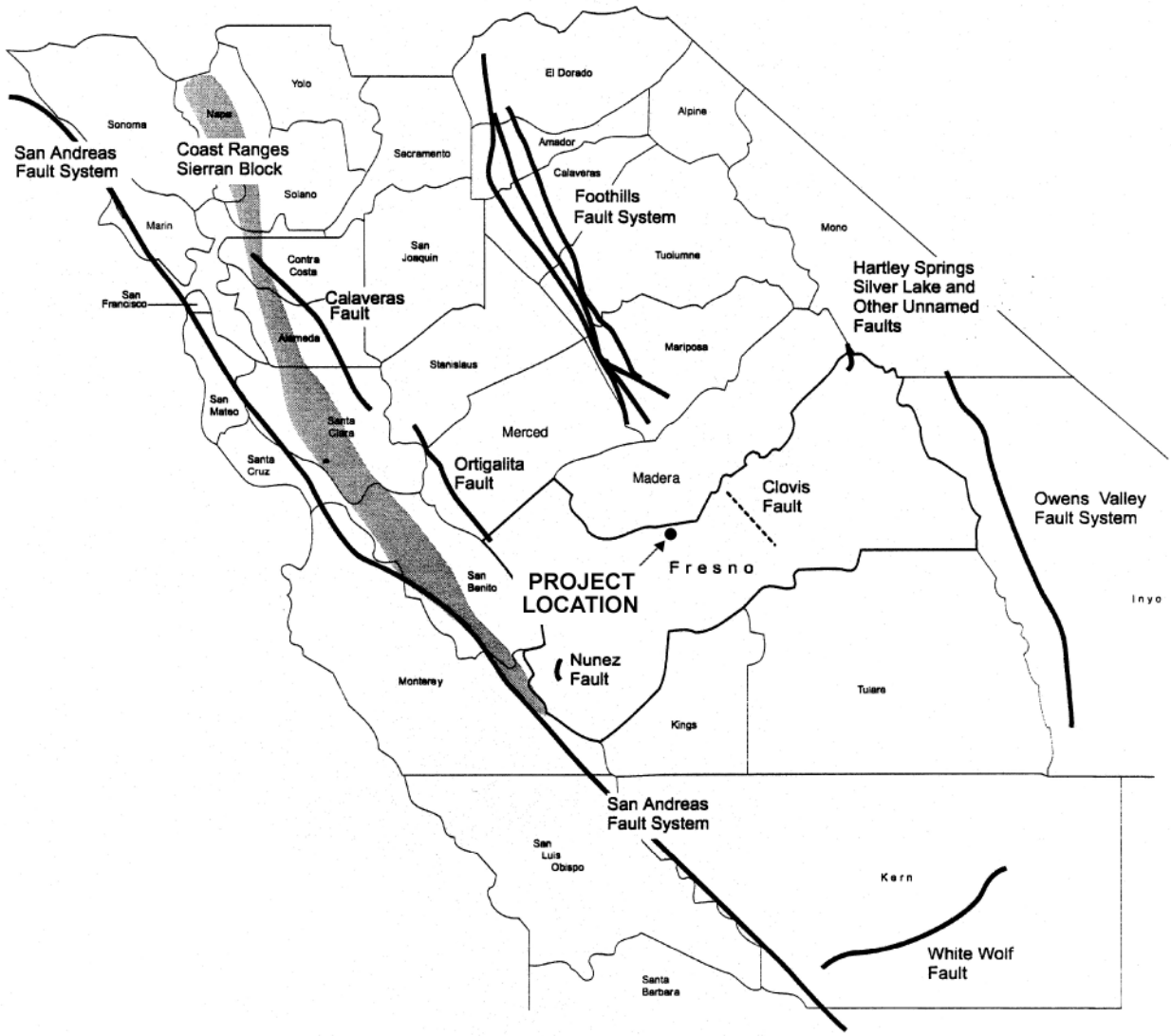

Approximate Fault Location

Inferred Fault Location

Blind Thrust Fault Zone

26 13 0 26 52 Miles

APPROXIMATE SCALE

N

SOURCES:
Fresno County, 2000.
Fresno County General Plan, Revised Public Review Draft, Background Report.

Regional Fault Map

Bullard Energy Center

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FIGURE 5.3-4

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