Chapter 9

Geology, Soils, Seismicity, and Groundwater

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Affected Environment

Geology

Freeport Intake Facility to Mokelumne Aqueducts

Sacramento and San Joaquin Counties are in the Central Valley in terrain consisting mainly of low alluvial plains and fans and dissected uplands, with local crossings of river floodplains and channels. This region is characterized by very gently west-sloping terrain of generally low relief except where it is incised by channels of large streams and the American, Sacramento, Cosumnes, and Mokelumne Rivers.

The region has been tectonically stable throughout the Cenozoic age. Erosion and sedimentation are the primary geologic processes in the area. Subsidence may occur in parts of the region where substantial groundwater extraction has lowered the water table extensively. Mineral resources in the project area include local accumulations of sand and gravel suitable for use as aggregate, some remaining placer gold in alluvium derived from gold-bearing source rocks in the foothills to the east, and natural gas (e.g., the Lodi gas field).

Enlarge Pardee Reservoir

Pardee Reservoir area is located in the western Sierra Nevada, near the margin of the Central Valley. Together, the Central Valley and the Sierra Nevada form a single tectonic province termed the *Sierran Block*, which is a block of basement rocks consisting of metamorphosed volcanic and sedimentary rocks of Paleozoic and Mesozoic age that tilts to the west. Bedding, discontinuities, and faults within this block dip in many directions. The bedrock complex of the western Sierra Nevada is separated into three northwest-trending structural blocks by the Melones fault zone and the Bear Mountain fault zone. From east to west, these three structural blocks are the Calaveras Terrane (east of the Melones fault zone), the Placerville Belt, and the Western Belt, which abuts the Bear Mountains fault zone on the west (Figure 9-1).

Geologic units at the existing Pardee Dam site include bedrock and overlying surficial materials. The bedrock units are Mesozoic-age, metamorphosed sedimentary and volcanic rocks. Regionally, these rocks are part of a northwest-southeast trending metamorphic belt that extends for a distance of 150 miles. The two bedrock formations present in the vicinity of the Pardee Dam site are the Gopher Ridge Volcanics and Salt Springs Slate. Locally, these formations are overlain by unconsolidated Quaternary stream deposits, landslides, colluvium, and artificial fill. The Gopher Ridge Volcanics is the primary rock unit at the existing Pardee Dam Site and are composed mostly of pyroclastic and flow rocks. The Gopher Ridge Volcanics is in contact with the Salt Springs Slate to the west in Mexican Gulch and in Pardee Reservoir.

The Salt Springs Slate formation underlies most of Pardee Reservoir, where it conformably overlies the Gopher Ridge Volcanics (to the west) and underlies the Copper Hill Volcanics (to the east); it is also exposed from approximately 600 to 3,000 ft west of the reservoir, where it is situated between two separate masses of the Gopher Ridge Volcanics. This pattern of repeated bedrock units along traverses perpendicular to structural trend is common in the Western Belt as a result of intense folding and faulting of these rocks in late Mesozoic time (approximately 150 million years ago).

The proposed dam site is located in the Western Belt, which comprises three bedrock formations: the Copper Hill Volcanics, the Salt Springs Slate, and the Gopher Ridge Volcanics. In particular, the proposed dam site area is in a zone of foliated tuff, which is immediately upstream of a mineralized zone that lies between 4,200 ft and 5,500 ft downstream of the existing Pardee Dam. Uplift and westward tilting of the Sierran Block in the past 5 million years or so has been accompanied by geologically recent faulting along pre-existing zones of weakness that are relics of earlier deformation.

According to the Preliminary Design Summary Technical Report (HCG 1998a), the bedrock at the proposed dam site is suitable for a concrete gravity dam foundation and is of generally higher quality than the bedrock at the existing Pardee Dam.

Active landslides were identified by HCG (1998b) in the Salt Springs Slate along the banks of Mexican Gulch. The landslides take the form of both rock toppling and translational failures. HCG (1998b) also identified a few wedge-type slope failures in the Gopher Ridge Volcanics (greenstone) on the steep slopes above the Mokelumne River between the existing dam and Mexican Gulch. Additionally, debris flows and earth flows were also identified (but not mapped by HCG 1998b) along the shoreline of the reservoir. Slopes surrounding the existing Pardee Dam range from approximately 30 to 50%. Along the shoreline of the Pardee Reservoir within the proposed inundation area, slopes range from approximately 3 to 50% (Sketchley 1965), with the shallowest slopes in the northern end of the reservoir and the steepest upstream of French Bar. At the proposed new dam site, the slopes range from approximately 30 to 70%. At proposed saddle dams 1 and 2, the slopes range from approximately 30 to 50%.

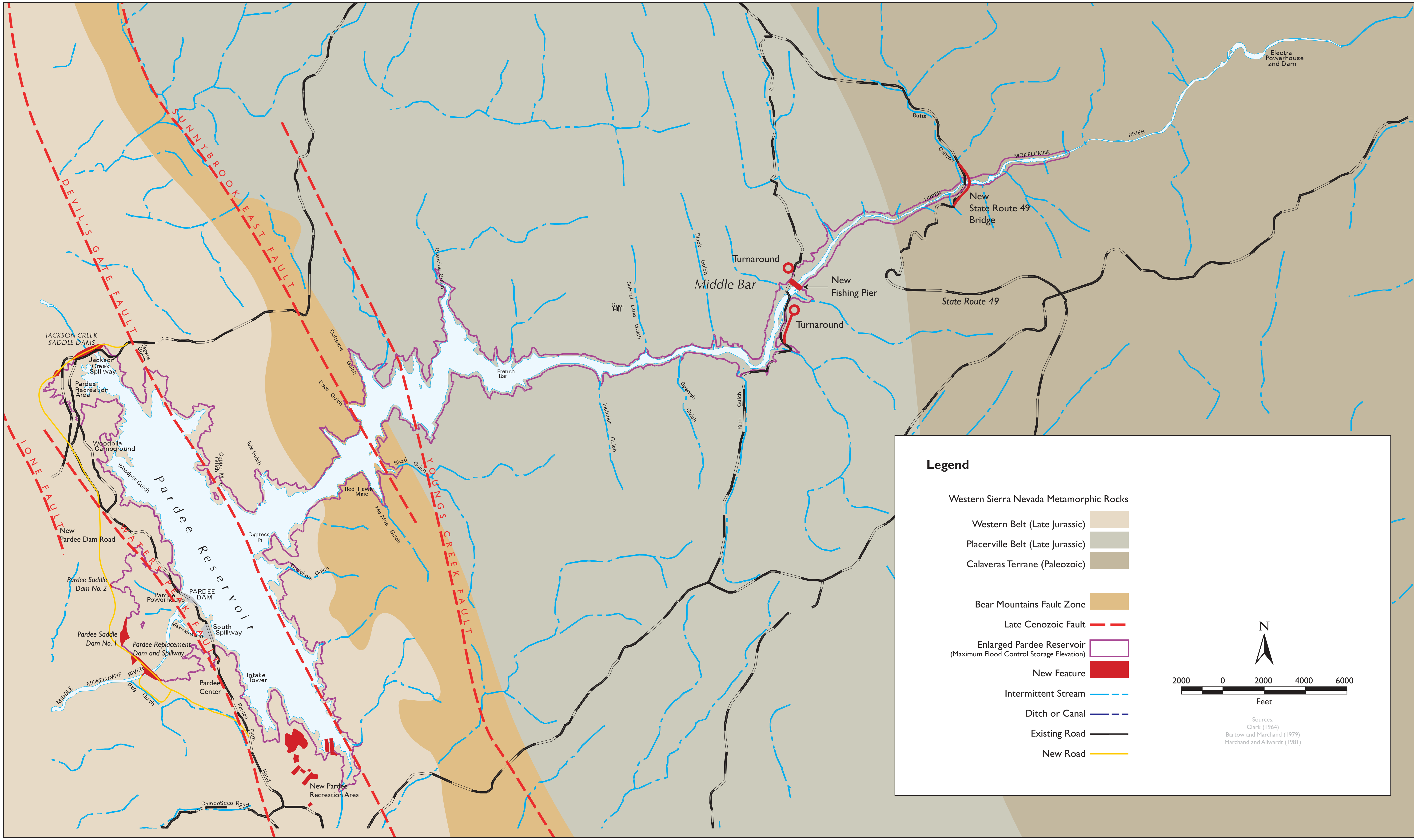

Figure 9-1
Geology and Soils

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Sediments and Soils

Freeport Intake Facility to Mokelumne Aqueducts

Sediments in Sacramento and San Joaquin Counties are characterized by a succession of underlying Tertiary and Quaternary formations and by the residual and alluvial soils that mantle the ground surface throughout the region. The Tertiary formations range from the Eocene (40 million years ago) for the Ione Formation, the oldest basal unit, to the Pliocene (2 million years ago) for the youngest, the Laguna Formation. The complete Tertiary succession consists of the Ione, Valley Springs, Mehrten, and Laguna formations. This Tertiary sequence is overlain by the Quaternary Riverbank and Modesto formations and by younger alluvial accumulations of varying age.

The project features, including the intake facility, Zone 40 Surface WTP, terminal facility, canal pumping plant, and pipeline alignments from the intake facility to the Zone 40 Surface WTP/FSC are underlain by the Riverbank and Laguna formations. Review of the Natural Resources Conservation Service's (NRCS's) Soil Survey Geographic Data Base indicates that about half of each alignment traverses soils that are highly corrosive to steel, and about half have an erosion hazard rating above slight. About a third of the soils traversed by the alignment are designated as having moderate to high shrink/swell potential, and about a third are designated as having low strength.

Most of the proposed pipeline alignments, water treatment plant, and pumping stations are on gentle slopes and therefore a relatively low erosion hazard. Erosion hazard is highest in and near streams and rivers.

Enlarge Pardee Reservoir

Surficial deposits occur in the general area in the form of landslide deposits, artificial fill, stream deposits, and colluvium. Areas of active landsliding have been identified in the Salt Springs Slate along the banks of Mexican Gulch (about 600 ft downstream from the existing dam site, about 3,600 ft upstream from the proposed dam site) and a few small wedge failures in the Gopher Ridge Volcanics (greenstone) in the steep slopes above the Mokelumne River. Artificial fill is present around Pardee Dam and in the vicinity of abutments, the powerhouse, spillway, roads, and benches. Colluvium, which is prone to landsliding and downslope creep during periods of heavy rainfall, has accumulated on the lower hillslopes and drainage swales overlying bedrock.

Based on the Soil Conservation Service (SCS) soil survey of the Amador area (Sketchley 1965), the soils within the proposed inundation area, at the proposed new dam, and at proposed saddle dams are generally very shallow to shallow over hard, fractured rock or weathered rock of the Auburn and Exchequer series.[1] The surface soil texture is generally rocky to very rocky loam or silt loam, and the subsoil (where present) is generally clay loam. In some areas, no appreciable soil material exists; such areas are mapped by the SCS as Rock land or Serpentine rock land. The soils have a surficial erosion hazard ranging from moderate to very severe. The soils' permeability is moderate to moderately slow, they are well drained or somewhat excessively drained, and their runoff rates are medium to very rapid.

Seismicity

Freeport Intake Facility to Mokelumne Aqueducts

Historically, little seismic activity has occurred in Sacramento and San Joaquin Counties, and no earthquakes exceeding magnitude 3.0 on the Richter scale have been recorded within an approximate 20-mile radius of this portion of the project area (CH2M Hill and Montgomery Watson 1996). The region is underlain by crystalline basement rock and overlying Cenozoic-age strata that have shown no evidence of local faulting for more than 40 million years.

The epicenters of most recorded earthquakes stronger than Richter magnitude 3.0 felt in Sacramento and San Joaquin Counties are coincident with the major faults in the San Francisco Bay Area. Major seismic sources (i.e., faults and fault systems) located in the immediate vicinity that could create moderate to strong ground shaking in the area, their corresponding maximum credible earthquakes (defined as the largest earthquake that a fault segment is considered capable of generating under the current tectonic setting and based on current knowledge.), and approximate distance and direction from the project area are shown in Table 9-1. The maximum credible earthquakes with the potential to have the greatest effect on the project area are a magnitude 7.0 event occurring on the Coast Ranges–Sierran Block fault and a 6.5 event occurring in the Prairie Creek–Spenceville-Dentman system. These seismic systems are projected to cause peak ground accelerations in the project area of between 0.1 and 0.2 g (California Department of Transportation 1996). (One g is equal to the force of gravity.)

[1] No detailed soil survey mapping is available for the Calaveras County part of the project area. However, because the geologic formations, topography, and vegetation there are similar to the Amador County part, it is reasonable to assume that the range of soil characteristics in the Calaveras County part are similar to those in Amador County.

Table 9-1. Major Seismic Sources with Potential to Affect Project Components from the Freeport Intake Facility to the Mokelumne Aqueducts

Seismic Source (Fault/Fault System)	MCE	Approximate Distance from Alignments (miles)	General Direction from Project Area
Big Bend–Wolf Creek–Maidu–Bear Mountain	6.50	18–25	Northeast
Coast Ranges–Sierran Block	7.00	23–43	Southwest
Dunnigan Hills	6.50	26–61	Northwest
Forest Hill–Melones	6.50	18–37	Northeast
Prairie Creek–Spenceville-Dentman	6.50	12–28	Northeast

MCE = Maximum Credible Earthquake, Richter magnitude

Water-saturated alluvium along the Sacramento River and some smaller streams could be subject to liquefaction if exposed to seismic ground shaking. (Liquefaction is the rapid loss of soil/sediment-bearing strength by ground shaking. Sediments and soils most subject to liquefaction are low cohesion, and silty or sandy materials saturated by groundwater within 50 feet of the surface.)

The liquefaction hazard at the proposed water treatment plants and the proposed pumping station sites is inferred to be low, based on their location on old terraces, plateaus, or hills, where the sediments or rocks are consolidated and the groundwater deep.

Enlarge Pardee Reservoir

Bedrock in the western Sierra Nevada is sheared and faulted as a result of deformation that most likely occurred during the Mesozoic age (143–163 million years ago). Two known fault zones exist in the proposed Pardee Dam area. The Melones and Bear Mountains fault zones, trending north-south, lie just to the east of the existing Pardee Dam site and northeast of the proposed dam site (Figure 9-1). Youngs Creek Fault, Devils Gate Fault, Waters Peak fault, and Ione Fault are all relatively near the existing dam and the proposed dam site. The closest known fault exposed near the existing and proposed dam sites is the Waters Peak fault zone. The Waters Peak fault zone crosses the Mokelumne River gorge approximately 550 ft downstream from the existing dam (about 3,650 ft upstream from the proposed dam site), crossing the South Spillway channel approximately 200 ft downstream from the spillway and 0.6 mile from the proposed dam site. The largest peak acceleration within the proposed dam site area is between 0.3 and 0.4 g (California Department of Transportation 1996). Table 9-2 illustrates the distance of the proposed dam site from each fault and the estimated maximum credible earthquake on each fault (HCG 1998b).

Table 9-2. Major Seismic Sources with Potential to Affect the Enlarge Pardee Reservoir Component

Fault	MCE	Approximate Distance from Proposed Dam Site (miles)	General Direction from Project Area
Youngs Creek	6.4	2.9	East
Devils Gate	6.4	1.3	East
Waters Peak	6.3	0.6	Northeast
Ione	6.4	1.0	Northwest

Note:

MCE = Maximum Credible Earthquake, Richter magnitude

Source: HCG 1998c.

Because of the absence of silty or sandy unconsolidated sediments, the liquefaction hazard at the proposed new dam site and saddle dams is expected to be low.

Reservoir-Induced Seismicity

In 1945, a relationship was recognized between the level of water impounded at Hoover Dam and the frequency of earthquakes at Lake Mead. The relationship between reservoirs and earthquakes is referred to as *reservoir-induced seismicity* (RIS). Since 1945, approximately 120 cases of RIS have been reported from the approximately 30,000 reservoirs worldwide.

RIS can be influenced by many factors, including reservoir size, reservoir geology, operation and filling characteristics, and preexisting tectonic stresses (stresses in the surface of the earth's crust). Seasonal water-level fluctuations and reservoir filling rates are two factors that influence tectonic stress changes beneath a reservoir, but reservoir-induced stresses alone are not sufficient to cause earthquakes. Under certain conditions, however, the stress changes caused by reservoir loading could trigger a seismic event in regions where stress conditions are already close to causing an earthquake. The majority of significant cases of RIS are associated with reservoirs that are very large or deep. In addition, as discussed below, most RIS events are of small magnitude and often occur unnoticed.

Reservoirs modify the tectonic stress regime by increasing elastic stress during reservoir filling and increasing subsurface pore pressures. For any particular site, the interaction between a reservoir and the geologic environment depends on local geologic and hydrologic conditions.

Groundwater

This section describes groundwater conditions in the geographic areas where the project alternatives would be constructed and areas where project implementation may have secondary impacts. Chapter 18, “Programmatic Evaluation of a Groundwater Banking/Exchange Component to the Freeport Regional Water Project,” contains a detailed discussion of the potential benefits and impacts of groundwater banking and exchange in the Sacramento area.

Freeport Intake Facility to Mokelumne Aqueducts

The project area overlies parts of the Sacramento County and eastern San Joaquin County groundwater basins. These basins consist of an upper unconfined water table within the unconsolidated Quaternary deposits and a series of deeper confined or semi-confined aquifers in the Laguna and Mehrten formations. The upper unconfined aquifer ranges in thickness from 200 ft to more than 1,000 ft and averages about 800 ft. It is recharged partly by direct infiltration of precipitation and agricultural irrigation and partly by underflow from the channels of the larger streams, especially the Cosumnes River, Dry Creek, and the Mokelumne River.

Groundwater levels in the vicinity of the proposed pipeline alignments and other project components from the intake facility to the Zone 40 Surface WTP/FSC were measured between about 18 and 106 ft below the land surface in 2000, with the shallowest depths near the Sacramento River and the deepest near the FSC. Depths to groundwater were greater in the vicinity of the alignments and other project components from the FSC to the Mokelumne Aqueducts (FSCC pipeline alignment), ranging between about 143 and 168 ft below the land surface (California Department of Water Resources 2002).

Groundwater conditions are expected to vary along the pipeline alignments; groundwater levels near rivers and streams would be affected by in-channel flow levels and would fluctuate seasonally. The water table would likely be deeper in areas distant from surface channels or water bodies; however, local perched groundwater could be present in some areas along the pipeline alignments (CH2M Hill and Montgomery Watson 1996).

Enlarge Pardee Reservoir

Groundwater was detected by HCG (1998d) at a depth of 5 ft in borings located along the channel of the Mokelumne River beneath the proposed new dam. This shallow depth is expected to be directly associated with the river water. However, in other borings located beneath the dam site on the slopes above the river canyon, groundwater was at 85 ft to more than 135 feet below grade.

At proposed saddle dam 1, a boring located adjacent to a drainage swale detected groundwater at a depth of 2.5 feet below grade (HCG 1998d); the depth to groundwater on the higher slopes beneath the proposed saddle dam is expected to be considerably deeper.

No information is readily available on groundwater at the proposed saddle dam 2 site; however, based on topography and depths to groundwater at the other saddle dam sites, it is expected to be similar to or deeper than at saddle dam 1.

At the proposed Jackson Creek saddle dams, groundwater was observed at a depth of approximately 8 feet below grade in the lower elevation areas near the reservoir water surface (HCG 1998e). It is deeper on the higher elevations.

South-of-Delta Agricultural Lands

Groundwater is used for irrigation by several CVP agricultural contractors, most notably those in agricultural areas south of the Sacramento—San Joaquin Delta such as San Joaquin River, Tulare Lake, and South Coast hydrologic regions. Groundwater conditions in these regions are generally characterized by alluvial aquifer systems that support significant groundwater development. The California Water Plan Update Bulletin 160-98 estimates for 1995 level groundwater supplies in these regions are shown in Table 9-3.

Table 9-3. Estimated 1995 Level Groundwater Supplies for Selected Hydrologic Regions (af)

Region	Average	Drought
South Coast	1,177,000	1,371,000
San Joaquin River	2,195,000	2,900,000
Tulare Lake	4,340,000	5,970,000

In these hydrologic regions, water users frequently take advantage of surface water available in wet years to recharge groundwater basins. In drought years when surface water is not available, water users increase groundwater pumping. Groundwater overdraft, which occurs in the San Joaquin River and Tulare Lake regions, is expected to decline by 2020 as a result of reduced irrigated acreage in drainage problem areas (California Department of Water Resources 1998).

Environmental Consequences

Methods and Assumptions

The evaluation of impacts related to geology, soils, seismicity, and groundwater was based on consideration of construction procedures and project design provided by the project engineers and review of available data and information, including publications of the USGS, NRCS, DWR, and other relevant sources.

Significance Criteria

According to Appendix G of the State CEQA Guidelines, a significant impact normally would result if the project would:

- expose people or structures to potential substantial adverse effects, including the risk of loss, injury, or death involving:
  - rupture of a known earthquake fault,
  - strong seismic ground shaking,
  - seismic-related ground failure, including liquefaction, and
  - landslides;
- result in substantial soil erosion or loss of topsoil;
- be located on a geologic unit or soil that is unstable, or that would become unstable as a result of the project, and potentially result in on- and off-site landslide, lateral spreading, subsidence, liquefaction or collapse; or
- be located on expansive soil, creating substantial risks to life or property;
- substantially deplete groundwater supplies or interfere substantially with groundwater recharge.

Less-than-Significant Impacts

Alternative 1

No FRWP facilities would be constructed under Alternative 1. No construction-related or operation-related impacts are associated with this alternative.

Alternatives 2–5

Alternatives 2 through 5 differ only in the pipeline alignments from the Freeport intake facility to the FSC. Project construction and operation for Alternatives 2 through 5 are very similar. Impacts related to geology, soils, seismicity, and groundwater for each alternative differ only slightly from each other; therefore, the results for Alternatives 2 through 5 are presented together but are representative of each individual alternative, unless otherwise noted.

Construction-Related Impacts

Impact 9-1: Localized Erosion and Sedimentation

Construction of the project components would require cut-and-fill operations, grading for site preparation and access, trenching, boring, and removal of vegetation. Most of the proposed pipeline alignments from the intake facility to the Zone 40 Surface WTP/FSC and the FSCC alignment are on gentle slopes; a few pipeline segments have steeper slopes, as do some of the pumping plant and treatment facilities. Accordingly, there is overall minimal potential for substantial slope failure and surficial erosion during and after construction.

The potential for erosion and sedimentation could be high at the intake facility site on the Sacramento River, where soils within the river channel would be disturbed. Sediment could also be directly introduced into Dry Creek from trenching across the channel. Additionally, drilling fluids and sediment could be introduced into the Mokelumne River during boring operations from “frac-outs” (seepage of drilling fluids from the bore alignment up to the bed of the river) and releases at the bore pit sites on both sides of the river.

The project would need to comply with the RWQCB’s requirements for discharges from general construction activity and trench dewatering in accordance with the NPDES. These requirements call for implementation of a SWPPP identifying the BMPs to be employed during and following construction to control soil erosion and possible waste discharges into waterways. BMPs may include, but would not be limited to, construction of berms and runoff diversion ditches, construction of temporary cofferdams to dewater work areas, hydroseeding, use of sediment retention devices, monitoring the Mokelumne River channel for frac-outs, and similar measures. The SWPPP also would specify measures for removing sediment from water pumped for trench dewatering before the water is released to waterways. The project would also include implementation of an erosion control plan that complies with all applicable city and county regulatory requirements for construction.

Given the duration of construction and the area covered by the project, the RWQCB could require specific pollution control measures through the issuance of waste discharge requirements pursuant to the state Porter-Cologne Water Quality Control Act. Long-term BMPs, such as revegetation of exposed soil, would also be implemented to minimize erosion after construction.

Erosion and sedimentation would be minimized because construction practices would be conducted in accordance with the SWPPP, erosion control plan, and all applicable NPDES and local agency requirements. The impact associated with localized erosion and sedimentation is considered less than significant because of the nearly level slopes on which project facilities would be located and the implementation of RWQCB requirements. No mitigation is required.

Impact 9-2: Hydrologic Hazards

Trench dewatering would be required in areas where the soil is saturated with surface water or shallow groundwater. Dewatering could temporarily interrupt natural hydrology or induce local soil subsidence. These effects would be avoided or minimized through standard engineering procedures that will be developed after the project geotechnical investigations have been completed. This impact is less than significant. No mitigation is required.

Impact 9-3: Destruction of Unique Geologic Features

No unique geologic features that could be adversely affected by project construction are known to exist along the alignments or near other project components. No impact would occur.

Operation-Related Impacts

Impact 9-4: Ground Shaking and Fault Rupture

No known faults exist in Sacramento and San Joaquin Counties in areas where the intake facility to Zone 40 Surface WTP/FSC or FSCC pipeline alignments and other project components would be constructed. Accordingly, there is a low hazard of surface fault rupture. Strong seismic activity is not anticipated in the pipeline or pumping plant area (see Table 9-1). For all project components, seismic safety measures would be incorporated into design and construction procedures. This impact is less than significant. No mitigation is required.

Impact 9-5: Increased Groundwater Pumping and Associated Subsidence South of the Delta

As described in Chapter 3, “Hydrology, Water Supply, and Power,” and Sections 3.4 and 3.5 in the Modeling Technical Appendix (Volume 3 in this EIR/EIS), the hydrologic modeling for the FRWP alternatives indicates that CVP agricultural contractors south of the Delta (primarily in the San Joaquin Valley) may experience slight reductions in water deliveries as a result of implementation of these alternatives. The modeling indicates that these reductions are expected to average approximately 2,900 af per year during all years, and approximately 5,600 af per year during the dry years. During these periods, average annual deliveries to CVP south of Delta agricultural contractors are approximately 1,080,000 af per year (average years), and 310,000 af per year (dry years), representing a –0.3% and –1.8% change in deliveries, respectively. No change in deliveries is expected for other CVP contractors.

Average annual deliveries to SWP contractors are expected to be slightly reduced (approximately 2,800 af per year total). However, during dry periods, average annual deliveries are expected to increase by approximately 11,000 af per year. During these periods, total SWP deliveries are approximately 2,950,000 af per year (average years) and 1,900,000 af per year (dry years), representing a –0.1% and +1.0% change, respectively.

Although the response of water purveyors and individual water users is not possible to predict accurately, the potential minor reductions in water deliveries could conceivably result in a response by affected water purveyors and individuals to pump additional groundwater to meet water needs in the San Joaquin Valley and coastal southern California. Currently, groundwater pumping in the San Joaquin Valley is estimated at between approximately 2,100,000 (average years) and 2,900,000 af per year (dry years), depending on year type. Within the coastal southern California area (where most SWP water is used), groundwater pumping is currently estimated to range between about 1,200,000 (average years) and 1,400,000 af per year (dry years) (California Department of Water Resources 1998).

Under a very conservative assumption that any reductions in deliveries would lead directly to a proportional increase in groundwater use, the FRWP alternatives may result in an increase in groundwater use in the San Joaquin Valley during dry years of approximately 0.2%. Making a similar assumption, average annual reductions in deliveries to SWP contractors could lead to increased groundwater use of approximately 0.3%. However, this conservative assumption does not reflect actual responses to any minor reductions in deliveries. Water purveyors and individuals would likely have independent responses to changes in water supply. The range of responses could include not planting crops on a portion of land, changing crop patterns, increasing irrigation efficiencies or accepting reduced yields, acquiring water from other sources, and water conservation, in addition to increased groundwater pumping.

Based on this information, any potential impact would be less than significant. Even under extremely conservative assumptions, any increase in groundwater pumping would be much less than 1% of existing levels, and there is no evidence to suggest that such a minor increase in the already large volume of groundwater pumping would have any effect on groundwater levels, availability, quality, or surface subsidence. It is not possible to predict how each water purveyor and individual would respond to minor reduction in one water supply source. This impact is considered speculative. No further analysis is required.

Alternative 6

As described in Chapter 2, “Project Description,” Alternative 6 consists of enlarging Pardee Reservoir and conveying water from the Sacramento River. Alternative 6 includes the following project components: enlarge Pardee Reservoir (which includes additional components), Freeport intake facility, pipeline from intake facility to the Zone 40 Surface WTP, and the Zone 40 Surface WTP. Though slightly different in size, the Freeport intake facility, pipeline from the intake facility to the Zone 40 Surface WTP, and the Zone 40 Surface WTP project components, are the same as those that make up Alternative 5. Therefore, several of the impacts associated with Alternative 5 (described above) are also associated with Alternative 6 and are restated below. Additionally, impacts associated with the enlarge Pardee Reservoir component of this alternative are described below.

Construction-Related Impacts

Impact 9-6: Localized Construction-Related Erosion and Sedimentation

Impacts associated with the project components from the Freeport intake facility to the Zone 40 Surface WTP would be the same as for Alternatives 2–5, described above.

Construction of the new replacement dam and saddle dams and extraction of borrow material would require removal of vegetation and grading for site preparation and access and for cut-and-fill operations. Because slopes are generally steep and the soils erodible in these areas, substantial shallow slope failure and accelerated erosion and sedimentation could occur if measures are not implemented to control such processes. However, as described above for Alternatives 2–5, the project would need to comply with the RWQCB's requirements for discharges from general construction activity in accordance with the NPDES. The impact associated with accelerated erosion and sedimentation is considered less than significant because the BMPs are expected to effectively control the erosion to the point that there is not a substantial increase in erosion rates. This impact is less than significant. No mitigation is required.

Impact 9-7: Hydrologic Hazards

Trench dewatering impacts associated with construction of the project components from the Freeport intake facility to the Zone 40 Surface WTP would be similar to those described in Alternatives 2–5. In areas where the soil is saturated with surface water or shallow groundwater, trench dewatering would be required and could temporarily interrupt natural hydrology or induce local soil subsidence. These effects would be avoided or minimized through standard engineering procedures that will be developed after the project geotechnical investigations have been completed. This impact is less than significant. No mitigation is required.

Impact 9-8: Destruction of Unique Geologic Features

As mentioned above in Alternatives 2–5, no unique geologic features that could be adversely affected by project construction are known to exist near the project components from the Freeport intake facility to the Zone 40 Surface WTP. Also, no unique geologic features would be adversely affected by construction of the enlarge-Pardee-Reservoir component. No impact would occur.

Operation-Related Impacts

Impact 9-9: Ground Shaking and Fault Rupture

Impacts associated with the project components from the Freeport intake facility to the Zone 40 Surface WTP would be the same as for Alternatives 2–5, described above.

No faults are known to underlie the new replacement dam site; therefore, surface fault rupture is not expected. However, a potential exists for ground shaking from a seismic event, which could affect the replacement dam. The replacement dam will be designed for the Maximum Credible Earthquake (MCE). The Division of Safety of Dams (DOSD) uses the MCE for developing dam design ground motions. The MCE magnitude, distance from the source fault to the replacement dam site, and appropriate statistical level of ground shaking are considered in computing design ground motions. The four faults that have been considered in the seismic design of the dam (i.e., Youngs Creek, Devils Gate, Waters Peak, and Ione faults) have an MCE of 6.3 to 6.4 (see Table 9-2). The replacement dam would be designed so that seismically induced damage would be accessible to inspection and would be repairable. All foundations would be designed to remain elastic when subjected to the MCE, allowing inelastic behavior to occur only above the level of 2.0 (HCG 1998c). For all project components, seismic safety measures would be incorporated into construction procedures, and applicable Uniform Building Code requirements would be met. This impact is less than significant. No mitigation is required.

Impact 9-10: Potential for Reservoir-Induced Seismic Event

The probability of a reservoir-induced earthquake occurring as a result of impounding water in the enlarged Pardee Reservoir is low. Reservoir impoundment is capable of causing an earthquake only along critically stressed faults that are already close to the point at which an earthquake would naturally occur. If RIS were to occur, the most probable activity would be small-magnitude earthquakes. The maximum magnitude of an earthquake is determined by the geometry and size of the rupture area. Because the enlarged Pardee Reservoir would not alter these physical dimensions, the maximum reservoir-induced earthquake would not exceed the MCE for a given fault.

The timing of possible RIS events cannot be accurately predicted. Based on observations of other reservoirs in California, however, such events would be most likely to occur during periods when reservoir water levels fluctuate rapidly or during reservoir filling. Rapid reservoir water-level fluctuations, which could enhance the possibility of a seismic event, would be unlikely at the enlarged Pardee Reservoir because the proposed reservoir would have a relatively high volume-to-depth ratio; large reservoir releases would result only in minor decreases in reservoir depth, thus minimizing tectonic stress changes beneath the reservoir.

The potential for RIS associated with the enlarged Pardee Reservoir is considered to have a very low probability of occurrence. No seismic activity has been associated with either Pardee Reservoir or Camanche Reservoir. There is no evidence to suggest that an enlarged Pardee Reservoir would result in RIS. This potential impact is speculative. No further analysis is warranted.

Impact 9-11: Erosion and Sedimentation within the Expanded Reservoir Inundation Zone from Reservoir Operations

Reservoir operation-related effects (i.e., raised water levels and subsequent lowering) may result in accelerated rates of soil erosion and soil mass movement along the shoreline of the reservoir. Among reservoirs in general, such effects may occur in the form of three primary mechanisms or types: (1) sheet erosion caused by the lack of vegetation cover from clearing or inundation; (2) mass movement (i.e., mass wasting or landsliding) caused by reduction of soil shear strength from saturation and rapid water level drawdown and by lowered soil shear resistance caused by mortality of deep-rooted, woody vegetation; and (3) erosion of areas particularly subject to wave action. Mass movements may be triggered by earthquake-induced ground shaking or occur in the absence of ground shaking. Further, undercutting of slopes by wave action may undermine areas prone to mass movement, thereby increasing the potential for this type of erosion to occur.

Factors that control whether one or more of these mechanisms of shoreline erosion occurs can be categorized as activating or passive (Reid 1993). Activating factors are those that trigger erosion. In the context of Alternative 6, possible activating factors are raindrop impact, sheetflow runoff, inundation, and rapid drawdown. Passive factors are properties inherent in the slope material or in the geometry of the slope. They exist all or most of the time and cause the slope to be relatively susceptible to activating factors (Reid 1993).

Passive factors include soils with high clay content (particularly expansive clays), alternating weak and strong beds of sediments with adverse bedding plane orientation, high moisture content, steep slopes, and lack of vegetation from wind-driven waves (Reid 1993). Along the shoreline of Pardee Reservoir, existing passive factors are limited to steep slopes and lack of vegetation (the latter as a result of vegetation clearing).

Based on the water surface elevation model, described in the Modeling Technical Appendix (Volume 3), the water level of the reservoir would almost always be at 601 ft elevation (i.e., up to the level of vegetation clearing). Accordingly, the removal of vegetation between 568 and 601 ft is expected to result in the loss of most of the soil above the more resistant bedrock within this zone and probably some of the soil slightly above it, the latter a result of undermining of the soil below it. Additionally, root systems of vegetation above 601 ft. may be disrupted from the clearing operation, making the soils more prone to slippage. According to Chapter 7, "Vegetation and Wetland Resources," vegetation clearing will be conducted over an approximate 963-acre area; consequently, loss of soil into the reservoir would occur over this same (and possibly a greater) area. In areas with steep slopes that are subject to significant wave run-up, wave action may undermine the soils slightly above 601 ft elevation.

The eroded soil would enter the reservoir and increase its turbidity. The coarser sediments will tend to settle to the bottom and the finer sediments (i.e., clay- and silt-sized particles) may be suspended long enough to be carried over the reservoir spillway. The volume of the eroded soil relative to the volume of sediment that enters the reservoir under existing conditions is unknown. Most of the shoreline slope soil erosion is expected to occur within the first 5–10 years following project construction, until the slope/soil above 601 ft reaches a stable angle of repose. The effects of this sedimentation are described in Chapter 5, "Fish," Chapter 3, "Hydrology," and Chapter 4, "Water Quality," and determined to be less than significant.

The water surface elevation model also shows that the water level may be raised from 601 to 614 ft to accommodate very infrequent inflow events (i.e., less frequent than every 100 years on average), after which the level is expected to return to 601 ft within 7 days. Accordingly, vegetation above 601 ft elevation is not likely to be significantly adversely affected to the point that soil cover is lost to the extent that accelerated erosion occurs. In the event that it does occur, the potential impact is addressed in Chapter 7, "Vegetation and Wetland Resources." In Chapter 7, mitigation measure 7-8 implements a monitoring and adaptive management program that would monitor conditions over the life of the project, identify any impacts, and mitigate according to Mitigation Measure 7-7. Mitigation Measure 7-7 compensates for the loss of riparian vegetation.

However, rapid drawdown of the water level to 601 ft following a high inflow event may cause localized mass movement within the zone from 601 ft to above the elevated water level. Because the soils that fringe the reservoir shoreline are generally shallow over bedrock, the depth of the mass movement would probably be less than 3 ft. Because any mass movement would tend to be localized and shallow and occur infrequently, the impact is less than significant. No mitigation is required.

Impact 9-12: Increased Groundwater Pumping and Associated Subsidence South of the Delta

As described in Chapter 3, "Hydrology, Water Supply, and Power," and Sections 3.4 and 3.5 in the Modeling Technical Appendix (Volume 3), the hydrologic modeling for the FRWP alternatives indicates that CVP agricultural contractors south of the Delta (primarily in the San Joaquin Valley) may experience small changes in water deliveries as a result of implementation of this alternative. The modeling indicates that these changes are expected to result in an annual average increase of approximately 1,100 af per year during all years, and an annual average reduction of approximately 2,000 af per year during dry years. During these periods, average annual deliveries to CVP south of Delta agricultural contractors are approximately 1,080,000 af per year (average years), and 310,000 af per year (dry years), representing a +0.1% and –0.2% change in deliveries, respectively. No change in deliveries is expected for other CVP contractors.

Average annual deliveries to SWP contractors are expected to be slightly reduced (approximately 3,000 af per year total). During the dry period, average annual deliveries are expected to be reduced by approximately 6,900 af per year. During these periods, total SWP deliveries are approximately 2,950,000 af per year (average years) and 1,900,000 af per year (dry years), representing a –0.2% and + 0.6% change, respectively.

Although the response of water purveyors and individual water users is not possible to predict accurately, the potential minor reductions in water deliveries could conceivably result in a response by affected water purveyors and individuals to pump additional groundwater to meet water needs in the San

Joaquin Valley and coastal southern California. Currently, groundwater pumping within the San Joaquin Valley is estimated at between approximately 2,100,000 (average years) and 2,900,000 af per year (dry years), depending on year type. Within the coastal southern California area (where most SWP water is used), groundwater pumping is currently estimated to range between about 1,200,000 (average years) and 1,400,000 af per year (dry years) (California Department of Water Resources 1998).

Under a very conservative assumption that any reductions in deliveries would lead directly to a proportional increase in groundwater use, the FRWP alternatives may result in an increase in groundwater use in the San Joaquin Valley during dry years of approximately 0.1%. Making a similar assumption, long-term average annual reductions in deliveries to SWP contractors could lead to increased groundwater use of approximately 0.3%. However, this conservative assumption does not reflect actual responses to any minor reductions in deliveries. Water purveyors and individuals would likely have independent responses to changes in water supply. The range of responses could include not planting crops on a portion of land, changing crop patterns, increasing irrigation efficiencies or accepting reduced yields, acquiring water from other sources, and water conservation, in addition to increased groundwater pumping.

Based on this information, any potential impact would be less than significant. Even under extremely conservative assumptions, any increase in groundwater pumping would be much less than 1% of existing levels, and there is no evidence to suggest that such a minor increase in the already large volume of groundwater pumping would have any effect on existing groundwater levels, availability, quality, or surface subsidence. It is not possible to predict how each water purveyor and individual would respond to minor reduction in one water supply source. This impact is considered speculative. No further analysis is required.

Significant Impacts and Mitigation Measures

Alternatives 2–5

Alternatives 2–5 would not result in significant construction-related or operation-related impacts related to geology, soils, seismicity, and groundwater, and no mitigation measures are necessary.

Alternative 6

Construction-Related Impacts

Impact 9-13: Inadvertent Soil Loss from Clearing Operations

Clearing of vegetation along the shoreline of the reservoir between 568 and 601 ft elevation may result in inadvertent vegetation loss and associated soil disturbance outside this zone, including heavy equipment intrusion beyond work areas. The potential impact is significant.

Mitigation Measure 9-1: Prevent Inadvertent Soil Loss from Clearing Operations

The 601-ft-elevation line should be marked at intervals using surveying equipment to avoid inadvertent clearing of vegetation and soil disturbance. Additionally, heavy equipment access routes should be identified and marked to minimize the extent of vegetation and soil disturbance above 601 ft elevation. This mitigation measure would reduce the impact of unnecessary soil disturbance and associated erosion to a less-than-significant level.

Operation-Related Impacts

There are no significant operation-related impacts on geology, soils, seismicity, and groundwater associated with this alternative.