Chapter 12 Geology and Soils

12.1 Introduction

This chapter describes the environmental setting, methods of analysis, and impact analysis for geology and soils that would potentially be affected by the construction and operation of the Project. Geology and soils are defined as consolidated and unconsolidated earthen materials and their structural characteristics. This chapter also discusses potential impacts related to faults, seismicity, and paleontology.

The study area for geology and soils consists of all areas of the Project where excavation, filling, topsoil salvage, and other soil disturbances would occur, as well as the geologic substrates through which tunnels would be bored. The geology and soils study area also includes regional earthquake faults capable of causing seismic shaking in the vicinity of the Project components.

Not included in the study area is the RBPP in Tehama County because the facility already exists, and soil disturbance is not expected at this locale.

A tsunami is a wave or series of waves that rush ashore in coastal areas. Because the elevation of the study area is well above the reach of a tsunami generated in the Pacific Ocean, tsunamis would not affect the study area and therefore are not discussed further in this chapter.

Tables 12-1a and 12-1b summarize the CEQA determinations and NEPA conclusions for construction and operation impacts, respectively, for each alternative described in the impact analysis.

Table 12-1a. Summary of Construction Impacts and Mitigation Measures for Geology and Soils Resources

Alternative	Level of Significance Before Mitigation	Mitigation Measures	Level of Significance After Mitigation
Impact GEO-1a: Directly or indirectly cause potential substantial adverse effects, including the risk of loss, injury, or death involving: Rupture of a known earthquake fault, as delineated on the most recent Alquist-Priolo Earthquake Fault Zoning Map, issued by the State Geologist for the area or based on other substantial evidence of a known fault			
No Project	NI/NE	-	NI/NE
Alternative 1	LTS/NE	-	LTS/NE
Alternative 2	LTS/NE	-	LTS/NE
Alternative 3	LTS/NE	-	LTS/NE
Impact GEO-1b: Strong seismic ground shaking			
No Project	NI/NE	-	NI/NE

Alternative	Level of Significance Before Mitigation	Mitigation Measures	Level of Significance After Mitigation
Alternative 1	LTS/NE	-	LTS/NE
Alternative 2	LTS/NE	-	LTS/NE
Alternative 3	LTS/NE	-	LTS/NE
Impact GEO-1c: Seismic-related ground failure, including liquefaction			
No Project	NI/NE	-	NI/NE
Alternative 1	LTS/NE	-	LTS/NE
Alternative 2	LTS/NE	-	LTS/NE
Alternative 3	LTS/NE	-	LTS/NE
Impact GEO-1d: Landslides			
No Project	NI/NE	-	NI/NE
Alternative 1	LTS/NE	-	LTS/NE
Alternative 2	LTS/NE	-	LTS/NE
Alternative 3	LTS/NE	-	LTS/NE
Impact GEO-2: Result in reservoir-triggered seismicity or be subject to a seiche			
No Project	NI/NE	-	NI/NE
Alternative 1	LTS/NE	-	LTS/NE
Alternative 2	LTS/NE	-	LTS/NE
Alternative 3	LTS/NE	-	LTS/NE
Impact GEO-3: Result in substantial soil erosion or the loss of topsoil			
No Project	NI/NE	-	NI/NE
Alternative 1	LTS/NE	-	LTS/NE
Alternative 2	LTS/NE	-	LTS/NE
Alternative 3	LTS/NE	-	LTS/NE
Impact GEO-4: Be located in a geologic unit or soil that is unstable, or that would become unstable as a result of the Project, and potentially result in onsite or offsite landslide, lateral spreading, subsidence, liquefaction, or collapse			
No Project	NI/NE	-	NI/NE
Alternative 1	LTS/NE	-	LTS/NE
Alternative 2	LTS/NE	-	LTS/NE
Alternative 3	LTS/NE	-	LTS/NE
Impact GEO-5: Be located on expansive soil, as defined in Table 18-1-B of the Uniform Building Code (1994), creating substantial direct or indirect risks to life or property			
No Project	NI/NE	-	NI/NE
Alternative 1	NI/NE	-	NI/NE
Alternative 2	NI/NE	-	NI/NE
Alternative 3	NI/NE	-	NI/NE
Impact GEO-6: Have soils incapable of adequately supporting the use of septic tanks or alternative wastewater disposal systems where sewers are not available for the disposal of wastewater			
No Project	NI/NE	-	NI/NE
Alternative 1	LTS/NE	-	LTS/NE
Alternative 2	LTS/NE	-	LTS/NE

Alternative	Level of Significance Before Mitigation	Mitigation Measures	Level of Significance After Mitigation
Alternative 3	LTS/NE	-	LTS/NE
Impact GEO-7: Directly or indirectly destroy a unique paleontological resource or site or unique geologic feature			
No Project	NI/NE	-	NI/NE
Alternative 1	S/SA	**Mitigation Measure GEO-7.1**: Retain a Qualified Paleontological Resource Specialist Prior to the Start of Construction **Mitigation Measure GEO-7.2**: Consultation with the Paleontological Resource Specialist Prior to and During Project Construction **Mitigation Measure GEO-7.3**: Prepare and Implement a Paleontological Resources Monitoring and Mitigation Plan **Mitigation Measure GEO-7.4**: Conduct Monitoring During Project Construction and Prepare Monthly Reports **Mitigation Measure GEO-7.5**: Ensure Implementation of the Paleontological Resources Monitoring and Mitigation Plan	SU/SA
Alternative 2	S/SA	**Mitigation Measure GEO-7.1**: Retain a Qualified Paleontological Resource Specialist Prior to the Start of Construction **Mitigation Measure GEO-7.2**: Consultation with the Paleontological Resource Specialist Prior to and During Project Construction **Mitigation Measure GEO-7.3**: Prepare and Implement a Paleontological Resources Monitoring and Mitigation Plan **Mitigation Measure GEO-7.4**: Conduct Monitoring During Project Construction and Prepare Monthly Reports **Mitigation Measure GEO-7.5**: Ensure Implementation of the Paleontological Resources Monitoring and Mitigation Plan	LTSM/NE

Alternative	Level of Significance Before Mitigation	Mitigation Measures	Level of Significance After Mitigation
Alternative 3	S/SA	**Mitigation Measure GEO-7.1**: Retain a Qualified Paleontological Resource Specialist Prior to the Start of Construction **Mitigation Measure GEO-7.2**: Consultation with the Paleontological Resource Specialist Prior to and During Project Construction **Mitigation Measure GEO-7.3**: Prepare and Implement a Paleontological Resources Monitoring and Mitigation Plan **Mitigation Measure GEO-7.4**: Conduct Monitoring During Project Construction and Prepare Monthly Reports **Mitigation Measure GEO-7.5**: Ensure Implementation of the Paleontological Resources Monitoring and Mitigation Plan	SU/SA

Notes:
NI = CEQA no impact
LTS = CEQA less-than-significant impact
LTSM = CEQA less than significant with mitigation
S = CEQA significant impact
SU = CEQA significant and unavoidable
NE = NEPA no effect or no adverse effect
SA = NEPA substantial adverse effect

Table 12-1b. Summary of Operations Impacts and Mitigation Measures for Geology and Soils Resources

Alternative	Level of Significance Before Mitigation	Mitigation Measures	Level of Significance After Mitigation
Impact GEO-1: Directly or indirectly cause potential substantial adverse effects, including the risk of loss, injury, or death involving: Impact GEO-1a: Rupture of a known earthquake fault, as delineated on the most recent Alquist-Priolo Earthquake Fault Zoning Map, issued by the State Geologist for the area or based on other substantial evidence of a known fault			
No Project	NI/NE	-	NI/NE
Alternative 1	LTS/NE	-	LTS/NE
Alternative 2	LTS/NE	-	LTS/NE
Alternative 3	LTS/NE	-	LTS/NE
Impact GEO-1b: Strong seismic ground shaking			
No Project	NI/NE	-	NI/NE
Alternative 1	LTS/NE	-	LTS/NE
Alternative 2	LTS/NE	-	LTS/NE

Alternative	Level of Significance Before Mitigation	Mitigation Measures	Level of Significance After Mitigation
Alternative 3	LTS/NE	-	LTS/NE
Impact GEO-1c: Seismic-related ground failure, including liquefaction			
No Project	NI/NE	-	NI/NE
Alternative 1	LTS/NE	-	LTS/NE
Alternative 2	LTS/NE	-	LTS/NE
Alternative 3	LTS/NE	-	LTS/NE
Impact GEO-1d: Landslides			
No Project	NI/NE	-	NI/NE
Alternative 1	LTS/NE	-	LTS/NE
Alternative 2	LTS/NE	-	LTS/NE
Alternative 3	LTS/NE	-	LTS/NE
Impact GEO-2: Result in reservoir-triggered seismicity or be subject to a seiche			
No Project	NI/NE	-	NI/NE
Alternative 1	LTS/NE	-	LTS/NE
Alternative 2	LTS/NE	-	LTS/NE
Alternative 3	LTS/NE	-	LTS/NE
Impact GEO-3: Result in substantial soil erosion or the loss of topsoil			
No Project	NI/NE	-	NI/NE
Alternative 1	LTS/NE	-	LTS/NE
Alternative 2	LTS/NE	-	LTS/NE
Alternative 3	LTS/NE	-	LTS/NE
Impact GEO-4: Be located in a geologic unit or soil that is unstable, or that would become unstable as a result of the Project, and potentially result in onsite or offsite landslide, lateral spreading, subsidence, liquefaction, or collapse			
No Project	NI/NE	-	NI/NE
Alternative 1	LTS/NE	-	LTS/NE
Alternative 2	LTS/NE	-	LTS/NE
Alternative 3	LTS/NE	-	LTS/NE
Impact GEO-5: Be located on expansive soil, as defined in Table 18-1-B of the Uniform Building Code (1994), creating substantial direct or indirect risks to life or property			
No Project	NI/NE	-	NI/NE
Alternative 1	LTS/NE	-	LTS/NE
Alternative 2	LTS/NE	-	LTS/NE
Alternative 3	LTS/NE	-	LTS/NE
Impact GEO-6: Have soils incapable of adequately supporting the use of septic tanks or alternative wastewater disposal systems where sewers are not available for the disposal of wastewater			
No Project	NI/NE	-	NI/NE
Alternative 1	LTS/NE	-	LTS/NE
Alternative 2	LTS/NE	-	LTS/NE
Alternative 3	LTS/NE	-	LTS/NE

Alternative	Level of Significance Before Mitigation	Mitigation Measures	Level of Significance After Mitigation
Impact GEO-7: Directly or indirectly destroy a unique paleontological resource or site or unique geologic feature			
No Project	NI/NE	-	NI/NE
Alternative 1	LTS/NE	-	LTS/NE
Alternative 2	LTS/NE	-	LTS/NE
Alternative 3	LTS/NE	-	LTS/NE

Notes:
NI = CEQA no impact
LTS = CEQA less-than-significant impact
NE = NEPA no effect or no adverse effect

12.2 Environmental Setting

12.2.1. Geology

This section describes the geomorphic setting, topography, rock formations, landslides, soil characteristics, and paleontological resources in the study area. Earthquake faults, both existing in the study area and in the region, that are capable of causing ground shaking and related hazards in the study area are also described.

12.2.1.1. Geomorphic Setting

The study area can be broadly divided into two areas based on geomorphic province: the Coast Ranges and Great Valley geomorphic provinces (California Geological Survey 2002:1–3). The western portion of the study area occurs in the Coast Ranges foothills surrounding the Antelope Valley and in a long swath of the northwestern Sacramento Valley (Figures 12-1a–c).

The Coast Ranges geomorphic province is characterized by a series of north-northwest trending mountain ranges and valleys. The province extends approximately 600 miles from Point Arguello northward to the Klamath Range (Norris and Webb 1990:359–366) and varies in width from a few miles to 70 miles. The rock types and ages and the geologic structure of the Coast Ranges province are complex and variable, with the Franciscan Formation, composed of metamorphosed sedimentary and igneous rocks, representing the basement rocks of the Coast Ranges.

The Great Valley geomorphic province is mostly a nearly level alluvial plain extending from the Tehachapi Mountains in the south to the Klamath Mountains in the north, to the Sierra Nevada in the east and the Coast Ranges in the west. The valley consists of the San Joaquin River watershed to the south of the Sacramento–San Joaquin Delta, and the Sacramento River watershed to the north. This northwest-trending trough has been filled with a thick (several miles deep) (Norris and Webb 1990: 412–414) accumulation of sediments eroded from the adjacent ancestral Sierra Nevada and Klamath Mountain ranges from the Jurassic to the Present. The part of the study area that occurs within this province consists of younger terrace, alluvial fan, and basin geomorphic surfaces (Natural Resources Conservation Service 2006:619–621).

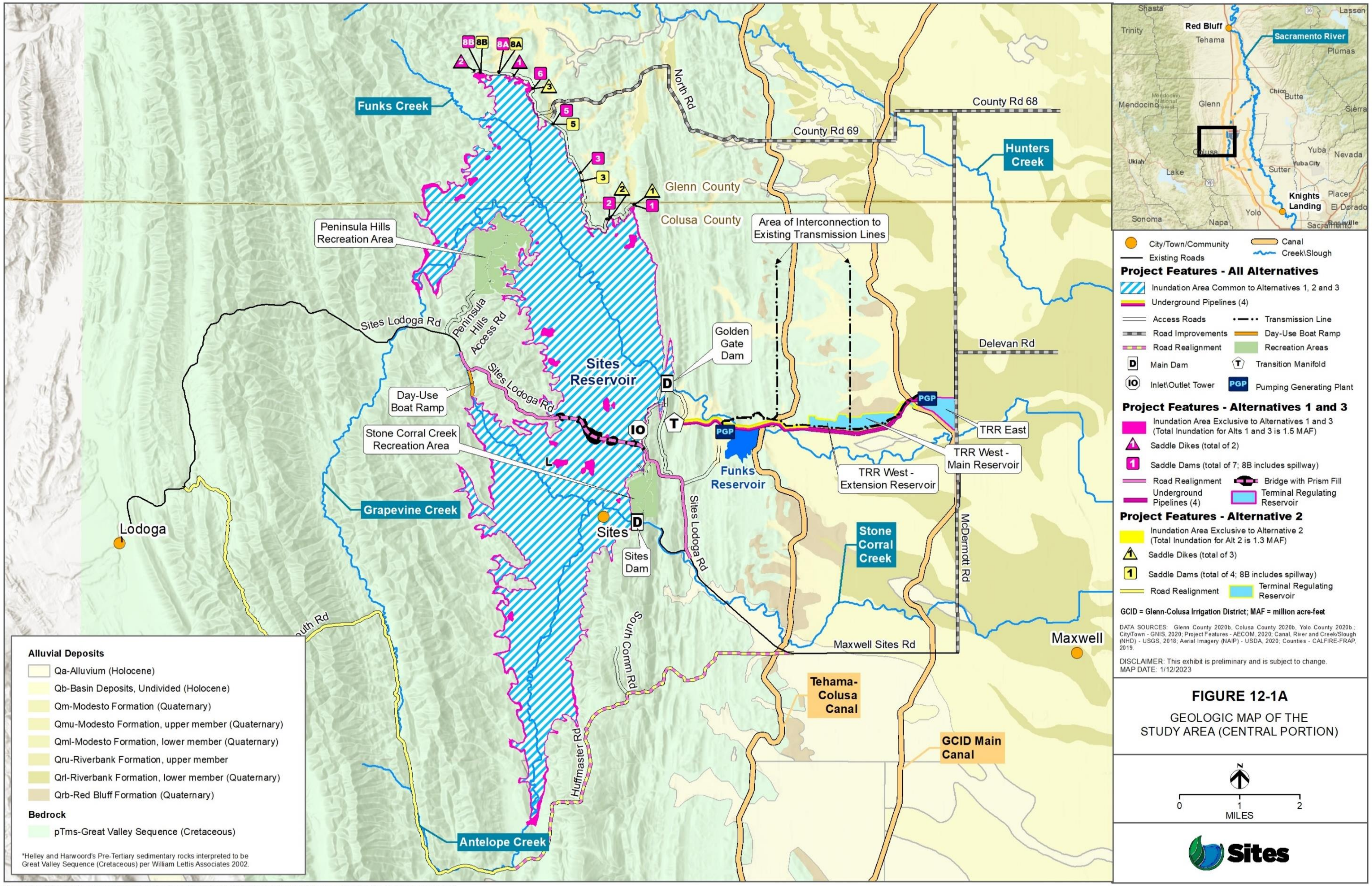

FIGURE 12-1A
GEOLOGIC MAP OF THE STUDY AREA (CENTRAL PORTION)

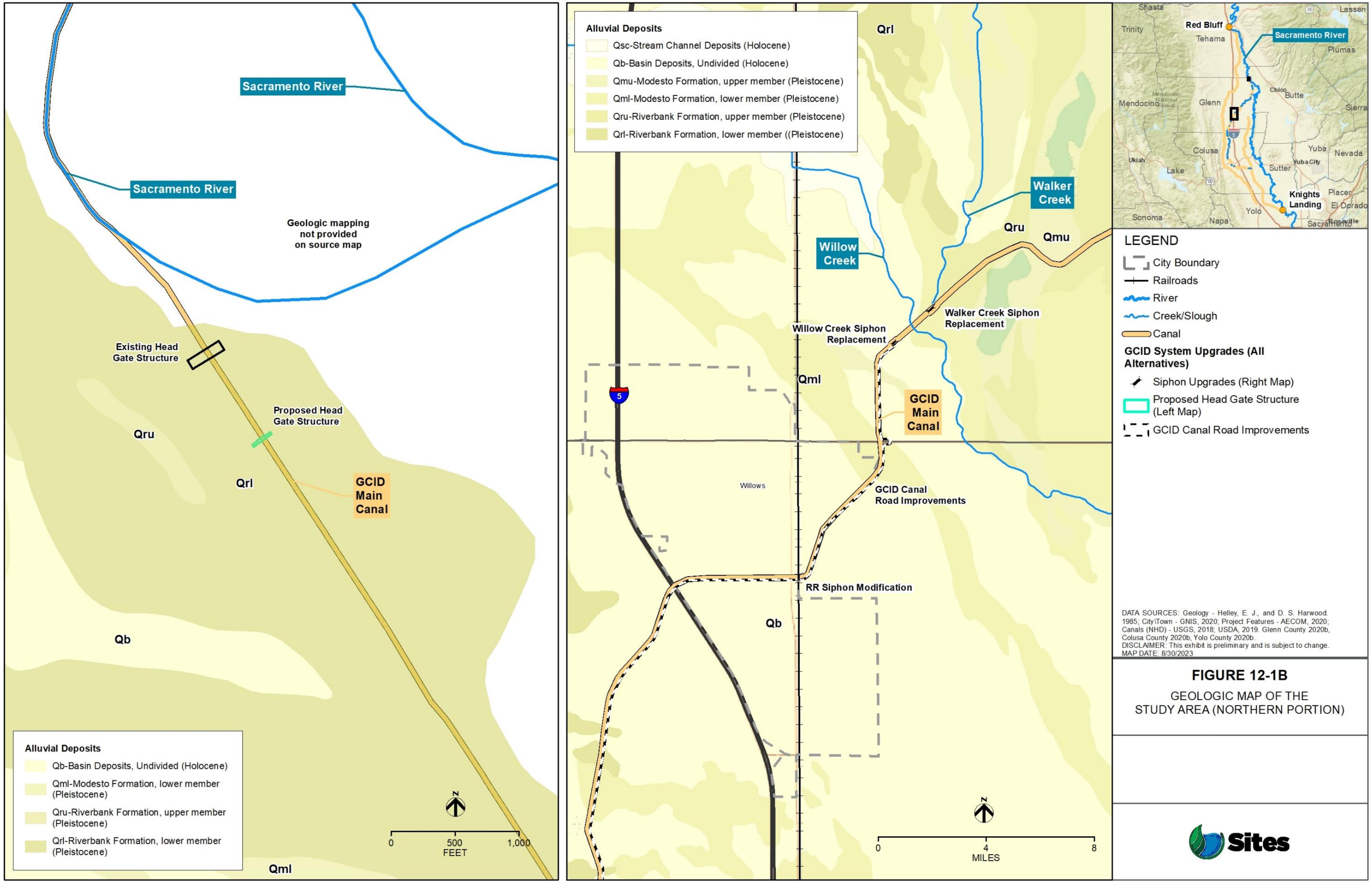

FIGURE 12-1B

GEOLOGIC MAP OF THE STUDY AREA (NORTHERN PORTION)

Sites

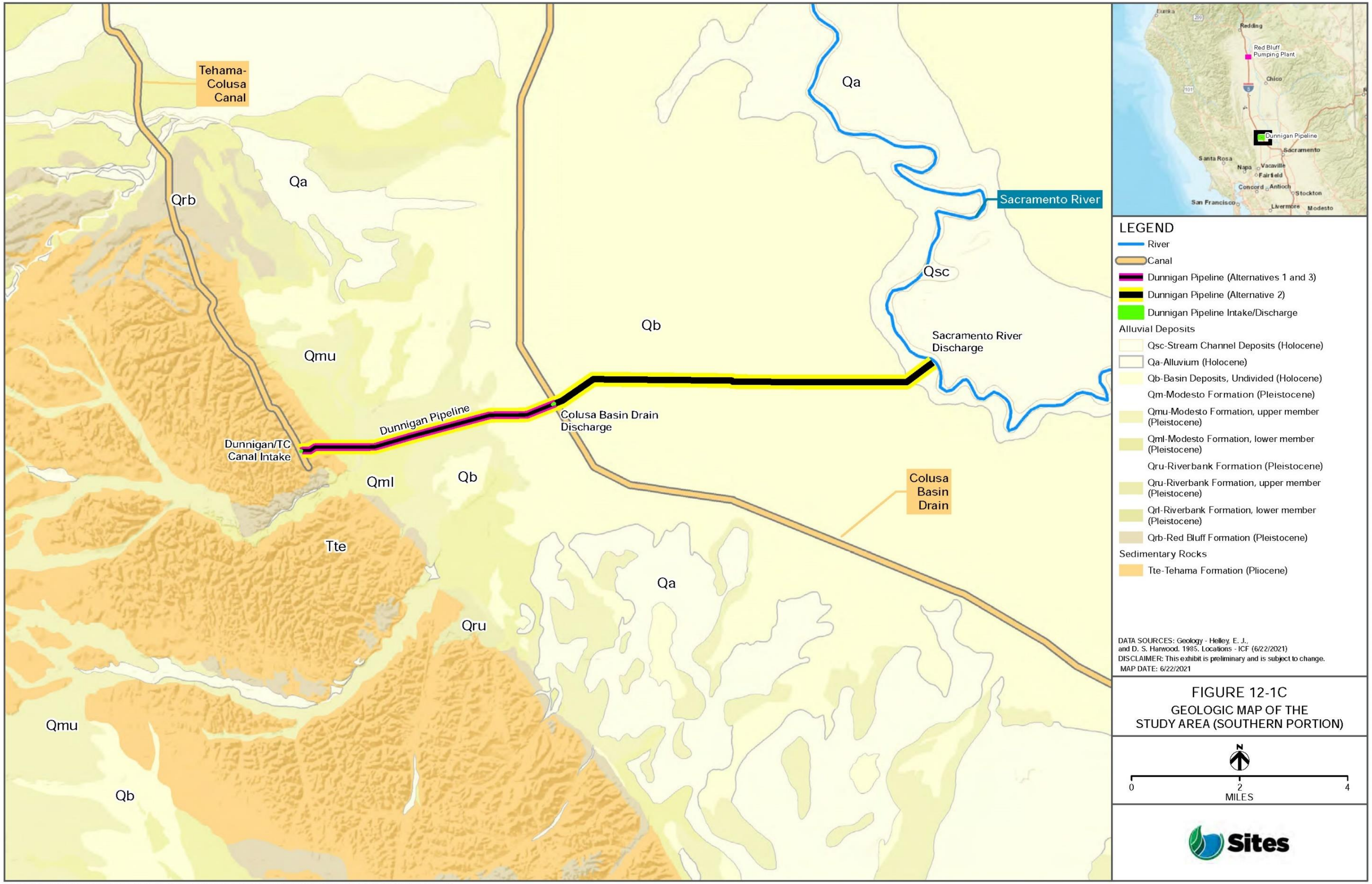

FIGURE 12-1C
GEOLOGIC MAP OF THE STUDY AREA (SOUTHERN PORTION)

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12.2.1.2. Topography

The topography of the study area varies from west to east. The west side of the study area in the vicinity of Funks Reservoir is characterized by low rolling foothills of the Coast Ranges, and elevations range from approximately 400 to 800 feet above mean sea level (msl) in the hills surrounding Antelope Valley to 200 feet above msl in the Funks Reservoir area. From the Funks Reservoir, the valley gently slopes to the study area's lowest point, which is approximately 30 feet above msl at the eastern edge of the study area, along the Sacramento River south of Dunnigan.

Within much of the immediate inundation area, the slopes are mostly subdued (as gentle as 0% to 3%), but the slopes in the vicinity of the Golden Gate and Sites Dam sites, saddle dams, and saddle dikes mostly range from 15% to 75%.

12.2.1.3. Geologic Overview

Coast Ranges and Antelope Valley

This overview of the geologic setting of the Antelope Valley and the Coast Ranges is based on the geologic technical memorandum prepared for the dams and reservoir portion of the Project (AECOM 2020a:6,7).

The largest portion of the study area (i.e., the Antelope Valley and foothills) is underlain by Upper Cretaceous sedimentary rocks of the Great Valley sequence (Cortina and Boxer Formations) and alluvial deposits of the Sacramento Valley. Surficial geologic units in the study area include Pliocene- to Pleistocene-age deposits of the Tehama Formation, Quaternary older alluvial terrace deposits, and Holocene (Recent) alluvium, colluvium, and landslide deposits. Figure 12-1a is a geologic map of the study area and environs, based on Helley and Harwood (1985:plates 2–4).

The two main formations in the Antelope Valley are the Cortina and Boxer Formations. Within the Cortina and Boxer Formations, the two primary rock units are sandstone and mudstone, with some interbedding of these two units occurring to varying degrees. The primarily sandstone portions are commonly ridge-formers, and the primarily mudstone portions are generally expressed as topographic lows.

A stream-cut water gap on Funks Creek is in the Venado sandstone member of the Cortina Formation. The lower portion of the channel is in the Yolo member of the Cortina Formation. The stream-cut water gap on Stone Corral Creek is in the Boxer and Cortina Formations.

Sacramento Valley

East of the Coast Ranges, the study area extends into the Sacramento Valley (Figures 12-1a–c). The Sacramento Valley is the northern portion of California's Great Valley, a nearly level alluvial plain that lies between the Sierra Nevada on the east and the Coast Ranges on the west. In the study area, the dominant geologic units of the Sacramento Valley are the Holocene basin and alluvial deposits that cover much of the valley floor and the Pleistocene alluvial deposits of the Modesto, Riverbank, and Red Bluff Formations (Helley and Harwood 1985:plates 2–4). These units were laid down as alluvial fans, terraces, or overbank flood basin deposits as a result of continuing erosion of the Coast Ranges and Sierra Nevada.

12.2.1.4. Geologic Units

This section describes the geologic units found in the study area. The locations and descriptions are based primarily on the regional geologic mapping by Helley and Harwood (1985:plates 2–4). Where available, additional geologic detail has been included from two reports prepared for the Project: the *Geology and Seismicity Technical Memorandum* (AECOM 2020a: 7–10) and the seismotectonic evaluation (William Lettis & Associates 2002:2-16 and figures). Figures 12-1a–c and 12-2 show the location, distribution, and relative relationships of these units.

None of the geologic units in the study area nor in the watershed of the Sites Reservoir are known to contain mercury and do not have the typical characteristics of mercury-bearing rocks. Mercury is generally associated with veins and fractures near recent hot spring or volcanic activity or associated with organic-rich sedimentary rocks. In California, mercury is associated with the Franciscan Formation, and most of the mercury mines in the state are located in this formation. Because these rock types do not occur in the study area, naturally occurring mercury is not expected to be present in the study area (U.S. Geological Survey 1970). Mercury is further discussed in Chapter 6, *Surface Water Quality*.

Stream Channel Deposits, Holocene (Qsc)

The stream channel deposits are Holocene in age and are located in the open, active channel of the Sacramento River and tributaries. These unweathered deposits are being transported by present-day processes and are continually reworked in the channel by streamflows (Helley and Harwood 1985:10).

Alluvium, Holocene (Qa)

The alluvium deposits unit is Holocene in age and made up of unweathered gravel, sand, and silt that was deposited by present-day streams and rivers. Its thickness ranges from a thin veneer to 30 feet. In the study area and vicinity, this unit originates from the Coast Ranges and forms broad alluvial fans along natural waterways. The unit is widespread in the study area, particularly in the southern portion, and overlies the Modesto Formation (Helley and Harwood 1985:10, plates 2–4).

Basin Deposits, Undivided, Holocene (Qb)

The basin deposits unit, undivided, is Holocene in age and made up of alluvium derived from the Coast Ranges. It ranges in thickness from 3 feet to 6 feet along the edge of the valley and up to 200 feet thick in the middle of the valley. This unit is widespread in the study area (Helley and Harwood 1985:12, plates 2–4) and overlies the Modesto Formation.

Modesto Formation, Upper and Lower Members, Pleistocene (Qmu and Qml)

The Modesto Formation is the youngest of the three Pleistocene deposits in the study area and is made up primarily of unconsolidated gravely sand, silt, and clay. It was deposited by modern day streams and forms broad alluvial fans, which occur throughout much of the valley and low-lying areas. This unit is divided into a lower and upper member, based largely on the degree of weathering, and overlies the Riverbank Formation (Helley and Harwood 1985:10, plates 2–4).

Riverbank Formation, Upper and Lower Members, Pleistocene (Qru and Qrl)

The Riverbank Formation is older than the Modesto Formation and is another Pleistocene alluvial deposit. It is made up of weathered reddish gravels, sand, silt, and clay and is divided into two informal members in the Sacramento Valley, the upper and lower members, based largely on the more eroded character of the lower member by comparison with exposures of the upper member. Both of these members are common in the study area and are typically found at topographically higher elevations along the edge of the valley (Helley and Harwood 1985:11, plates 2–4).

Red Bluff Formation, Pleistocene (Qrb)

The Red Bluff Formation is third and oldest of the Pleistocene deposits and is made up of bright red, highly weathered gravels. In the study area, it occurs in small lenses along the edge of the Sacramento Valley (Helley and Harwood 1985:11, plates 2–4).

Tehama Formation, Pliocene (Tte)

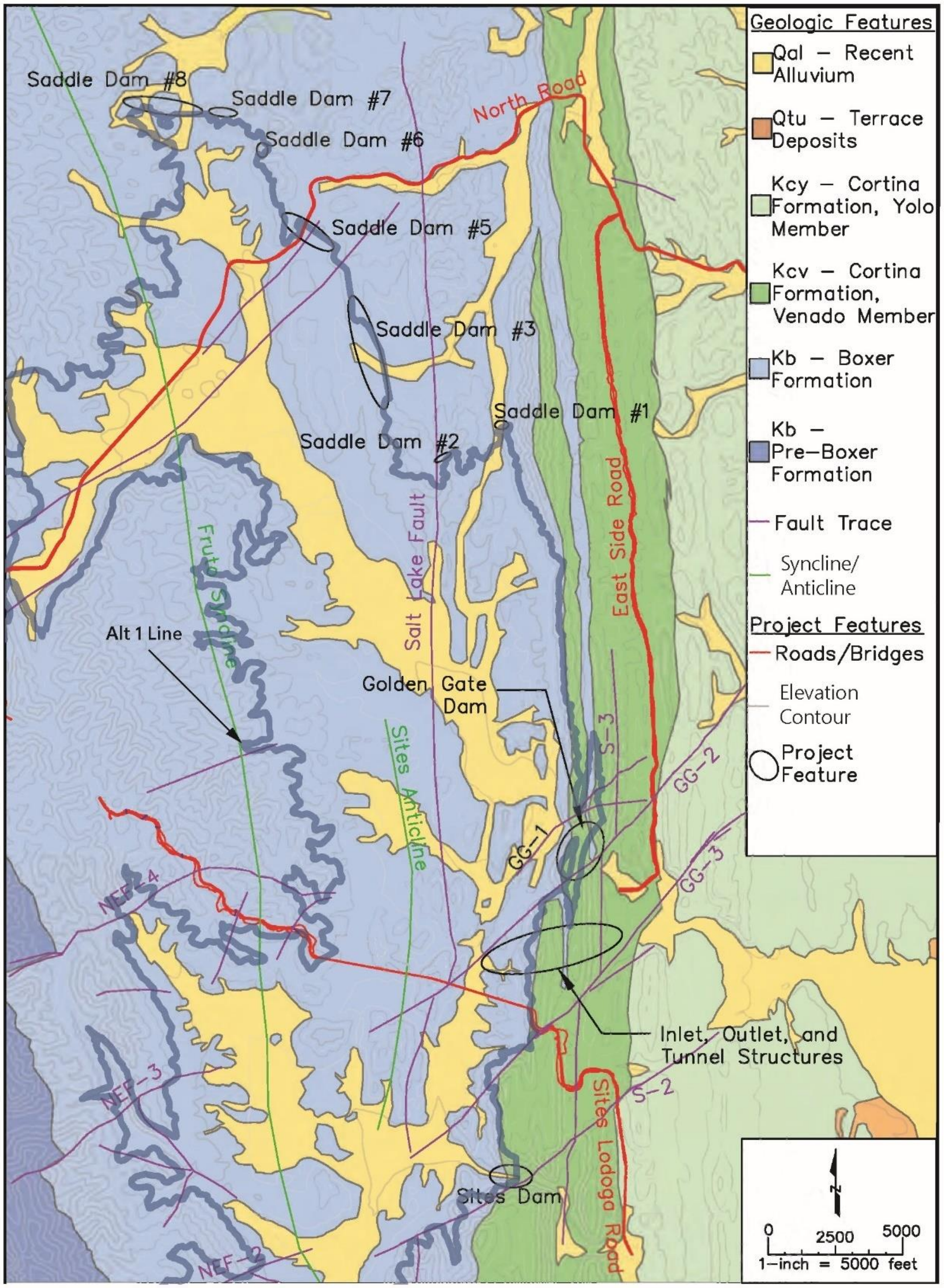
The Tehama Formation is Pliocene in age and made up of green, gray, and tan sandstone and siltstone that are derived from sediments of the Coast Ranges. It overlies the Cretaceous rocks of the Great Valley sequence. The unit can be up to 2,000 feet thick (Helley and Harwood 1985:15,16). It occurs in the southernmost portion of the study area.

Great Valley Sequence, Cretaceous (pTms, generally)

The oldest rocks in the study area are part of the Great Valley sequence, which is of Cretaceous age and made up of numerous formations and members. Helley and Harwood (1985:18) assigned all bedrock older than the Cretaceous to a single pre-Tertiary (pTms) unit, which is a broad designation of metamorphic, intrusive, and sedimentary rocks. Given that Helley and Harwood (1985) indicate that the uppermost rocks of this designation are the Great Valley sequence and that William Lettis & Associates (2002:Figures 2-3 and 2-4) indicate the study area is immediately underlain by the Great Valley sequence, this designation is generally assumed in this analysis to be the Great Valley sequence in the study area (Figure 12-2). Where detail is provided by AECOM (2020a:4, 5), this unit is further divided into the Cortina (the Yolo and Venado members) and Boxer Formations, both of which are marine deposits (William Lettis & Associates 2002:2-16). The Great Valley sequence occurs in the westernmost part of the study area.

Boxer Formation, Upper Cretaceous (Kb)

According to the geologic technical memorandum prepared for the Project (AECOM 2020a:6,7), the Boxer Formation consists mainly of mudstone, interbedded sandstone and mudstone, and minor sandstone and conglomerate. In general, the unit is not resistant to erosion and therefore does not form outcrops.



Source: AECOM June 29, 2020 Geology and Seismicity Technical Memorandum. Note: Alternative 1 inundation area shown only

Figure 12-2
Detailed Geologic Map of Dam and Inundation Area

Cortina Formation, Yolo and Venado Members, Upper Cretaceous (Kcy and Kcv)

The Cortina Formation is predominantly a sandstone. The lowest member of the formation is the Venado sandstone, which is made up of 1-foot-thick to 10-foot-thick, well-indurated sandstone layers interbedded with much thinner mudstone layers. The Venado sandstone is more resistant to erosion than the surrounding rock and therefore forms outcrops. Overlying the Venado member is the Yolo member, which is a laminated to thinly bedded mudstone. It ranges in thickness from 800 feet to 1,000 feet thick. The exposed mudstone easily erodes and tends to readily slake (AECOM 2020a:6,7). The Cortina Formation is fairly impermeable (AECOM 2020b:9).

12.2.1.5. Landslides and Landslide Hazards

Slope failures, commonly referred to as landslides, include many phenomena that involve the downslope displacement and movement of soil and rock material, either triggered by static (i.e., gravity) or dynamic (i.e., earthquake) forces. Slope failures may take the form of rockfalls, rockslides, rock avalanches, shallow soil slides/slips, rapid debris flows, and deep-seated rotational slides (i.e., slumps).

The geologic mapping performed during the California Department of Water Resources' (DWR's) 2003 feasibility study (California Department of Water Resources 2003:14,18,21,24,38,41, and 46) revealed that existing landslides occur in the Antelope Valley portion of the study area, as follows:

- Small, shallow debris flows and earth flows on the slopes of the valley and on steep, west-facing ridges.
- Two landslides in the Stone Corral Creek stream gap. The smaller of the two landslides appears to be shallow-seated. The larger landslide is approximately 250 feet wide by 400 feet long and roughly 30 feet deep, is approximately 400 feet upstream and adjacent to the smaller one and consists of colluvium and slumped Boxer mudstone.
- Two minor landslides are also present in the Stone Corral Creek stream gap. The larger of the two is approximately 100 feet by 100 feet.
- A 550 feet by 450 feet landslide is located approximately 600 feet upstream of the axis of the Sites Dam and has a maximum depth of 35 feet.
- Minor, shallow-seated landslides or surficial colluvial slumps are located in the Funks Creek stream gap.
- A 200 feet by 100 feet, shallow-seated landslide is located immediately above the Funks Creek channel in the stream gap.
- An approximately 200 feet by 150 feet area in the Funks Creek stream gap appears to be a minor rock fall that has an accumulation of talus at the toe of the slope.

No landslides exist in the Sacramento Valley portion of the study area due to the gently sloping topography.

The potential for landslides to occur is low in the Sacramento Valley part of the study area, where the slopes are shallow. Landslide potential increases in the upland areas in the Antelope

Valley part, where the slopes are steeper and the bedding of the rocks may present failure planes along which sliding can occur.

12.2.2. Seismicity

The section is excerpted primarily from the two geotechnical reports prepared for the Project: the William Lettis & Associates (2002) *Seismotectonic Evaluation, Phase II Fault and Seismic Hazards Evaluation* and the AECOM (2020a) *Geology and Seismicity Technical Memorandum*. The William Lettis & Associates (2002) seismotectonic evaluation was prepared for DWR to evaluate surface-faulting hazards and maximum levels of strong ground shaking in the study area. The AECOM (2020a) technical memorandum provides a further overview of site geology and seismicity. Where noted, additional information from the California Geological Survey (CGS) has been included.

12.2.2.1. Tectonic Setting

The study area is part of a tectonically active boundary between the Pacific Plate to the west and the Sierra Nevada-Great Valley (*Sierran*) microplate to the east. Geodetic data show that the Pacific Plate moves approximately 1.5 inches/year toward N30°W, relative to the Sierran microplate (Argus and Gordon 2001:1,580–1,592). Because major strike-slip faults (i.e., a fault in which the two blocks slide past one another) of the San Andreas system strike more westerly than average Pacific-Sierran motion north of the San Francisco Bay, there is a small component of transpressional (oblique shear) plate motion, which is accommodated by a combination of active strike-slip and thrust faulting (i.e., faulting in which the upper block, above the fault plane, moves up and over the lower block), and over the past several million years this motion has produced uplift of the Coast Ranges (AECOM 2020a:9).

Ongoing research suggests that transpressional plate motion is accommodated in part by movement on the Great Valley fault, which is a segmented system of hidden or blind thrust faults (i.e., a type of thrust fault which does not appear on the surface) beneath the western margin of the Central Valley. The western valley margin has been referred to as the Coast Ranges – Sierran Block Boundary Zone (CRSBZ) and described as a belt of active crustal shortening driven by impingement of the Sierra Nevada block against the Coast Ranges. The Great Valley fault is the potentially seismogenic (active or capable of movement) fault that accommodates most of the shortening within the CRSBZ. The Funks and Bear Valley segments are the structural segments of the Great Valley fault closest to the study area and are discussed below. Investigations have documented evidence for Quaternary growth of folds overlying segments of the Great Valley fault beneath the Rumsey Hills and Dunnigan Hills, 27 miles south of the Antelope Valley, and there is a general consensus among the seismotectonic community that the Great Valley fault is an active or potentially active seismic source in the modern transpressional tectonic setting[1] (AECOM 2020a:9).

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[1] Seismic sources or faults can generally be described by one of three activity classes as defined by CGS: active, potentially active, or inactive. Active describes historical and Holocene faults that have had displacements within the past 11,000 years. Potentially active describes faults showing evidence of displacements during Quaternary time (the past 1.6 million years). Pre-Quaternary age faults with no subsequent offset are classified as inactive. An inactive classification by CGS does not mean that a fault will not rupture in the future, but only that it has not been shown to have ruptured within the past 1.6 million years.

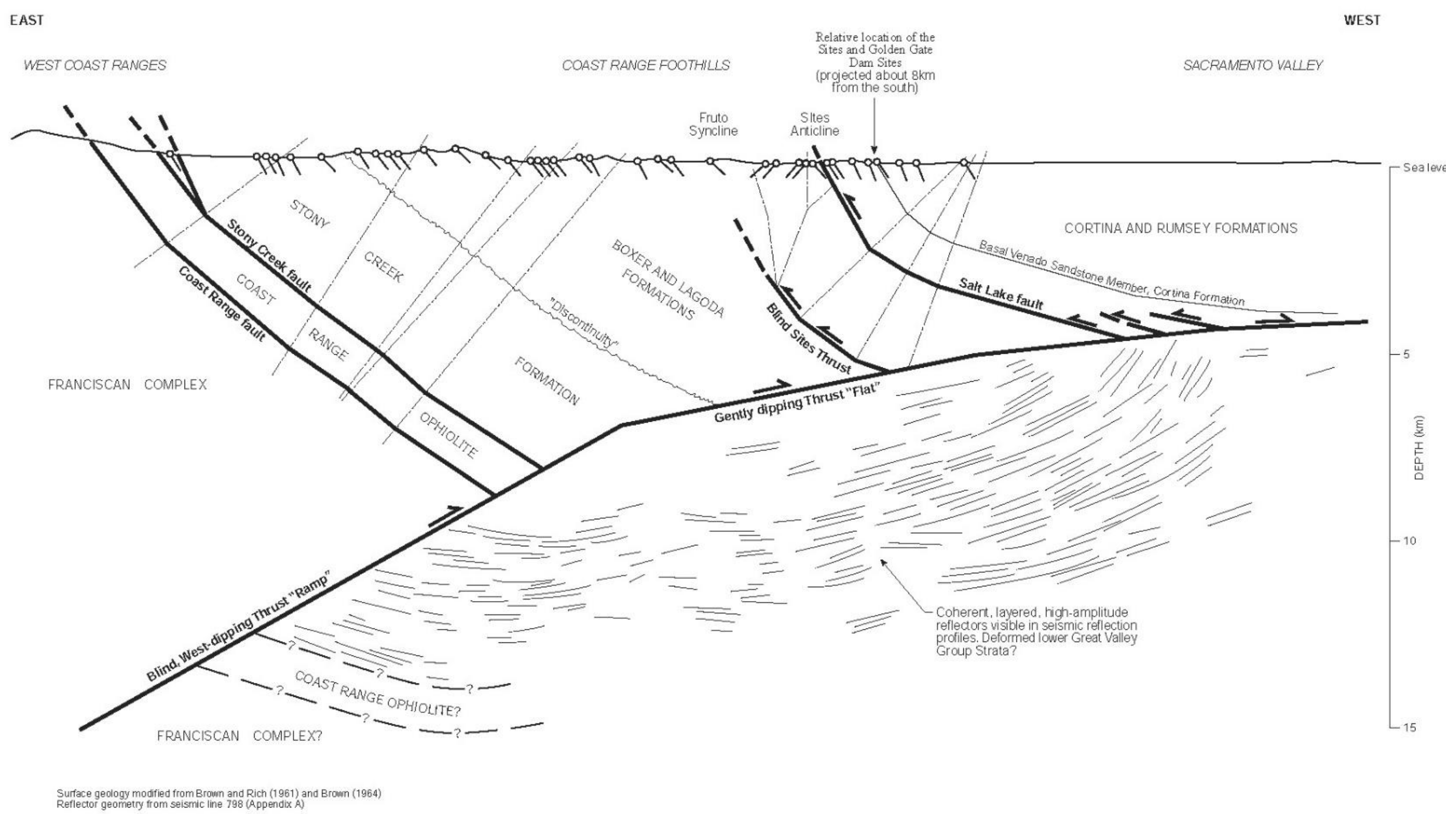
In the Antelope Valley portion of the study area, the Cortina and Boxer Formations are part of a series of an east-dipping, Great Valley sequence of rocks exposed in the foothills bordering the eastern Coast Ranges, which are folded about the axes of the north-trending Sites anticline and Fruto syncline. The most prominent structural geologic features in this area are the trend of the bedding associated with folding, jointing, and faulting (Figures 12-2 and 12-3) (AECOM 2020a:9).

Folding consists of the Fruto syncline and the associated adjacent Sites anticline. The Sites anticline is located approximately 1,000 feet to 2,000 feet west of the Salt Lake fault. The Sites anticline is a doubly plunging anticline about 3 miles long within the reservoir dying out slightly south of the town of Sites. The anticline is a tight fold with steeply dipping and overturned strata on both limbs. The Fruto syncline is located about 1 mile west of the Sites anticline near the west side of the Antelope Valley. It is continuous for roughly 9 miles in the Antelope Valley and plunges out slightly south of the unincorporated community of Sites (AECOM 2020a:9).

As shown in Figures 12-2 and 12-3, several surface faults have developed from the blind Great Valley fault, with one set striking north, parallel to the bedding, and another striking northeast, obliquely cutting the bedding.

Based on analysis of seismic reflection data and surface geologic relationships, William Lettis & Associates (2002) interpreted that the Fruto syncline, Sites anticline, and surface faults described above are underlain by a blind, west-dipping thrust fault informally named the Funks segment of the Great Valley fault. The Funks segment is about 10.6 miles long, dips approximately 27° toward the west beneath the Fruto syncline and flattens eastward beneath the Sites anticline on seismic reflection profiles. Two faults are associated with the Funks segment of the Great Valley fault (AECOM 2020a:10): the Salt Lake fault and the S-3 fault. The Salt Lake fault is a bedding-parallel, north-striking, high-angle thrust fault that developed adjacent to the axis of the doubly plunging Sites anticline and can be traced confidently for about 12 miles from north of Logan Creek and south to Stone Corral Creek near the unincorporated community of Sites (William Lettis & Associates 2002:3-62). It traverses through the Antelope Valley and is defined by a series of saltwater springs and gas seeps that occur along the fault trace. A bedding-parallel, north-striking, thrust fault, referred to as the S-3 fault was mapped. It is similar to the Salt Lake fault and is interpreted to be a bedding-parallel thrust fault that has accommodated shearing of the sedimentary rocks during uplift and eastward tilting along the Antelope Valley margin.

Based on analysis of seismic reflection data, a distinct segment of the Great Valley fault, referred to as the Bear Valley segment, is present south of the Funks segment. The Bear Valley segment is about 14 miles long and strikes almost due north-south. Four surface faults are associated with this segment of the Great Valley fault: GG-1, GG-2, GG-3, and S-2. These northeast-striking, high-angle, tear faults (i.e., a small fault that forms to accommodate the irregular shapes of dip-slip faults) trend through the Antelope Valley and traverse either through or near the stream-cut water gaps for Funks and Stone Corral Creeks and the ridge line. These four faults are considered active but are not seismic sources (AECOM 2020a:10).



Source: William Lettis & Associates

Figure 12-3
Cross Section of Geologic Structures

12.2.2.2. Primary Seismic Hazards

The State of California considers two aspects of earthquake events primary seismic hazards: seismic ground shaking and surface fault rupture (disruption at the ground surface as a result of fault activity).

Seismic Sources and Strong Ground Shaking

The regional and local faults described above are capable of producing moderately low ground shaking in the study area (California Geological Survey 2016). William Lettis & Associates (2002) investigated numerous faults and geologic structures as seismic sources that could affect the study area. They found that the controlling seismic source for the study area is the Bear Valley segment of the Great Valley fault system (Figures 12-2, 12-4, 12-5, and 12-6; Table 12-2).

The structural model adopted by William Lettis & Associates (2002) indicates that the GG-1, GG-2, GG-3, and S-2 faults move sympathetically during moderate to large magnitude earthquakes on the Funks thrust ramp and probably do not behave as independent seismic sources. They may, however, be a source of aftershocks following an earthquake on the Funks or Bear Valley segments. William Lettis & Associates (2002) calculated an associated range of aftershock magnitudes from Mw 5.3 to Mw 5.4. The firm conservatively adopts Mw 5.4 as the maximum magnitude for aftershocks on faults GG-2, GG-3, and S-2 (William Lettis & Associates 2002).

Table 12-2. Regional and Local Fault Information

<table>
<tr><th>Fault Name</th><th>Fault Type</th><th>Activity</th><th>Fault Length</th><th>Other Information</th><th>Comments</th></tr>
<tr><td>GG-1</td><td>Right Lateral, Strike Slip</td><td>No Holocene Activity</td><td>1.1 mi (1.8 km)</td><td>Not a seismic source</td><td rowspan="4">GG-1, GG-2, GG-3 and S-2 are interpreted to be shallow tear faults along Funks/Bear Valley segment boundary. Conservatively assumed to be sources of aftershocks. Possible surface-rupture hazards.</td></tr>
<tr><td>GG-2</td><td>Right Lateral, Strike Slip</td><td>No Holocene Activity</td><td>3.7 mi (5.9 km)</td><td rowspan="3">Faults GG-2, GG-3 are S-2 are considered potential sources of shallow aftershocks. Maximum earthquake magnitude for these structures is M_w 5.4.</td></tr>
<tr><td>GG-3</td><td>Right Lateral, Strike Slip</td><td>No Holocene Activity</td><td>3.0 mi (4.8 km)</td></tr>
<tr><td>S-2</td><td>Right Lateral, Strike Slip</td><td>No Holocene Activity</td><td>2.4 mi (3.9 km)</td></tr>
<tr><td>Salt Lake Fault</td><td>Thrust</td><td>Multiple Late Quaternary Surface Ruptures</td><td>12 mi (20 km)</td><td>Not a seismic source</td><td>Interpreted to accommodate triggered, aseismic slip</td></tr>
<tr><td>S-3</td><td>Thrust</td><td>No Holocene Activity</td><td>≥4.25 mi (6 km)</td><td>Not a seismic source</td><td>May accommodate triggered, aseismic slip</td></tr>
<tr><td>Funks Segment, Great Valley Fault</td><td>Blind Thrust</td><td>Late Quaternary Activity</td><td>11 mi (17 km)</td><td>Width is14 mi (22 km), rupture area is 146 mi^2 (374 km^2), and maximum magnitude</td><td>Indirect evidence of late Quaternary activity</td></tr>
</table>

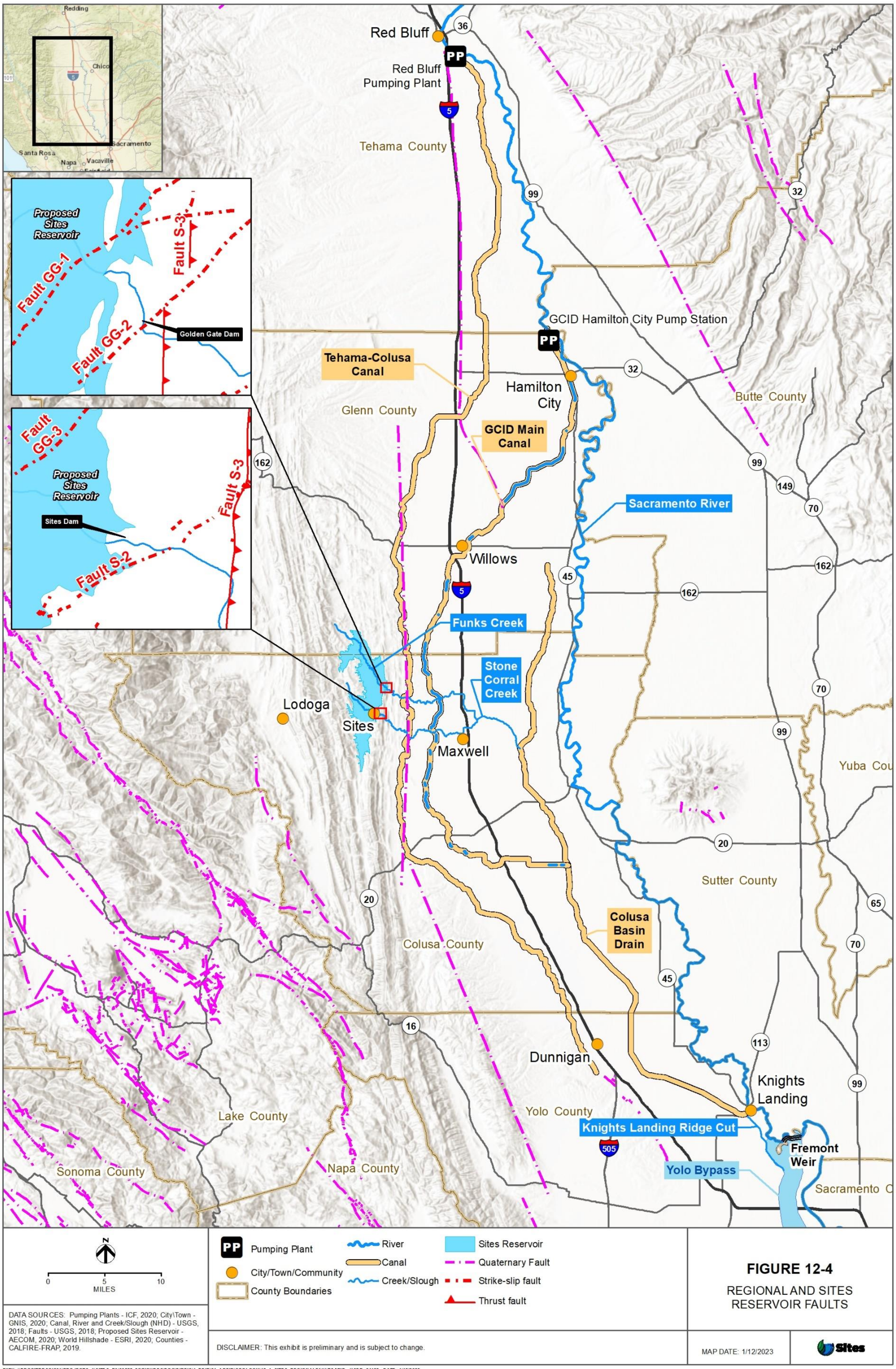
Fault Name	Fault Type	Activity	Fault Length	Other Information	Comments
				is M_w 6.6	
Bear Valley Segment, Great Valley Fault	Blind Thrust	Assumed to be Active	14.4 mi (23 km)	Width is 14.4 mi (23 km), rupture area is 207 mi^2 (529 km^2), and maximum magnitude is M_w 6.8	Conservatively assumed to be active
San Andreas Fault	Strike Slip	Active	650 mi (1,050 km)	Maximum magnitude = M_w 8	Assumes maximum earthquake would rupture 272 mi (435 km)
Southern Reach, Corning Fault	Oblique-Reverse	Active	13 mi (21 km)	Maximum magnitude = M_w 6.7	Associated with clusters of seismicity

Source: Modified from William Lettis & Associates 2002:xv
Notes:
mi = miles
km = kilometers
M_w = moment magnitude (i.e., a measure of the overall strength or "size" of an earthquake)

William Lettis & Associates (2002) also reviewed the ground-shaking hazard in the study area. Based on a probabilistic seismic hazard map that depicts the peak horizontal ground acceleration values exceeded at a 10% probability in 50 years, the probabilistic peak horizontal ground acceleration values ranged from 0.284g (where g equals the acceleration speed of gravity) in Antelope Valley, to 0.261g near the community of Maxwell, to 0.286g in the southern portion of the study area near the town of Dunnigan. As a point of comparison, probabilistic peak horizontal ground acceleration values for the San Francisco Bay Area range from 0.4g to more than 0.8g (California Geological Survey 2008a) (Figure 12-5).

Surface Fault Rupture

The Great Valley fault and a group of northeast-striking faults are present in the Antelope Valley portion of the study area. William Lettis & Associates (2002:6-28) estimated that during an earthquake on the Funks segment of the Great Valley fault, surface displacements/offsets on the Salt Lake fault would likely range from 4.5 inches to 16 inches, and AECOM assumed the offset for the S-3 fault would be equal to the Salt Lake fault (AECOM 2020a:14). The northeast-striking faults include the GG-1, GG-2, GG-3, and S-2 faults. William Lettis & Associates (2002:6-30–6-32) estimated the maximum surface displacements from these faults would not exceed about 8 inches and are likely to be lower, on the order of 2.4 inches to 4 inches (AECOM 2020a:14,15). Other faults in the Antelope Valley and foothills portion of the study area have not been analyzed, but those, such as LSSD5-4, located in critical areas will require investigation and analysis once property is purchased or access granted (AECOM 2020a:15). In the Sacramento Valley portion of the study area, there are no known active faults (Figure 12-4) (U.S. Geological Survey 2018; California Geological Survey 2010). Figure 12-6 provides the major structural features in the region and the site-specific faults mapped in the study area, as described by William Lettis & Associates (2002:Plate 1).


Red Bluff
Red Bluff Pumping Plant
Tehama County
GCID Hamilton City Pump Station
Tehama-Colusa Canal
Hamilton City
Glenn County
GCID Main Canal
Butte County
Sacramento River
Willows
Funks Creek
Stone Corral Creek
Lodoga
Sites
Maxwell
Yuba Cou
Sutter County
Colusa Basin Drain
Colusa County
Dunnigan
Knights Landing
Yolo County
Knights Landing Ridge Cut
Fremont Weir
Yolo Bypass
Sacramento C
Lake County
Sonoma County
Napa County
Proposed Sites Reservoir
Fault GG-1
Fault S-3
Fault GG-2
Golden Gate Dam
Fault GG-3
Sites Dam
Fault S-2
Pumping Plant
City/Town/Community
County Boundaries
River
Canal
Creek/Slough
Sites Reservoir
Quaternary Fault
Strike-slip fault
Thrust fault
MILES
FIGURE 12-4
REGIONAL AND SITES RESERVOIR FAULTS
DATA SOURCES: Pumping Plants - ICF, 2020; City\Town - GNIS, 2020; Canal, River and Creek/Slough (NHD) - USGS, 2018; Faults - USGS, 2018; Proposed Sites Reservoir - AECOM, 2020; World Hillshade - ESRI, 2020; Counties - CALFIRE-FRAP, 2019.
DISCLAIMER: This exhibit is preliminary and is subject to change.
MAP DATE: 1/12/2023
Sites

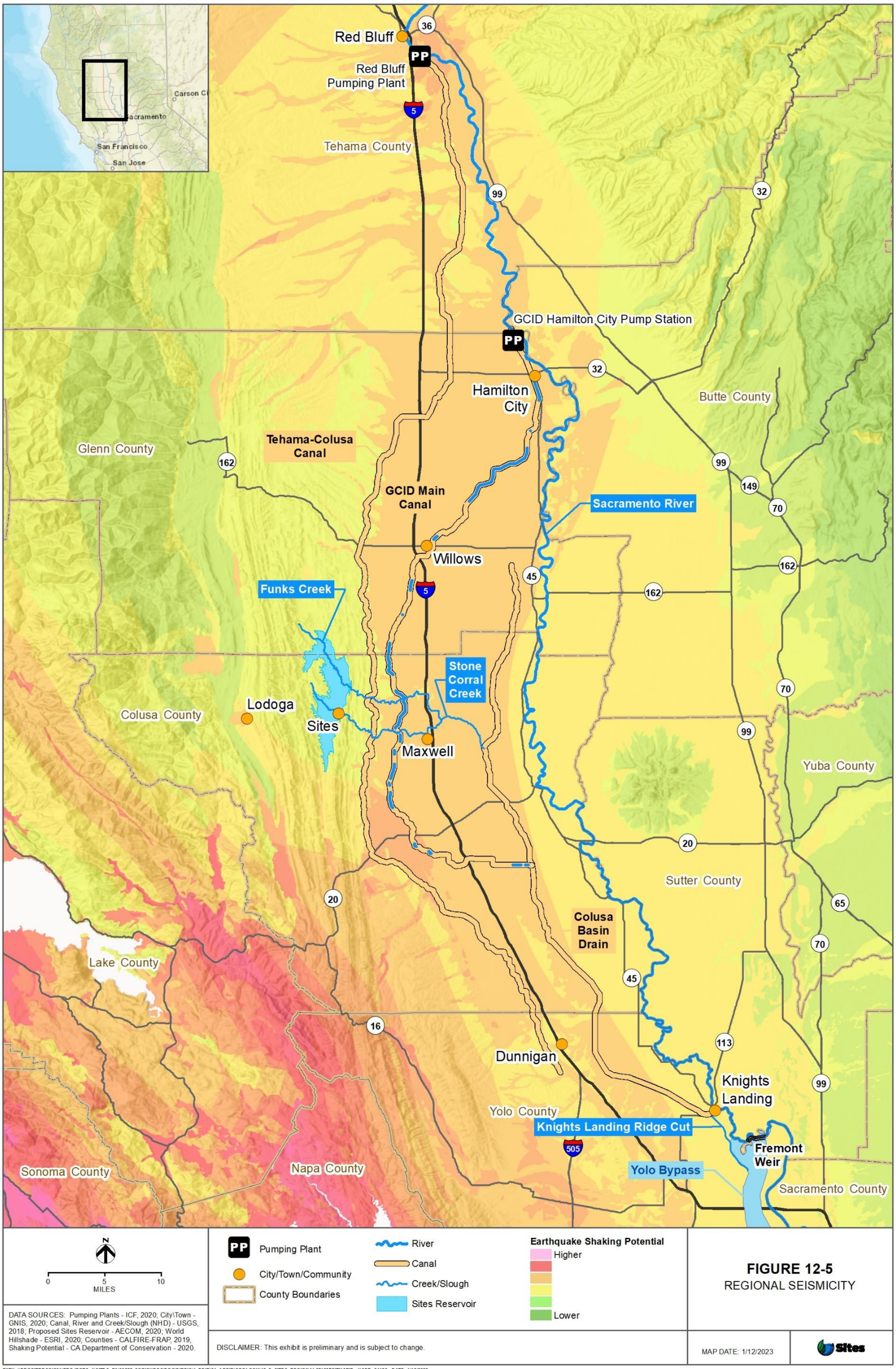
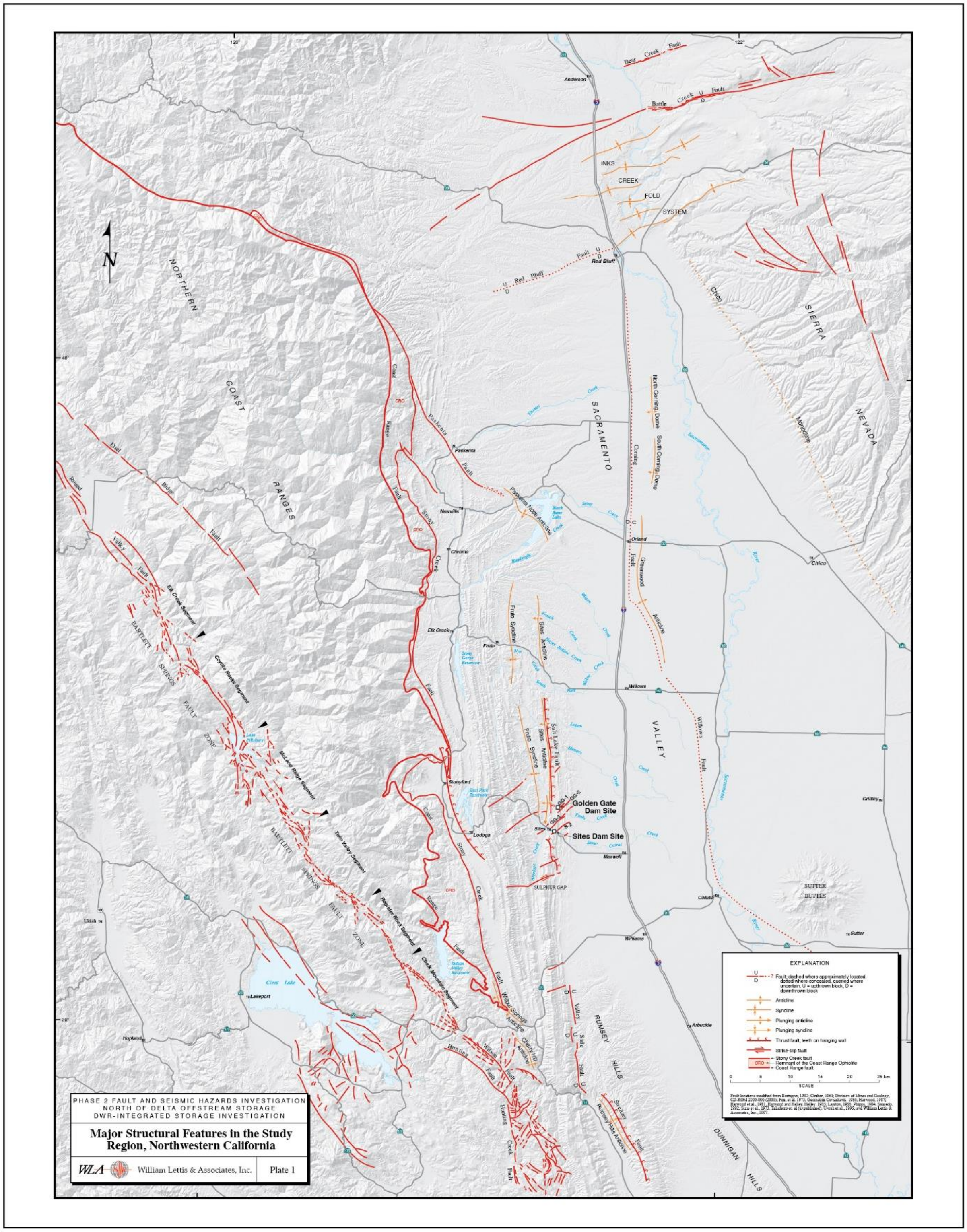


FIGURE 12-5
REGIONAL SEISMICITY



Graphics ... 00537.20 (01-31-2023) JC

Figure 12-6
Major Structural Features in the Region and the Site-Specific Faults Mapped in the Study Area

12.2.2.3. Secondary Seismic Hazards

Secondary seismic hazards refer to seismically induced landsliding, liquefaction and related ground failures, and seiche. The State of California maps areas that are subject to certain secondary seismic hazards pursuant to the Seismic Hazards Mapping Act of 1990. No such hazard maps have been prepared for the study area or vicinity (California Geological Survey 2020), but landslide and liquefaction hazards are addressed briefly below based on available information.

Seismically Induced Landsliding

Seismically induced landslides are a secondary effect of ground shaking. Factors that contribute to a seismically induced landslide include the underlying geology, degree of soil/rock cohesiveness, steepness of the slope, ground saturation, and magnitude of ground shaking. As described in Section 12.2.1.5, *Landslides and Landslide Hazards*, steep slopes with some evidence of landsliding are present in the hills surrounding Antelope Valley. These slopes could become unstable during an earthquake. In the Sacramento Valley portion of the study area, the gently sloping topography makes landsliding much less likely.

Liquefaction and Related Ground Failures

Liquefaction is the process by which soils and sediments lose shear strength and fail during seismic ground shaking. The vibrations caused by an earthquake can increase pore pressure in saturated materials. If the pore pressure is raised to be equivalent to the load pressure, this causes a temporary loss of shear strength, allowing the material to flow as a fluid. This temporary condition can result in severe settlement of foundations and slope failure. The susceptibility of an area to liquefaction is determined largely by the depth to groundwater and the properties (e.g., grain size, density, and degree of consolidation) of the soil and sediment within and above the groundwater. The sediments most susceptible to liquefaction are saturated, unconsolidated sand and silt within 50 feet of the ground surface (California Geological Survey 2008b:35–36).

The CGS recommends further investigation of liquefaction susceptibility before building based on age of the sediments, peak acceleration that has a 10% probability of being exceeded in 50 years, and depth to groundwater. It recommends further investigation if a site has latest Pleistocene-age sediments, a peak acceleration greater than or equal to 0.30g, and when the depth to saturated soil is less than 20 feet; Holocene-age sediments, a peak acceleration greater than or equal to 0.20g, and the anticipated depth to saturated soil is less than 30 feet; or latest Holocene-age sediments (e.g., current river channels and floodplains), a peak acceleration greater than or equal to 0.10g, and the anticipated depth to saturated soil is less than 40 feet (California Geological Survey 2004:5).

Based on these CGS-identified risk factors, the liquefaction hazard in the study area varies by location. In the Antelope Valley portion of the study area, the Cretaceous Great Valley sequence units are too well consolidated to be susceptible to liquefaction, and the lenses of Quaternary and Pleistocene sediments are likely to be too thin and localized to be susceptible. In the Sacramento Valley portion of the study area, a liquefaction hazard could be present because Holocene-age sediments are widespread and peak acceleration is greater than 0.20g. Depth to shallow groundwater in this portion of the study area ranges from 4 to 20 feet.

Other types of ground failure related to liquefaction include lateral spreading and differential settlement. *Lateral spreading* is a failure of soil and sediment within a nearly horizontal zone that causes the soil to move toward a free face (such as a streambank or canal) or down a gentle slope. Even a relatively thin seam of liquefiable sediment can create planes of weakness that could result in continuous lateral spreading over large areas (California Geological Survey 2008b:36). *Differential settlement*—the uneven settling of soil—is the most common displacement hazard in fill soil. It commonly occurs in interbedded sediments at alluvial sites. This hazard affects cut side hill benches and roads built on fill material. (California Geological Survey 2008b:49,56)

Seiche

A seiche is a standing wave that forms in a semi- or fully enclosed body of water, such as a lake, reservoir, or river. A seiche can be triggered by atmospheric conditions (e.g., rapid changes in atmospheric pressure) (National Oceanic and Atmospheric Administration 2018) or by an earthquake even if it is distant (U.S. Geological Survey 2020). For example, the 1964 Alaska earthquake caused many seiches to form in the southeastern United States, including 6-foot-high waves on the Gulf Coast. The quake also caused seiches in Kansas and Michigan but none in the western United States. This seemingly unlikely distribution of seiches was likely due to the structural geologic features of the affected areas, such as sediment thickness, presence of thrust faults, and presence of uplifts and basins, and by the resonance of the surface wave (U.S. Geological Survey 2020).

The "sloshing" waves of a seiche can reach tens of feet high, damage or destroy property, and adversely affect people. Seiches can temporarily flood a shoreline in a manner similar to tsunamis; however, their destructive capacity is not as great. Seiches may cause overtopping of impoundments such as dams, particularly when the impoundment is in a near-filled condition, releasing water downstream. Seiches can also damage levees and dams and cause water to inundate the surrounding areas.

12.2.3. Soils

For the purposes of this section, the soils[2] in the study area can be within the context of the two geomorphic provinces described above: the Great Valley and the Coast Ranges provinces. Within the study area, the soils occurring in the Great Valley province formed in alluvium, while the soils in the Coast Ranges province formed in place from weathered rock, colluvium, and alluvium.

The TRR East, TRR East PGP, eastern end of the TRR East pipelines, TC Canal intake, TRR East bridge over the GCID Main Canal, Dunnigan Pipeline, CBD outlet, eastern end of Road 69, Delevan Road, and McDermott Road occur in the Great Valley province. The soils in the area of the eastern end of the TRR East pipelines, TRR East PGP, and roads were formed in flood basins and terraces (Soil Survey Staff 2020). The soils that formed in the flood basins, most of which have been levelled for rice production, are now subject to rare flooding (if any) due to flood control improvements (Natural Resources Conservation Service 2006:16). They are generally

[2] As used in this section, the terms "soil" and "soils" pertain to the upper 5-6 feet of earthen material as mapped and classified by the Natural Resources Conservation Service. However, in other instances in this chapter, the terms "soil" and "soils" may pertain to any unconsolidated earthen material, irrespective of the depth at which it occurs.

clayey, have very slow permeability and high expansion potential, and are very deep; some have a high sodium content and can be corrosive to concrete and uncoated steel. The water erosion hazard is generally slight. (Soil Survey Staff 2020)

Antelope Valley, where most[3] of the Project components would be located, occurs in the Coast Ranges province. The soils in this province are on gentle to very steep slopes. Most of the soils are clayey and have high expansion potential. The soils are shallow to very deep and have a slight to moderate water erosion hazard. (Soil Survey Staff 2020)

The Natural Resources Conservation Service (NRCS) has mapped 99 detailed soil map units in the study area, as shown in Appendix 12A, *Soil Survey Map of the Study Area*. Appendix 12B, *Soil Map Units in the Study Area*, provides the soil map unit name, the county in which it occurs, and the soil properties that are most relevant to potential soil impacts, specifically: erosion hazard, expansion potential (expressed as linear extensibility for the layer with the greatest potential), risk of corrosion of uncoated steel, risk of corrosion of concrete, and limitations for septic tank absorption fields.

Those soil map units identified in Appendix 12B, *Soil Map Units in the Study Area*, as having a linear extensibility percentage of 9 or more (see U.S. Department of Agriculture 2019:618-A.45) are regarded here to be roughly equivalent to soils that are expansive, as defined in Table 18-1-B of the Uniform Building Code. With the exception of the existing concrete foundation facilities (i.e., GCID head gate and GCID Main Canal siphons) and the sediment in Funks Reservoir, expansive soils underlie part or all of the facilities that comprise the Project, either as a particular layer or throughout the entire profile to a depth of 5–6 feet.

12.2.4. Paleontological Resources

This section describes the paleontological sensitivity of the geologic units in the study area.

Paleontological resources, commonly referred to as fossils, are the remains, traces, imprints, or life history artifacts (e.g., nests) of prehistoric plants and animals found in ancient sediments, which may be either unconsolidated or lithified (i.e., either poorly or well cemented). Fossils are considered nonrenewable scientific and educational resources. Fossils include the bones and teeth of animals, the casts and molds of ancient burrows and animal tracks, and very small remains such as the bones of birds and rodents. They also include plant remains such as logs, prehistoric leaf litter, and seeds. Recovered specimens in the study area vicinity range from the shells of marine invertebrates to the bones and teeth of extinct Pleistocene megafauna, such as mammoths (*Mammuthus*) and giant ground sloths (*Megalonyx)* that are less than 200,000 years old.

The determination of paleontological sensitivity is a qualitative assessment based on the paleontological resource potential of the stratigraphic units present, the local geology and geomorphology, and other factors relevant to fossil preservation and potential yield. According

[3] Includes Sites Reservoir inundation area; Sites and Golden Gate Dams; saddle dams; intake and outlet footprints; intake tunnel; Funks Reservoir, pipelines, and associated facilities; TRR West and associated facilities; administration and operations and maintenance and storage buildings; Sites Lodoga Road realignment; maintenance roads and roads to recreation areas; and the recreation areas and boat ramp.

to the Society of Vertebrate Paleontology (SVP) (2010:2), standard considerations for determining sensitivity are: (1) the potential for a geological unit to yield abundant or significant vertebrate fossils or to yield a few significant fossils, large or small, vertebrate, invertebrate, or paleobotanical remains; and (2) the importance of recovered evidence for new and significant taxonomic, phylogenetic, paleoecological, or stratigraphic data (Table 12-3).

Table 12-3. Paleontological Sensitivity Ratings

Potential	Definition
High	Rock units from which vertebrate or significant invertebrate, plant, or trace fossils have been recovered are considered to have a high potential for containing additional significant paleontological resources. Paleontological potential consists of both (a) the potential for yielding abundant or significant vertebrate fossils or for yielding a few significant fossils, large or small, vertebrate, invertebrate, plant, or trace fossils and (b) the importance of recovered evidence for new and significant taxonomic, phylogenetic, paleoecologic, taphonomic, biochronologic, or stratigraphic data.
Undetermined	Rock units for which little information is available concerning their paleontological content, geologic age, and depositional environment are considered to have undetermined potential. Further study is necessary to determine if these rock units have high or low potential to contain significant paleontological resources.
Low	Reports in the paleontological literature or field surveys by a qualified professional paleontologist may allow determination that some rock units have low potential for yielding significant fossils. Such rock units will be poorly represented by fossil specimens in institutional collections, or based on general scientific consensus, will only preserve fossils in rare circumstances and the presence of fossils is the exception not the rule.
None	Some rock units, such as high-grade metamorphic rocks (e.g., gneisses and schists) and plutonic igneous rocks (e.g., granites and diorites), have no potential to contain significant paleontological resources. Rock units with no potential require neither protection nor mitigation measures relative to paleontological resources.

Source: Society of Vertebrate Paleontology 2010:1–2.

Unlike archaeological sites, which are narrowly defined, paleontological sites are defined by the entire extent (both areal and stratigraphic) of a unit or formation. In other words, once a unit is identified as containing vertebrate fossils, or other rare fossils, the entire unit is a paleontological site (Society of Vertebrate Paleontology 2010:2). For this reason, the paleontological sensitivity of geologic units is described and analyzed broadly.

SVP (2010:11) defines *significant paleontological resources* (i.e., scientifically important resources) as:

> fossils and fossiliferous deposits, here defined as consisting of identifiable vertebrate fossils, large or small, uncommon invertebrate, plant, and trace fossils, and other data that provide taphonomic, taxonomic, phylogenetic, paleoecologic, stratigraphic, and/or biochronologic information. Paleontological resources are considered to be older than recorded human history and/or older than middle Holocene (i.e., older than about 5,000 radiocarbon years).

This analysis focuses on vertebrate paleontological resources because of their rarity and scientific importance. No rare or unique occurrences of plant or invertebrate fossils are known to occur in the study area, and all geologic units in the study area with plant or invertebrate fossils also contained vertebrate fossils and were therefore considered sensitive. The paleontological sensitivity of the geologic units in the study area is summarized in Table 12-4.

Table 12-4. University of California Museum of Paleontology Vertebrate Fossil Records, by Formation Extent and Study Area Counties, and Paleontological Sensitivity of Geologic Units in the Study Area

Map Symbol	Unit and Age	Records Throughout Formation's Extent	Records in Study Area Counties	Paleontological Sensitivity
Qsc	Stream channel deposits, Holocene	None in the study area	0	None
Qa	Alluvium, Holocene	None in the study area	0	Low
Qb	Basin deposits, undivided, Holocene	None in the study area	0	Low
Qmu and Qml	Modesto Formation, upper and lower member, Pleistocene	27	8—in Yolo County	High
Qru and Qrl	Riverbank Formation, upper and lower members, Pleistocene	350	0	High
Qrb	Red Bluff Formation, Pleistocene	2	2—in Yolo County	High
Tte	Tehama Formation, Pliocene	175	6—in Colusa County,12—in Glenn County, 85—in Tehama County, 70—in Yolo County	High
pTms	Great Valley sequence, general, Cretaceous (see description of geologic unit for assumption regarding pTms in study area)	None for sequence overall, but some formations may be fossil bearing	0	Low to Unknown
Kcy	Great Valley sequence, Cortina Formation, Yolo Member, Upper Cretaceous	0	0	Low
Kcv	Great Valley sequence, Cortina Formation, Venado Member, Upper Cretaceous	0	0	Low
Kb	Great Valley sequence, Boxer Formation, Upper Cretaceous	0	0	Low

Source: University of California Museum of Paleontology 2020.

12.2.4.1. Stream Channel, Alluvium, and Basin Deposits—Holocene

Holocene deposits (i.e., the alluvial fan deposits) are not typically evaluated as paleontologically sensitive, because biological remains are not considered fossils unless they are older than 10,000 years. There may be site-specific exceptions to this general approach, but the University of California Museum of Paleontology (UCMP) database contains no records for fossil finds from Holocene units in Colusa, Glenn, Tehama, or Yolo Counties (University of California Museum of Paleontology 2020). Accordingly, the Holocene alluvial fan deposits that immediately underlie most of the study area are considered to have no sensitivity to low sensitivity for paleontological resources.

12.2.4.2. Modesto, Riverbank, and Red Bluff Formations—Pleistocene

The Pleistocene deposits underlying the Holocene alluvial deposits are considered to have high sensitivity for paleontological resources, consistent with prevailing professional standards—California's Pleistocene nonmarine strata have yielded stratigraphically important vertebrate fossils, including the assemblages that defined both the Rancholabrean and Irvingtonian Stages of the North American Land Mammal Chronology, which is used as a reference by paleontologists and stratigraphers across the country. Because of this information, continental deposits of Pleistocene age are almost universally treated as paleontologically sensitive in California.

The UCMP database contains 27 records of vertebrate fossils from the Modesto Formation, including mammoth (*Mammuthus*), ground sloth (*Megalonyx jeffersoni*), camel (*Camelops hesternus*), bison (*Bison*), horse (*Equus*), pocket gopher (*Thomomys*), and bony fish (*Osteichthyes*) (University of California Museum of Paleontology 2020). Two of these records are from Yolo County (Table 12-4). Given the fossils known for this unit, its paleontological sensitivity is considered high.

The UCMP database contains 350 records of vertebrate fossils from the Riverbank Formation. These records include ground sloth (*Glossotherium harlani*), dire wolf (*Canis dirus*), horse (*Equus*), rabbit (*Sylvilagus*), bird (*Aves*), diverse rodents (e.g., *Neotoma*, *Reithrodontomys*, *Thomomys*, *Microtus*, and *Spermophilus*), bison (*Bison*), camel (*Camelops hesternus*), coyote (*Canis latrans*), mammoth (*Mammuthus columbi*), and fish (*Osteichthyes*) (University of California Museum of Paleontology 2020). None are known from the study area (Table 12-4). Given the large number of fossil records, the paleontological sensitivity for this unit is considered high.

Two records of Pleistocene horse (*Equus*) fossils are known from the Red Bluff Formation (University of California Museum of Paleontology 2020). These fossils occur in Yolo County (Table 12-4). Given the fossils known for this unit, its paleontological sensitivity is considered high.

12.2.4.3. Tehama Formation—Pliocene

There are 175 vertebrate fossils records from the Tehama Formation, including a large number of horses (e.g., *Equus simplicidens*, *Nannippus*, and *Pliohippus*) and fish (*Osteichthyes*), as well as rodents (e.g., *Reithrodontomys*, *Peromyscus*, and *Neotoma*) and deer (*Odocoileus*) (University of California Museum of Paleontology 2020). These fossils are almost entirely from the counties of the study area (Table 12-4). The paleontological sensitivity for this unit is therefore considered high.

12.2.4.4. *Great Valley Sequence, General and Cortina and Boxer Formations—Upper Cretaceous*

There are no vertebrate fossil records for the two Great Valley sequence formations in the study area: the Cortina Formation (no records), Yolo and Venado Members (records of microfossils only), and the Boxer Formation (records of microfossils only) (University of California Museum of Paleontology 2020). Because no vertebrate fossils are known from these units, the paleontological sensitivity for these units is considered low.

The Great Valley sequence contains numerous other formations, and vertebrate fossils are present in some of those formations. For areas broadly defined as Great Valley sequence (pTms) by Helley and Harwood (1985) (see description of geologic unit in Section 12.2.1.4, *Geologic Units*, for assumptions regarding pTms in study area), the paleontological sensitivity is considered unknown because it is not known which formations of the Great Valley sequence are present.

12.3 Methods of Analysis

The primary sources of information used in preparing the analysis of geologic and seismic hazards were the *Geology and Seismicity Technical Memorandum* (AECOM 2020a), the DWR *Geologic Feasibility Report, Sites Reservoir Project* (California Department of Water Resources 2003), and the William Lettis & Associates (2002) *Seismotectonic Evaluation, Phase II Fault and Seismic Hazards Evaluation*. The information in these and other relevant reports was evaluated both qualitatively and quantitatively, depending on the hazard, based on the conclusions contained in the technical reports prepared for the Project and professional judgment.

The Authority will prepare an Initial Sites Reservoir Fill Plan that is discussed in Section 2D.2 of Appendix 2D, *Best Management Practices, Management Plans, and Technical Studies*. The Authority will implement the following BMPs, which are described in Appendix 2D. These BMPs, which are based on regulations and industry and discipline standards, are considered part of the Project and are incorporated into the analysis of potential construction and operations impact on geology and soils.

- BMP-1, Conformance with Applicable Design Standards and Building Codes, includes a broad range of civil and geotechnical engineering and seismic design studies and design measures.
- BMP-10, Salvage, Stockpiling, and Replacement of Topsoil and Preparation of a Topsoil Storage and Handling Plan, requires evaluation of topsoil for salvaging suitability and preparation of storage and handling plans.
- BMP-12, Development and Implementation of Stormwater Pollution Prevention Plan(s) (SWPPP) and Obtainment of Coverage under Stormwater Construction General Permit

(Stormwater and Non-stormwater) (Water Quality Order No. 2022-0057-DWQ/NPDES No. CAS000002 and any amendments thereto), requires a suite of measures to control soil erosion and sediment, stormwater and non-stormwater runoff, and "housekeeping" considerations (e.g., construction materials stockpiles, waste management).

- BMP-3, Completion of Pre-Construction Geotechnical Evaluations and Data Reports, requires geotechnical testing, data collection, and reporting necessary to describe expected construction conditions and provide design and construction recommendations.
- BMP-2, Siting of Recreational Structures, requires recreational facilities be sited outside the predicted seiche wave run-up elevation.
- BMP-9, Siting and Design of Onsite Wastewater Disposal Systems, requires soil testing to determine the suitability and parameters for septic system design.
- BMP-33, Implementation of a Worker Environmental Awareness Program (WEAP), requires training of all construction crews and contractors on protection and avoidance of biological, cultural, archaeological, paleontological, and other sensitive resources.

As described in Chapter 2, *Project Description and Alternatives*, Section 2.5.3.1, *Geotechnical Investigations*, the Authority would conduct geotechnical studies (e.g., reservoir rim study, seismic fault study) to provide Project-specific recommendations for the engineering and final design of all facilities.[4] These studies will be conducted once property is purchased or access granted. The impact analysis assumes the Project would be designed and constructed in accordance with the following standards, criteria, and regulations, as described in BMP-1:

- All facilities would be designed to meet a wide variety of seismic design criteria, such as the California Building Standards Code regulations for structures and transmission lines, the International Building Code for structural design, the seismic design for railway structures, and the seismic provisions for structural steel buildings.
- The main dams, saddle dams, saddle dikes, I/O Works, and TRR East embankment or TRR West would be designed to conform with Project-specific geotechnical design recommendations and the seismic design criteria of the Reclamation and/or DSOD, such that dam embankments, foundations, abutments, and appurtenant facilities would be stable under design conditions of construction and reservoir operation including seismic.
- TRR East would be designed to meet both DSOD and Reclamation design criteria because of its height of embankment, whereas TRR West would be designed to meet only Reclamation design criteria because it is constructed through excavation rather than an embankment.
- Roads and the bridge would be designed to meet national, state, and county standards. In addition, the bridge would be designed to meet California Department of Transportation

[4] The Authority has initiated preliminary geotechnical field investigations to support ongoing engineering evaluations and design development. These efforts include the *2022–2024 Sites Reservoir Geologic, Geophysical, and Geotechnical Investigations* (Sites Project Authority and Bureau of Reclamation 2022) and the *2023–2024 Sites Reservoir Test Pits, Fault Studies, and Quarry Studies* (Sites Project Authority 2022). More extensive field investigation would be needed to finalize Project design, as noted in Chapter 2.

(Caltrans) Seismic Design Criteria, including its "no collapse" criteria (California Department of Transportation 2020:3-1–3-4). The bridge's earthen fill prisms would be designed to meet American Association of State Highway and Transportation Officials (AASHTO) Load and Resistance Factor Design (LRFD) Bridge Design Specifications, Caltrans Seismic Design Criteria, and Caltrans California Amendments to the AASHTO LRFD Bridge Design Specifications.

- All buildings and the recreation areas would be built to the seismic design standards of the California Building Standards Code.

The analysis of geology, seismicity, and soils combines the Project components that would be subject to similar types and level of hazards and resultant impacts.

The discussion of seiche hazards in this chapter is based on a review of the literature to provide an overview of the types of conditions that are associated with the occurrence of seiches. Fieldwork and other analyses will be conducted in support of the seiche evaluation when property is purchased or access granted, which is anticipated before 2023 (Forrest pers. comm.). Because more detailed information is not available, the analysis of seiche hazard uses a conservative approach (i.e., likely overestimates the run-up zone). Chapter 5, *Surface Water Resources*, discusses the inundation and flooding impacts associated with dam failure.

The primary sources of information used in preparing the analysis of soil limitations and hazards in the study area within 5–6 feet below ground level (i.e., the depth to which the NRCS describes soil profiles) were data from the NRCS Soil Survey Geographic (SSURGO) database (Natural Resources Conservation Service 2020) and Web Soil Survey (Soil Survey Staff 2020). SSURGO and Web Soil Survey provide information on soil morphologic, hydrologic, and chemical characteristics, as well as ratings of suitability and limitations for various uses, such as soil expansion, erosion hazard, corrosivity, and suitability for onsite wastewater disposal systems. The SSURGO and Web Soil Survey data were evaluated both qualitatively and quantitatively, depending on the soil characteristic or limitation.

The primary source of information used in developing the paleontological resources analysis is the paleontological database at the UCMP. Effects on paleontological resources were analyzed qualitatively, based on professional judgment and SVP guidelines below.

SVP's *Standard Procedures for the Assessment and Mitigation of Adverse Impacts to Paleontological Resources* provides standard guidelines that are widely followed (Society of Vertebrate Paleontology 2010:1–11). These guidelines reflect the accepted standard of care for paleontological resources. The SVP guidelines identify two key phases in the process for protecting paleontological resources from project impacts (Society of Vertebrate Paleontology 2010:1).

- Assess the likelihood that the project's area of potential effect contains significant nonrenewable paleontological resources that could be directly or indirectly impacted, damaged, or destroyed as a result of the project.
- Formulate and implement measures to mitigate potential adverse impacts.

The SVP guidelines provide general standardization in evaluating paleontological sensitivity (Table 12-3) to assess potential impacts on paleontological resources. Table 12-4 lists the sensitivity of the geologic units in the study area, and Table 12-5 summarizes SVP's recommended treatments to avoid adverse effects in each sensitivity category. The analysis combines the Project components that would have impacts on geologic units of similar paleontological sensitivity.

Table 12-5. Society of Vertebrate Paleontology's Recommended Treatment for Paleontological Resources

Sensitivity Category	Mitigation Treatment
High or Undetermined	• An intensive field survey and surface salvage prior to earth moving, if applicable. • Monitoring by a qualified Paleontological Resource Monitor of excavations. • Salvage of unearthed fossil remains and/or traces (e.g., tracks, trails, burrows). • Screen washing to recover small specimens, if applicable. • Preliminary survey and surface salvage before construction begins. • Preparation of salvaged fossils to a point of being ready for curation (i.e., removal of enclosing matrix, stabilization and repair of specimens, and construction of reinforced support cradles where appropriate). • Identification, cataloging, curation, and provision for repository storage of prepared fossil specimens. • A final report of the finds and their significance.
Low or no	Rock units with low or no potential typically will not require impact mitigation measures to protect fossils.

Source: Society of Vertebrate Paleontology 2010:1–2.

12.3.1. Thresholds of Significance

An impact on geology and soils would be considered significant if the Project would:

- Directly or indirectly cause potential substantial adverse effects, including the risk of loss, injury, or death involving:
  - Rupture of a known earthquake fault, as delineated in the most recent Alquist-Priolo Earthquake Fault Zoning Map issued by the State Geologist for the area or based on other substantial evidence of a known fault (refer to Division of Mines and Geology Special Publication Number 42)
  - Strong seismic ground shaking
  - Seismic-related ground failure, including liquefaction
  - Landslides
- Result in reservoir-triggered seismicity or create potential for a significant seiche
- Result in substantial soil erosion or the 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 onsite or offsite landslide, lateral spreading, subsidence, liquefaction, or collapse
- Be located on expansive soil, as defined in Table 18-1-B of the Uniform Building Code (1994), creating substantial risks to life or property
- Have soils incapable of adequately supporting the use of septic tanks or alternative wastewater disposal systems where sewers are not available for the disposal of wastewater
- Directly or indirectly destroy a unique paleontological resource or unique geologic feature

Although CEQA does not define "unique paleontological resource," the California Public Resources Code (§ 5097.5) specifies vertebrate fossils in its protection of paleontological sites, and the presence of vertebrate fossils is used by agencies such as the U.S. Department of Interior Bureau of Land Management (Potential Fossil Yield Classification System) and Caltrans to determine the scientific importance and paleontological sensitivity of geologic units. In addition, all vertebrate fossils contribute to our understanding of evolution and changes in ecosystems, and determining the "uniqueness" of a vertebrate fossil often requires examination in the laboratory (Scott and Springer 2003:5–7). Therefore, given the rarity of vertebrate fossils and their scientific importance, all terrestrial vertebrate fossils are considered unique for the purposes of this analysis. Geologic units sensitive for paleontological resources (i.e., with a high or undetermined sensitivity rating) (Table 12-4) were considered to have potential to contain unique paleontological resources.

12.4 Impact Analysis and Mitigation Measures

Impact GEO-1: Directly or indirectly cause potential substantial adverse effects, including the risk of loss, injury, or death involving *(impact subdivided into a, b, c, and d to address the individual aspects of seismic and geologic hazards)*:

Impact GEO-1a: Rupture of a known earthquake fault, as delineated on the most recent Alquist-Priolo Earthquake Fault Zoning Map, issued by the State Geologist for the area or based on other substantial evidence of a known fault

No Project

Under the No Project Alternative, the operations of the existing TC Canal, RBPP, and GCID Main Canal would continue. None of these facilities would likely be affected by surface fault rupture because no active faults are known to be present in the vicinity. No new facilities would be built.

Significance Determination

The No Project Alternative would not directly or indirectly cause potential substantial adverse effects, including the risk of loss, injury, or death involving surface fault rupture, because existing facilities are not located near known active faults and no new facilities would be constructed and operated. There would be no impact/no effect.

Alternatives 1 and 3

Alternatives 1 and 3 are analyzed together because they require construction of the same facilities. Under these alternatives, constructed facilities near active faults could be damaged or fail if exposed to surface fault rupture; damage to or failure of the facilities could cause potential substantial adverse effects. Facilities located in the Sacramento Valley (i.e., Red Bluff Diversion, Funks Reservoir, TRR East, Funks and TRR East PGPs, Funks and TRR East pipelines, TC Canal intake, Dunnigan Pipeline, CBD outlet, and GCID system upgrades) are not anticipated to be affected by surface fault rupture because no known active faults are present in the valley.

DWR (2003) and William Lettis & Associates (2002) conducted extensive seismotectonic studies in the vicinity of the proposed dams. These studies have identified several faults crossing through or near the dam sites and facilities in the Antelope Valley and surrounding foothills (Figure 12-4; Table 12-6). These studies provide an adequate characterization of the study area for the purposes of this impact analysis. Advances in the ground motion modeling since the studies were conducted have resulted in newer state-of-the-art ground motion prediction equations, and these advances have been incorporated into engineering analysis and design for the Project (AECOM 2020a). Additional geotechnical information will be incorporated into the Project design as further studies are conducted (Chapter 2, *Project Description and Alternatives*, Section 2.5.3.1, *Geotechnical Investigations*).

Table 12-6. Location of Faults Relative to Alternative 1 or 3 Structures

Fault	Structures on or Near Fault	Potential Offset
Salt Lake	Saddle Dam 2, bridge, North Road, and TC Canal intake	Between 4.5 and 16 inches
S-3	Outlet portal and Sites Lodoga Road on the east side of the reservoir	Between 4.5 and 16 inches
GG-1, GG-2, GG-3, and S-2	Golden Gate Dam (GG-2 passes through the right abutment and GG-1 passes approximately 500 to 1,000 feet north of the left abutment), intake tower cut slope (GG-2), outlet portal (GG-3), bridge (G-2), and Sites Lodoga Road (S-2)	2.4 to 4 inches but the maximum would not exceed 8 inches
LSSD5-4	Center of Saddle Dam 5	Further investigation will be conducted

Sources: William Lettis & Associates 2002, California Department of Water Resources 2003

<u>Construction</u>

Golden Gate Dam, Sites Dam, the saddle dams, and the saddle dikes are located in an area with known faults. If surface fault rupture occurred during dam construction, people could be endangered by shifting materials and structures. However, dam embankments, foundations, abutments, and appurtenant facilities would be constructed in such a way as to be stable under design conditions of construction, and only construction personnel would be allowed on the site. If surface fault rupture resulted in dam failure, it could cause widespread flooding in the region downstream of the dams (Impact HYDRO-2 in Chapter 5, *Surface Water Resources,* provides more detailed discussion). To address the risk posed by these conditions (Figure 12-7), the known faults, geologic structures, and seismic activity of the area would be considered in the final design of the main dams, saddle dams, and saddle dikes. The dams and dikes would be designed to accommodate the maximum predicted fault offset (Table 12-6). The dams would be designed to ensure the dam embankment would not be impaired by extensive cracking, crest settlement, or excessive deformation in critical zones, and the design would limit seismic deformation to 5 feet. Response spectra, which are properties used during engineering design to analyze the performance of structures and equipment during earthquakes, would continue to be refined as further geotechnical data and analyses become available. Monitoring equipment and tools, including strong motion seismic detectors, piezometers, settlement points, and seepage weirs, would be permanently installed at each dam site, and strong motion seismic detectors would be installed at center crests, abutments, and toes of the main dams. Potential seismic impacts related to initial filling and subsequent draining and refilling the reservoir are described in Impact GEO-2.

Similarly, the I/O Works, tunnel, and pipelines in the Antelope Valley and foothills would be located near or on known faults. Surface fault rupture could damage these facilities, which could cause flooding along Funks and Stone Corral Creeks (Chapter 5, *Surface Water Resources*). As described in Chapter 2, *Project Description and Alternatives,* a seismic fault study would map the faults adjacent to the I/O Works and ensure that the location of the tunnel and pipeline alignments would minimize fault crossings. The power and supervisory controls required to operate the I/O Works and other appurtenances would be designed to remain fully operable following a seismic event, which would enable operators to shut down facilities as needed.

The roads and bridge would be designed to limit the potential for damage if a surface fault rupture should occur. The faults intersecting roads would be characterized during the geotechnical studies and the final road design would incorporate geotechnical recommendations. Structures in the recreation areas, such as vault toilets, would not be sited on an active fault and therefore would not be damaged by surface fault rupture.

Operation

The operation impacts of Alternative 1 or 3 related to earthquake faults would be the same because differences in water deliveries would not affect surface fault ruptures and both alternatives have the same permanent facility footprints. Operation under both Alternatives 1 and 3 could result in flooding caused by surface fault rupture if a tunnel or pipeline were to break and uncontrolled release were to occur. However, power and supervisory controls required to operate the I/O Works and other appurtenances would be designed to remain fully operable following a seismic event, which would enable operators to shut down facilities as needed. As noted above for construction, dam failure is not anticipated because the dams and dikes would be designed to meet all applicable design criteria, which would include accommodating the maximum anticipated offset from surface fault rupture. As discussed in Impact HYDRO-3, which describes the potential impacts related to flooding during operations, flood maps would be developed in accordance with the California Office of Emergency Services, along with evacuation plans for areas within the potential inundation area.

Operation of facilities for Alternatives 1 and 3 (i.e., Red Bluff Diversion, Funks Reservoir, TRR East, Funks and TRR East PGPs, Funks and TRR East pipelines, TC Canal intake, Dunnigan Pipeline, CBD outlet, and GCID system upgrades) in the Sacramento Valley is not anticipated to be affected by surface fault rupture because no known active faults are present in the Sacramento Valley. As described in BMP-1, the administration and operations building, which would be considered a habitable structure, would be built to meet the requirements of the California Building Standards Code to protect the staff using the building, including by siting buildings away from active faults.

	Very High Slip Rate 9 or greater mm/yr	High Slip Rate 8.9 to1.1 mm/yr	Moderate Slip Rate 1.0 to 0.1 mm/yr	Low Slip Rate less than 0.1 mm/yr
Extreme Consequence Total Class Weight 31-36	84th	84th	84th	50th to 84th
High Consequence Total Class Weight 19-30	84th	84th	50th to 84th	50th to 84th
Moderate Consequence Total Class Weight 7-18	84th	50th to 84th	50th to 84th	50th
Low Consequence Total Class Weight 0-6	50th	50th	50th	50th

Source: Fraser and Howard 2002

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Figure 12-7
Division of Safety of Dams' Fault Slip Consequence-Hazard Matrix

CEQA Significance Determination and Mitigation Measures

The impact of construction of Alternatives 1 and 3 would be less than significant because all facilities would be designed to meet all applicable design criteria, which would include ensuring that structures remain stable during an earthquake. Where needed, seismic fault studies would be conducted to inform final design of the main dams, saddle dams, saddle dikes, I/O Works (including the tunnel), and roads. The impact of operation under Alternative 1 or 3 would be less than significant because all facilities would be designed to meet the applicable design criteria and safety measures would be in place. Overall, construction and operation of Alternative 1 or 3 would not directly or indirectly cause potential substantial adverse effects, including the risk of loss, injury, or death involving the rupture of a known earthquake fault. This impact would be less than significant.

NEPA Conclusion

Construction and operation effects of Alternatives 1 and 3 would be the same as described above for CEQA. Construction and operation of Alternatives 1 and 3 would not directly or indirectly cause potential substantial adverse effects, including the risk of loss, injury, or death involving the rupture of a known earthquake fault, as compared to the No Project Alternative. All facilities would be designed to meet all applicable design criteria, which would include ensuring that structures remain stable during an earthquake, and safety measures would be in place. No adverse effects due to surface fault rupture would occur as the result of construction or operation of Alternatives 1 and 3.

Alternative 2

Surface fault rupture hazards under Alternative 2 would be the same as Alternatives 1 and 3 for most components (i.e., main dams, I/O Works, Funks Reservoir and TRR West, conveyance from the Sacramento River, recreation areas, and most roads); would be similar for the saddle dams, saddle dikes, and Dunnigan Pipeline between the TC Canal and Sacramento River discharge; and would differ in regards to the bridge and road along the reservoir. The South Road would connect to the realigned Huffmaster Road and continue around the southern end of the reservoir to Lodoga. The Dunnigan Pipeline would continue past the CBD to the Sacramento River.

Construction

For those facilities that are the same under Alternative 2 and Alternatives 1 and 3, the impacts would be the same. The impacts for those facilities that are similar (i.e., the saddle dams, inundation area and regulating reservoirs) would also be the same because the seismic conditions would be the same and the differences in the size and location of facilities under Alternative 2 as compared to Alternatives 1 and 3 would not cause a greater risk. Saddle dam impacts would be the same because although there would be fewer saddle dams under Alternative 2, the dams would be in the same location and have the same proximity to faults; therefore, there would be no decrease in risk. The smaller inundation area under Alternative 2 would not have decreased risks associated with surface fault rupture because the location would be the same as Alternatives 1 and 3 relative to faults.

Under Alternative 2, the bridge would not be constructed, and the South Road would be constructed. The South Road would connect to the realigned Huffmaster Road and continue around the southern end of the reservoir to Lodoga. The realigned Huffmaster Road and South Road would be built in the same seismic setting and to the same design criteria as roads under Alternatives 1 and 3. Site-specific studies would inform final design and ensure that the realigned Huffmaster Road and South Road would be designed to address the risk of surface fault rupture. Because no bridge would be built, the risks associated with surface fault rupture could be somewhat less under Alternative 2.

Although the Dunnigan Pipeline would continue past the CBD to the Sacramento River discharge, the eastern corridor from the CBD to the Sacramento River is geologically similar to the western corridor and no active faults are known to be present. The Dunnigan Pipeline would be designed and constructed to the same standards as Alternatives 1 and 3. The impacts would therefore be the same.

Operation

No differences in operation between Alternative 2 and Alternative 1 or 3 would be associated with the risk of surface fault rupture because the same design and operating standards would be in place for Alternative 2 as described above for Alternative 1 or 3.

CEQA Significance Determination and Mitigation Measures

Construction and operation impacts associated with surface fault rupture under Alternative 2 would be similar to Alternative 1 or 3 but slightly less. All facilities would be designed to meet the applicable design criteria and the same safety measures would be in place; however, the bridge crossing a fault would be absent under Alternative 2, which could reduce the impacts associated with surface fault rupture. Overall, construction and operation of Alternative 2 would not directly or indirectly cause potential substantial adverse effects, including the risk of loss, injury, or death involving the rupture of a known earthquake fault. This impact would be less than significant.

NEPA Conclusion

Construction and operation effects under Alternative 2 would be the same as described above for CEQA. Construction and operation of Alternative 2 would not directly or indirectly cause potential substantial adverse effects, including the risk of loss, injury, or death involving the rupture of a known earthquake fault, as compared to the No Project Alternative. All facilities would be designed to meet all applicable design criteria, which would include ensuring that structures remain stable during an earthquake, and safety measures would be in place. No adverse effects associated with surface fault rupture would occur as the result of construction or operation of Alternative 2.

Impact GEO-1b: Strong seismic ground shaking

No Project

Under the No Project Alternative, the operations of the existing TC Canal, RBPP, and GCID Main Canal would continue. Although these facilities could be affected by strong ground shaking, including damage to canals and siphons, they are designed to accommodate shaking and procedures are in place to shut off operations if necessary. No new facilities associated with the Project would be built.

Significance Determination

The No Project Alternative would not directly or indirectly cause potential substantial adverse effects, including the risk of loss, injury, or death involving strong seismic ground shaking, because existing facilities would accommodate strong seismic ground shaking and no new facilities would be constructed and operated. There would be no impact/no effect.

Alternatives 1 and 3

Under Alternatives 1 and 3, all facilities could theoretically be damaged or fail if exposed to strong seismic ground shaking. DWR (2003), William Lettis & Associates (2002), and AECOM (2020a, 2020b) conducted extensive seismotectonic studies in the vicinity of the proposed dams. Figure 12-8 shows the preliminary response spectra (calculated by AECOM) to be used in the design of the main dams along with any appurtenant hydraulic structures at those locations. A V_{S30} value (i.e., the time-averaged shear-wave velocity of seismic ground motions in the upper 100 feet) of 1,840 feet per second was used in the analyses to compare to the generic rock conditions of the models used by William Lettis & Associates (2002).

Construction

Project facilities would be constructed according to the design requirements described in BMP-1. These requirements ensure that facilities, including levees, pipelines, excavations and shoring, pumping stations, dams, grading, foundations, bridges, access roads, and buildings are built to withstand local seismic conditions and accommodate strong ground shaking.

As part of final design for the main and saddle dams, saddle dikes, and I/O Works, the characteristic magnitude calculations would be reviewed using newer empirical models, fault distances would be updated if necessary, basin effects would be considered if necessary, and fault directivity would be incorporated into the final design. Additionally, the site-specific V_{S30} needs would be determined and additional response spectra would be developed for each of the saddle dams, which would also need to examine the controlling seismic source. This information would be used to design the facilities to meet the applicable seismic design criteria. For example, the 84^{th} percentile Maximum Credible Earthquake ground motions (Figure 12-8) would be used for dam design to ensure the main dams, saddle dams, and appurtenant works would remain functional after an earthquake. During final design, refined geotechnical studies would also evaluate the most suitable excavation methods, excavated material use for dam construction, dewatering requirements for foundation excavation, confirmation of fault locations and surface fault rupture potential, foundation deformability, hydraulic conductivity and strength, foundation treatment, and foundation grouting/cutoff requirements The main dams and saddle dams would be designed to prevent the safety of the dam embankment from being impaired by extensive cracking, crest settlement that would impair freeboard, or excessive deformation in critical zones such as filters and drains. The design would limit seismic deformation of the embankments to 5 feet.

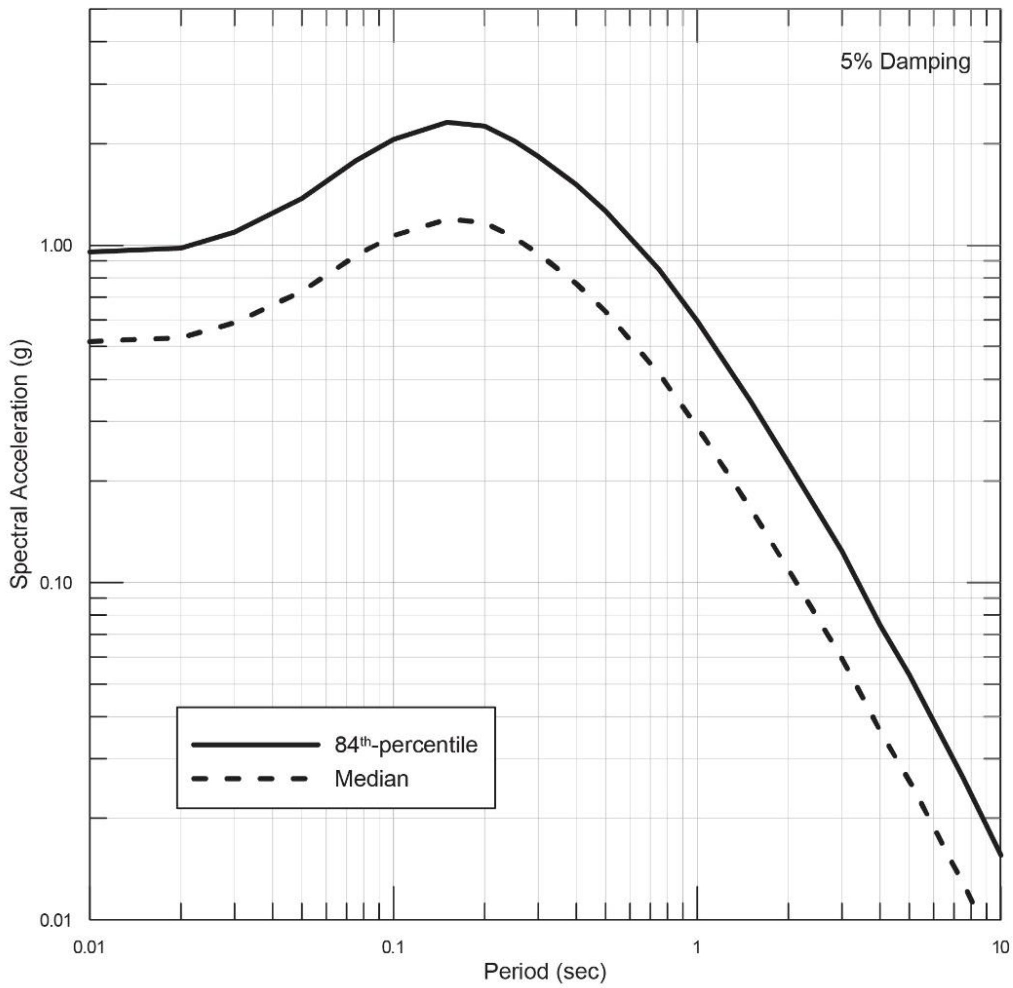

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Figure 12-8
Median and 84th Percentile Deterministic Seismic Response Spectra

Similarly, the tunnel and pipelines in the Antelope Valley and foothills could be subject to strong ground shaking that could damage these facilities. Damage to these facilities could cause flooding along Funks and Stone Corral Creeks (Chapter 5, *Surface Water Resources*). These facilities would be designed to meet the applicable seismic design criteria described in BMP-1.

Other facilities that could be damaged by strong ground shaking are the Sites Lodoga Road realignment including the bridge, roads in the Antelope Valley and foothills, and the recreation areas. The roads and bridge would be designed to meet all applicable design standards described in BMP-1. In addition, the bridge would be designed to meet Caltrans Seismic Design Criteria. The structure would meet the standard safety requirements for bridges in California. Structures in the recreation areas, such as vault toilets, would also be constructed to meet applicable design criteria.

Facilities in the Sacramento Valley (i.e., the regulating reservoir complex, GCID system upgrades, road improvements, transmission lines, and Dunnigan Pipeline) could also be affected by strong ground shaking. These facilities are located in areas of low to moderate ground shaking. Structures that would be occupied by people are the administration and operations building and the maintenance building at Funks Reservoir. All buildings and structures would be designed to meet a wide variety of seismic design criteria, such as the California Building Standards Code regulations for structures and transmission lines, the International Building Code for structural design, the seismic design for railway structures, and the seismic provisions for structural steel buildings. The embankment enclosing the TRR East would be designed according to the applicable seismic design criteria, including seismic design criteria of the Reclamation and/or DSOD.

Operation

Similar to Impact GEO-1a, operation of Alternative 1 or 3 could result in flooding caused by strong ground shaking if a tunnel or pipeline were to break and uncontrolled release were to occur. However, power and supervisory controls required to operate the I/O Works and other appurtenances would be designed to remain fully operable following a seismic event, which would enable operators to shut down facilities as needed during a seismic event. In the event of an emergency, flow could be shut off at the I/O Works, the TC Canal, and the Dunnigan Pipeline. As described for construction, the dams would be designed and monitored to address the site-specific seismic hazard.

CEQA Significance Determination and Mitigation Measures

Construction and operation of Alternatives 1 and 3 would result in impacts from strong seismic ground shaking (i.e., structural failure) that are less than significant because all facilities would be designed and constructed to meet the applicable design standards. Safety measures would be in place to allow operations to be shut down during a seismic event. Overall, construction and operation of Alternatives 1 and 3 would not directly or indirectly cause potential substantial adverse effects, including the risk of loss, injury, or death involving strong seismic ground shaking. The impact would be less than significant.

NEPA Conclusion

Construction and operation effects of Alternatives 1 and 3 would be the same as described above for CEQA. Construction and operation of Alternatives 1 and 3 would not directly or indirectly cause potential substantial adverse effects, including the risk of loss, injury, or death involving strong seismic ground shaking, as compared to the No Project Alternative. All facilities would be designed and constructed to meet the applicable design standards. Safety measures would be in place to allow operations to be shut down during a seismic event. No adverse effects related to strong seismic ground shaking would occur as the result of construction or operation of Alternatives 1 and 3.

Alternative 2

The risk of strong seismic ground shaking under Alternative 2 would be similar to Alternatives 1 and 3 except that the TRR West would be in a slightly different location; the bridge would not be constructed; South Road would be constructed around the southern end of the reservoir; and the Dunnigan Pipeline would continue past the CBD to the Sacramento River discharge.

Construction

Although TRR West would be in a different location than TRR East, it would be built in the same seismic setting and to the applicable design criteria.

The South Road would be built in the same seismic setting and to the same design criteria as under Alternatives 1 and 3. Site-specific geotechnical studies would be conducted to ensure the South Road would be designed to address the risk of strong ground shaking.

For the Dunnigan Pipeline, the eastern corridor from the CBD to the Sacramento River discharge is geologically similar to the western corridor and the risk of strong ground shaking is similar. The Dunnigan Pipeline would be designed and constructed to the same standards as Alternatives 1 and 3, and the Sacramento River discharge would be designed to meet standards set by the U.S. Army Corps of Engineers Section 408 permit process, the Central Valley Flood Protection Board, and the State Lands Commission.

Operation

The risk of strong ground shaking for operation of Alternative 2 is the same as that for Alternatives 1 and 3 because the facilities would use the same design and operating standards.

CEQA Significance Determination and Mitigation Measures

The construction and operation impacts under Alternative 2 would be the same as described under Alternative 1 or 3 with the exception of those associated with the bridge. The absence of the bridge crossing a fault under Alternative 2 would reduce the impacts associated with strong seismic ground shaking compared with Alternatives 1 and 3. The differences in the size and location of facilities for Alternative 2 would not cause a greater seismic risk. All facilities would be designed to meet the applicable design criteria and the same safety measures to allow operation to shut down during a seismic event would be in place. Overall, construction and operation of Alternative 2 would not directly or indirectly cause potential substantial adverse effects, including the risk of loss, injury, or death involving the rupture of a known earthquake fault and impacts would be less than significant.

NEPA Conclusion

Construction and operation effects under Alternative 2 would be the same as described above for CEQA. Construction and operation of Alternative 2 would not directly or indirectly cause potential substantial adverse effects, including the risk of loss, injury, or death involving strong seismic ground shaking, as compared to the No Project Alternative. The differences in the size and location of facilities for Alternative 2 as compared to Alternative 1 or 3 would not cause a greater seismic risk. All facilities would be designed and constructed to meet the applicable design standards. Safety measures would be in place to allow operations to be shut down during a seismic event. No adverse effects related to strong seismic ground shaking would occur as the result of construction or operation of Alternative 2.

Impact GEO-1c: Seismic-related ground failure, including liquefaction

No Project

Under the No Project Alternative, the operations of the existing TC Canal, RBPP, and GCID Main Canal would continue. Although these facilities could be affected by strong ground shaking, including damage to canals and siphons, they are designed to accommodate the effects of shaking, such as ground failure, and procedures are in place to shut off operations if necessary. No new facilities related to the Project would be built.

Significance Determination

The No Project Alternative would not directly or indirectly cause potential substantial adverse effects, including the risk of loss, injury, or death involving seismic-related ground failure, including liquefaction, because existing facilities are designed to accommodate effects of shaking and no new facilities would be constructed and operated. There would be no impact/no effect.

Alternatives 1 and 3

Facilities that could be susceptible to liquefaction and lateral spread are those located in areas underlain by Holocene sediments (Qa, Qb, and Qsc) and shallow groundwater, whereas those located on well consolidated units would not be susceptible to these kinds of seismic ground failure. Facilities that could be susceptible to seismically induced landsliding are those located on moderate to steep slopes with poor material strengths, such as Holocene colluvium and alluvium and weathered bedrock on slopes. Structures built on fill could also be susceptible to liquefaction or lateral spread. Liquefaction, lateral spread, and landsliding could result in the collapse of structures, failure of slopes, rupture of canals or pipelines, and other hazards.

Construction

During construction in areas underlain by Holocene sediments (Qa, Qb, and Qsc) and shallow groundwater, cut slopes and open trenches could become unstable and collapse during an earthquake. Failure could occur due to high levels of ground shaking or liquefaction of susceptible soils. Construction activities that involve cut slopes or trenching in Holocene sediments include road work in the Sacramento Valley (e.g., Road 69), construction of the buildings at Funks Reservoir and pipelines for Funks and TRR East in the regulating reservoir complex, construction of the new GCID head gate and replacement of three GCID Main Canal siphons, and the Dunnigan Pipeline. In addition, structures built in these areas could fail during an earthquake if liquefaction occurs. Similarly, the TRR East embankment (which would be founded on soft clays and potentially liquefiable granular soils) and the earthen fill prism required for the bridge could also be susceptible to liquefaction.

Alternatives 1 and 3 facilities would be designed and constructed to conform to seismic design criteria, such as the California Building Standards Code regulations for structures and transmission lines, the International Building Code for structural design, the seismic design for railway structures, the seismic provisions for structural steel buildings, and Caltrans Seismic Design Criteria. These criteria describe different requirements; for example, where necessary, the soil would be amended to remediate the risk of liquefaction.

Facilities not likely to be affected by widespread liquefaction or lateral spread are those in the Antelope Valley that are founded on well consolidated Boxer and Cortina Formations: the main and saddle dams, saddle dikes, Sites Lodoga Road, Huffmaster Road, other roads not located in the Sacramento Valley (e.g., North Road, Saddle Dam Roads North and South, Comm Road South, access roads), and recreation areas. Should future investigations associated with later design phases for specific structures identify isolated locations of potential liquefaction risk, Project components would be designed to address liquefaction and meet applicable design criteria. This could include soil amendments to remediate the risk.

Alternatives 1 and 3 facilities that could be susceptible to seismically induced landslides are the slopes at the main and saddle dam and dike locations and slopes around the I/O Works and tunnel. During an earthquake, existing landslides could move further downslope and new slides could develop, threatening structures above and below the slides. Extensive excavation would occur for the structure foundations to ensure that they would be anchored in unweathered bedrock. Specific geotechnical investigations would be conducted to evaluate the most suitable excavation methods, dewatering requirements for foundation excavation, hydraulic conductivity and strength, foundation treatment, and foundation grouting/cutoff requirements.

Although some slopes surrounding the inundation area could also be susceptible to seismically induced landslides, facilities and private structures would not be affected. A reservoir rim study would be conducted to evaluate seepage and shoreline slope stability, and landslides into the inundation area would not harm structures because facilities would be appropriately designed and private structures are not located above or near the rim—the nearest private structure above the reservoir shoreline is a home located approximately 500 feet from the southern tip of the reservoir. The slope between the shoreline and the home has an approximate 5–10% gradient; therefore, a seismically induced landslide in this vicinity is unlikely.

Operation

The operation of Alternatives 1 and 3 would be the same because differences in water deliveries would not affect the risk of liquefaction and both alternatives have the same TRR East footprint. Operation of the TRR East could create shallow groundwater conditions as a result of seepage, which could increase the risk of liquefaction by reducing the depth to groundwater. However, the TRR East would be constructed to prevent water in the reservoir from percolating into the subsurface. Construction techniques would include amending the ground under the TRR East embankment using the cement deep soil mixing (CDSM) method to provide a stable foundation and key into more competent material for the embankment. A geomembrane overlying geocomposite would be placed over the compacted earth to form an impermeable liner in the TRR East reservoir to prevent water percolation. In addition, no structures are present adjacent to the TRR East that could be susceptible to liquefaction, and the TRR East PGP and other facilities would be designed and built based on site-specific geotechnical investigations and in accordance with applicable seismic design criteria, as described in BMP-1.

CEQA Significance Determination and Mitigation Measures

Construction and operation of Alternatives 1 and 3 facilities that are underlain by Holocene sediments (Qa, Qb, and Qsc) and shallow groundwater and on moderate to steep slopes with poor cohesion (e.g., Holocene colluvium and alluvium and weathered bedrock on slopes) would be constructed to meet design criteria. These facilities are the buildings at Funks Reservoir, pipelines for Funks and TRR East in the regulating reservoir complex, new GCID head gate, replacement of three GCID Main Canal siphons, and the Dunnigan Pipeline. The earthen fill prism required for the bridge could also be susceptible to liquefaction but would be designed to meet AASHTO and LRFD Bridge Design Specifications, Caltrans Seismic Design Criteria, and Caltrans California Amendments to the AASHTO LRFD Bridge Design Specifications. Overall, construction and operation of Alternatives 1 and 3 would not directly or indirectly cause potential substantial adverse effects, including the risk of loss, injury, or death involving seismic-related ground failure, including liquefaction. The impact would be less than significant.

NEPA Conclusion

Construction and operation effects under Alternatives 1 and 3 would be the same as described above for CEQA. Construction and operation of Alternatives 1 and 3 would not directly or indirectly cause potential substantial adverse effects, including the risk of loss, injury, or death involving seismic-related ground failure, including liquefaction, as compared to the No Project Alternative. Construction and operation effects associated with seismic-related ground failure including liquefaction as compared to the No Project Alternative would not occur because either existing soil conditions conducive to ground failure are not present or facilities would be designed to meet AASHTO and LRFD Bridge Design Specifications, Caltrans Seismic Design Criteria, and Caltrans California Amendments to the AASHTO LRFD Bridge Design Specifications. No adverse effects related to seismic ground failure would occur as the result of construction or operation of Alternatives 1 and 3.

Alternative 2

The potential for seismically induced ground failure, including liquefaction, during construction and operation of Alternative 2 would be the same as Alternatives 1 and 3 for all facilities, excluding the TRR West, bridge, South Road, and Dunnigan Pipeline, because the seismic conditions would be the same and the differences in the size and location of facilities would not cause a greater risk.

The TRR West would be located in an area less susceptible to liquefaction than the TRR East because it would be excavated in the Great Valley sequence and Red Bluff Formation. The Great Valley sequence is not susceptible to liquefaction and the Red Bluff Formation is likely less susceptible to liquefaction than the Riverbank Formation because of its greater age and therefore greater degree of consolidation. The earthen prisms needed for the bridge would not be constructed because the bridge is not part of Alternative 2. The risk of seismically induced ground failure would be somewhat less under Alternative 2 compared to Alternatives 1 and 3 with respect to the absence of the bridge. In contrast, because the South Road would be constructed around the reservoir, there would be a greater number of cuts and fills, which could become unstable. Although the Dunnigan Pipeline would be longer, it would be in the same seismic setting and the structures would not be more susceptible to seismic ground failure than described above for Alternatives 1 and 3. Where the pipeline penetrates the levee at the Sacramento River, the design would follow the requirements of the U.S. Army Corps of Engineers, which would prevent damage or destabilization of the levee.

The impact of operation under Alternative 2 would be the same as described above for Alternatives 1 and 3 because the facilities likely to be affected by liquefaction (i.e., the TRR facilities) would be the same under all Project alternatives.

CEQA Significance Determination and Mitigation Measures

The impacts associated with seismically induced ground failure during construction and operation of Alternative 2 would be similar to those for Alternatives 1 and 3 because the seismic conditions would be the same and the differences in the size and location of facilities would not cause greater risk. Additionally, all facilities would be designed to meet design criteria. Overall, construction and operation of Alternative 2 would not directly or indirectly cause potential substantial adverse effects, including the risk of loss, injury, or death involving seismic-related ground failure, including liquefaction. Impacts would be less than significant.

NEPA Conclusion

Construction and operation effects under Alternative 2 would be the same as described above for CEQA. Construction and operation of Alternative 2 would not directly or indirectly cause potential substantial adverse effects, including the risk of loss, injury, or death involving seismic-related ground failure, including liquefaction, as compared to the No Project Alternative. Construction and operation effects associated with seismic-related ground failure including liquefaction as compared to the No Project Alternative would not occur because either existing soil conditions conducive to ground failure are not present or facilities would be designed to meet design criteria and specifications. The differences in the size and location of facilities for Alternative 2 as compared to Alternative 1 or 3 would not cause greater seismic-related ground failure risk. No adverse effects related to seismic ground failure would occur as the result of construction or operation of Alternative 2.

Impact GEO-1d: Landslides

No Project

Under the No Project Alternative, the operations of the existing TC Canal, RBPP, and GCID Main Canal would continue. These facilities are not expected to be affected by landslides because they are located in areas of gently sloping terrain. No new facilities would be built in Antelope Valley and therefore would not have the potential to exacerbate landslide conditions; land uses are expected to continue in the Antelope Valley, including rural agricultural uses and grazing.

Significance Determination

The No Project Alternative, involving operations of the existing TC Canal, RBPP, and GCID Main Canal, would not directly or indirectly cause potential substantial adverse effects, including the risk of loss, injury, or death involving landslides. Existing facilities are located in gently sloped terrain and thus lack the potential for landslides to occur. No new facilities would be constructed and operated in areas susceptible to landslides in the Antelope Valley, and land uses would continue as they currently do, related to rural agriculture. There would be no impact/no effect.

Alternatives 1 and 3

Construction and operation activities for Alternatives 1 and 3 that could cause or be affected by landslides are those that would occur on moderate to steep slopes of the Antelope Valley and foothills, particularly in geologic units known to be prone to landsliding, such as the Boxer Formation. Landslides could result in collapse of structures and damage to roads.

Construction and Operation

Facilities constructed in the Sacramento Valley would not be expected to affect landslide conditions because of the gentle slopes, which are not generally susceptible to landsliding. These facilities are the Red Bluff Diversion, regulating reservoir facilities, the GCID system upgrades, TC Canal intake, Dunnigan Pipeline, and CBD outlet. The recreation areas would also not be expected to be affected because only minimal grading would occur for road work and minor improvements (e.g., campsites, picnic areas, vault toilets).

Deep excavation or cut and fill would be needed for the main and saddle dams and dikes, the I/O Works, and the bridge. The Sites Lodoga Road realignment before and after the bridge and other roads in the Antelope Valley and foothills would require earthwork that included cut slope excavation, ditch excavation, benching, and embankment construction. Foundations would be required for the bridge, main and saddle dams, saddle dikes, I/O Works, and the transition manifold. Slopes in the vicinity of the dams, dikes, and I/O Works would be evaluated and any instability addressed through site-specific geotechnical studies to determine the most suitable excavation methods, use of excavated material for dam construction, and dewatering requirements for foundation excavation. Construction methods would meet the applicable design criteria, as described in BMP-1. Similarly, the bridge would be designed in accordance with AASHTO LRFD Bridge Design Specifications, and the design and construction of the bridge would comply with all applicable federal, state, and regional legal requirements.

Steep slopes in and adjoining the inundation area could be susceptible to landslides. The existing (and generally small) shallow debris slope failures or earth flows that occur along the reservoir rim or steep west-facing ridges could activate or enlarge in the event of a rapid drawdown of the reservoir, such as for emergency drawdown releases. Although a number of minor landslides and surficial slumps are present in the footprint of the Golden Gate Dam site, it is unknown if any of the slides would require remediation (e.g., excavation and removal). These determinations would be addressed during the design process in accordance with the findings of the geotechnical studies and DSOD permit conditions (DWR 2003:85,86). To meet the foundation objectives for construction, decomposed and intensely weathered bedrock would be excavated from the entire footprints of the main dams to reach a stable subgrade (AECOM 2020b:7).

Reservoir filling could cause slope instability if unstable slopes become saturated and fail. The geologic mapping conducted for DWR (2003) did not reveal any large landslide complexes that would create reservoir instability during filling of the reservoir. The landslides that have been mapped are primarily surficial slumps and are mostly shallow-seated (i.e., less than 20 feet thick) (DWR 2003:85,86). The Initial Sites Reservoir Fill Plan (Appendix 2D, *Best Management Practices, Management Plans, and Technical Studies,* Section 2D.2) would describe the monitoring program for Sites and Golden Gate Dams along with the saddle dams, saddle dikes, and areas around the reservoir. This plan would be completed as part of the DSOD approval process and would be completed at least 1 year prior to beginning to fill Sites Reservoir. A fill plan would typically identify acceptable rates for filling the reservoir in consideration of soil pore pressure, material strength, and degree of antecedent saturation to minimize the potential for sliding. Additionally, any other existing landslides within the inundation area and along the shoreline that could result in a seiche in the reservoir would be remediated. Given the nature of the geology of the reservoir, the potential for such a landslide occurring within and adjoining the reservoir is likely to be low.

The Boxer Formation in the footprint of the Sites Dam site is more susceptible to landslides and contains slides of various sizes and shapes that are mainly upstream of the dam axis. According to the DWR (2003) feasibility report, larger landslides in the footprint of the dam would be removed during the excavation of the abutment. No other instability on the left abutment was recognized during the feasibility mapping (California Department of Water Resources 2003:85, 86).

Although the dam foundations would be in the Cortina Formation, which is fairly impermeable, seepage under the main or saddle dams and saddle dikes could also cause slope failure. As the reservoir is filled, soil pore-water pressure would build and could cause through-seepage and ground failure. To address through-seepage, geotechnical studies would be conducted to evaluate the most suitable excavation methods, excavated material use for dam construction, dewatering requirements for foundation excavation, foundation deformability, hydraulic conductivity and strength, foundation treatment, and foundation grouting/cutoff requirements. Consolidation and curtain grouting would be installed to prevent through-seepage, and the main dams and saddle dams would be designed to prevent the safety of the dam embankment from being impaired. The design would meet the applicable standards, as described in BMP-1. Operations for Alternative 1 or 3 would not affect landsliding potential because they would not undermine or otherwise alter slopes or change soil drainage that could affect slope stability.

<u>*CEQA Significance Determination and Mitigation Measures*</u>

Impacts related to landslides caused by excavation or cut and fill during construction of Alternatives 1 and 3 would be addressed through the implementation of applicable design criteria (BMP-1) and the Initial Sites Reservoir Fill Plan (Appendix 2D, *Best Management Practices, Management Plans, and Technical Studies,* Section 2D.2). Furthermore, impacts related to landslides caused by reservoir filling or through-seepage would also be addressed through adherence to applicable design criteria. Overall, construction and operation of Alternatives 1 and 3 would not directly or indirectly cause potential substantial adverse effects, including the risk of loss, injury, or death involving landslides. Construction and operation impacts would be less than significant.

<u>*NEPA Conclusion*</u>

Construction and operation effects under Alternatives 1 and 3 would be the same as described above for CEQA. Construction and operation of Alternatives 1 and 3 would not directly or indirectly cause potential substantial adverse effects, including the risk of loss, injury, or death involving landslides as compared to the No Project Alternative. Construction and operation for Alternative 1 or 3 would not affect landsliding potential because either existing slopes and soils provide stable conditions or implementation of applicable design criteria (BMP-1) and the Initial Sites Reservoir Fill Plan (Appendix 2D, *Best Management Practices, Management Plans, and Technical Studies,* Section 2D.2) is required. No adverse effects related to landsliding would occur as the result of construction or operation of Alternatives 1 and 3.

Alternative 2

Under Alternative 2, the impacts related to landslides would be similar to Alternatives 1 and 3, but they would be slightly greater because of the increased excavation required for the TRR West and South Road. All other facilities that could cause or be affected by landslides on the moderate to steep slopes of the Antelope Valley and foothills would be the same between Alternative 2 and Alternatives 1 and 3. Facilities constructed in the Sacramento Valley, such as the longer Dunnigan Pipeline and the Sacramento Discharge, would not be expected to be affected by landslides because of the gentle slopes.

<u>*Construction and Operation*</u>

The TRR West under Alternative 2 would involve a slightly greater risk of landsliding compared to TRR East under Alternatives 1 and 3 because it would require excavation into a hillslope to form a steep cut slope on the north side of the reservoir. The South Road would entail much more excavation related to cut slope excavation, ditch excavation, benching, and embankment construction in hilly terrain. The risk of landsliding for both construction and operation would therefore be greater under Alternative 2 as compared to Alternatives 1 and 3. The absence of the bridge would not affect the risk of landsliding. Although the main and saddle dams and reservoir would be smaller and fewer saddle dams would be built under Alternative 2 than under Alternatives 1 and 3, these features would be generally similar and the risk of landsliding would remain the same. The risks of landsliding related to slope erosion and through-seepage would also largely be the same because the inundation area and soil pore-water pressure would be only slightly less.

<u>*CEQA Significance Determination and Mitigation Measures*</u>

Impacts related to landsliding would be somewhat greater during construction of Alternative 2 as compared to Alternatives 1 and 3 because of the increased excavation in a hillslope for TRR West and the increased length of road building required for the South Road around the reservoir. Potential landsliding would be addressed through the adherence to applicable design criteria (BMP-1) and the Initial Sites Reservoir Fill Plan (Appendix 2D, *Best Management Practices, Management Plans, and Technical Studies,* Section 2D.2). Reservoir filling and through-seepage conditions would be largely the same between Alternatives 1 and 3 and Alternative 2, despite the smaller size of the reservoir under Alternative 2. Overall, construction and operation of Alternative 2 would not directly or indirectly cause potential substantial adverse effects, including the risk of loss, injury, or death involving landslides. Construction and operation impacts would be less than significant.

<u>*NEPA Conclusion*</u>

Construction and operation effects under Alternative 2 would be the same as described above for CEQA. Construction and operation of Alternative 2 would not directly or indirectly cause potential substantial adverse effects, including the risk of loss, injury, or death involving landslides as compared to the No Project Alternative. Landsliding would be somewhat greater during construction of Alternative 2 as compared to Alternatives 1 and 3 because of the increased excavation in a hillslope for TRR West and the increased length of road building required for the South Road around the reservoir. Construction and operation for Alternative 2 would not affect landsliding potential because either existing slopes and soils provide stable conditions or implementation of applicable design criteria (BMP-1) and the Initial Sites Reservoir Fill Plan (Appendix 2D, *Best Management Practices, Management Plans, and Technical Studies*, Section 2D.2) is required. No adverse effects related to landsliding would occur as the result of construction or operation of Alternative 2.

Impact GEO-2: Result in reservoir-triggered seismicity or be subject to a seiche

No Project

Under the No Project Alternative, the operations of the existing TC Canal, RBPP, and GCID Main Canal would continue. The risk of reservoir-triggered seismicity (RTS) or seiche is expected to be low because Funks Reservoir is relatively small and shallow, conditions that are not conducive for a seiche wave to be generated. RTS is a phenomenon in which earthquakes are triggered by the filling of a reservoir or by water-level changes during reservoir operation.

<u>*Significance Determination*</u>

The No Project Alternative is not expected to result in RTS or be subject to a seiche because the risks of RTS and seiche at Funks Reservoir is low and no new facilities would be constructed and operated. There would be no impact/no effect.

Alternatives 1 and 3

Construction and Operation

Activities for Alternatives 1 and 3 that could cause RTS are those related to the initial filling of Sites Reservoir or the subsequent draining and refilling of the reservoir under operations. The operation of Alternatives 1 and 3 would generally be the same because the differences in water deliveries would not affect the risk of RTS.

This description of RTS and discussion of risk of RTS in the study area are excerpted, with minor modifications, from the geologic feasibility report prepared for the Project (California Department of Water Resources 2003:115–119). The probability of the occurrence of earthquakes in and around a reservoir may be increased by impoundment through two mechanisms: reservoir filling and water-level changes. An investigation at a number of RTS sites suggests that the effects are manifested as two general types of RTS seismicity patterns: (1) rapid response, in which activity increases almost immediately on the first filling of the reservoir; and (2) delayed response, in which increased activity does not occur until several seasonal filling cycles have occurred. In general, it has been observed that cases of rapid response tend to produce swarms of small, shallow earthquakes located in the immediate vicinity of the reservoir and that cases of delayed response tend to produce larger, deeper earthquakes located at some distance (approximately 6 miles in the cases of Lake Oroville and a reservoir near Koyna, India) from the reservoir.

The geologic feasibility report (California Department of Water Resources 2003:115–119) further indicated that reservoir-triggered earthquakes appear to be caused by very small stress changes, sometimes a fraction of a bar[5]. This suggests that the affected faults are in a state of pre-critical stress, requiring only minor reductions in effective normal stress to relieve the strain. In regions where the principal tectonic stress is extensional, these conditions for failure may be easier to meet. Most examples of triggered seismicity occur in regions of low tectonic loading dominated by normal faulting or strike-slip faulting. The dam sites are located in the actively folding and thrusting section of the CRSBZ, where the maximum principal stress is expected to be horizontal. Despite its proximity to Lake Oroville, the tectonic environment at the Sites Reservoir location is distinctly different. The Sites anticline is inferred to overlie an east-dipping reverse fault that represents a backthrust to the underlying west-dipping blind detachment fault at approximately 3 miles below the surface. The permeability of fractures in the rock might reasonably be expected to be less in this compressional environment relative to the extensional environment across the valley. Water from the Sites Reservoir could still diffuse down to seismogenic depths (approximately 3 miles) if the pressure is high enough (i.e., a deep water column in the reservoir). But the increase in elastic stress from the reservoir would tend to reinforce the normal stress across the detachment fault, moving it away from failure conditions. Based on these cases of RTS, it appears that conditions at the Sites Dam and Golden Gate Dam sites do not favor the triggering of earthquakes by construction or operation of a reservoir.

Reservoir-triggered seismic motions and seismic shaking generated by regional faults (whose movement is unrelated to the presence of the reservoir) could cause a seiche in the Sites

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[5]A unit used to measure atmospheric pressure. One bar is equal to a force of 100,000 newtons per square meter of surface area, or 0.987 atmosphere.

Reservoir. Based on the characteristics of the Boxer Formation (which underlies the reservoir footprint and adjoins the reservoir slopes), it is possible that a landslide, whether triggered by seismic shaking or high rainfall, could also be capable of causing significant seiche waves.

The potential magnitude (i.e., wave height) of any seiche that may occur in the Sites Reservoir is currently unknown; however, based on current understanding of the ground-shaking hazard, it is unlikely that any seiche would be large enough to overtop the main and saddle dams or bridge. The minimum freeboard for the dams would be 19 feet, and the height of the bridge would be 2 feet above the maximum flood elevation plus wave height, where maximum flood elevation plus wave height would be set at 10 feet above the normal water surface elevation of 498 feet, for a total bridge height of 510 feet.

Seiche waves could extend upslope above the normal high water elevation of the reservoir. This effect would be comparatively more pronounced on shallower slopes, on slopes not protected with riprap, and/or in areas closer to the source of the seiche. During final design, additional data and studies would identify the potential magnitude of any seismically induced seiche. Final design studies would also assess the potential for a seiche to occur as a result of a landslide entering the reservoir, whether the landslide is triggered by seismic shaking (Forrest pers. comm.) or by high soil/rock pore-water pressures. Facilities under Alternatives 1 and 3 that could be affected by RTS are the main dams, saddle dams, saddle dikes, I/O Works, the bridge, and recreation facilities (both adjacent to the reservoir and in the recreation areas).

The hazard of a seiche occurring in the TRR East is expected to be low because of its small size and distance from seismic sources. The hazard of a seiche occurring in the TRR East would be evaluated during the detailed design phase. If the evaluation determines that there is a potential for a seiche to occur, the expected wave height would be incorporated into the embankment freeboard design in accordance with Reclamation Design Standards No. 13 Embankment Dams, Chapter 13 (Bureau of Reclamation 2015:13-10, 13-76, 13-77).

The hazard of a seiche occurring in the Funks Reservoir is not addressed because it is an existing facility that is relatively small and shallow, and Alternatives 1 and 3 would not increase the depth of the reservoir by removing sediment to achieve design capacity. The potential for a seiche to occur is partly controlled by water depth. With the other factors held constant, deeper water bodies are more prone to seiche than shallower water bodies. Therefore, because Alternatives 1 and 3 would not increase the depth of the reservoir, the alternatives would not increase the potential for a seiche.

CEQA Significance Determination and Mitigation Measures

The filling of the Sites Reservoir could result in RTS. Project effects caused by RTS would be similar to that described for Impact GEO-1b. Under Alternatives 1 and 3, all facilities could be damaged or fail if exposed to strong ground shaking. All main dams, saddle dams, and saddle dikes would be designed and constructed to meet the applicable criteria (BMP-1) and adhere to the Initial Sites Reservoir Fill Plan (Appendix 2D, *Best Management Practices, Management Plans, and Technical Studies,* Section 2D.2). Furthermore, safety measures would be in place to allow operations to be shut down during a seismic event. Therefore, construction and operation of Alternatives 1 and 3 would result in impacts from structural failure caused by RTS that are less than significant.

Under Alternatives 1 and 3, the risk of seiche in the TRR East is expected to be low, but a seiche could occur in the Sites Reservoir. Although seiche waves caused by a seismic event or RTS at Sites Reservoir would not overtop the dams, they could extend into the recreation areas, thereby threatening public safety and cause loss of life or damage the recreation areas. As part of final design, and the locating of recreational facilities, these facilities would be located outside of a potential run-up elevation and the location would be based on the findings of the geotechnical studies (BMP-2). Construction and operation impacts would be less than significant.

NEPA Conclusion

Construction and operation effects under Alternatives 1 and 3 would be the same as described above for CEQA. Construction and operation of Alternatives 1 and 3 would not increase the risk of RTS or be subject to a seiche relative to the No Project Alternative. Under Alternatives 1 and 3, the risk of seiche in the TRR East is expected to be low, but a seiche could occur in the Sites Reservoir. Although seiche waves caused by a seismic event or RTS at Sites Reservoir would not overtop the dams, they could extend into the recreation areas, thereby threatening public safety. As part of final design and the locating of recreational facilities, these facilities would be located outside of a potential run-up elevation, and the location would be based on the findings of the geotechnical studies (BMP-2). No adverse effects related to RTS or seiche would occur as the result of construction or operation of Alternatives 1 and 3.

Alternative 2

RTS and seiche hazard conditions under Alternative 2 would be similar to Alternatives 1 and 3 except that the Sites Reservoir would be smaller, the bridge would not be constructed, and South Road would be constructed around the southern end of the reservoir.

Construction and Operation

Under Alternative 2, the likelihood of RTS would be less than described above for Alternatives 1 and 3 because the reservoir's shallower water column would weigh less and therefore would exert less pressure on the underlying rock. The same design and operating standards would be in place to address strong ground shaking, and the main and saddle dams would be sufficiently high to prevent overtopping by a seiche. The TRR West risk of RTS and seiche would be overall similar to TRR East because of their similar seismic setting, water depth, and size of the waterbodies. The South Road would not be adjacent to the reservoir and therefore would not be susceptible to RTS or be subject to a seiche.

CEQA Significance Determination and Mitigation Measures

The potential for RTS to occur in the Sites Reservoir would be slightly less for Alternative 2 as compared to Alternatives 1 and 3 because the shallower water column would exert less pressure on the underlying rocks. All facilities would be built to the same seismic design criteria as under Alternatives 1 and 3. The potential magnitude of a seiche occurring in the Sites Reservoir is unknown; however, based on current understanding of the site geology, it is unlikely that any seiche would be large enough to overtop the main or saddle dams with the current minimum freeboard of 18 feet for Alternative 2. However, as with Alternatives 1 and 3, a seiche could affect recreation facilities under Alternative 2. As part of final design, the recreational facilities would be located outside of a potential run-up elevation and the location would be based on the findings of the geotechnical studies (BMP-2). Construction and operation impacts would be less than significant.

NEPA Conclusion

Construction and operation effects under Alternative 2 would be the same as described above for CEQA. Construction and operation of Alternative 2 would not increase the risk of RTS or be subject to a seiche relative to the No Project Alternative. The potential for RTS to occur in the Sites Reservoir would be slightly less for Alternative 2 as compared to Alternatives 1 and 3 because the shallower water column would exert less pressure on the underlying rocks. Although seiche waves caused by a seismic event or RTS at Sites Reservoir would not overtop the dams, they could extend into the recreation areas, thereby threatening public safety. As part of final design, and the locating of recreational facilities, these facilities would be located outside of a potential run-up elevation and the location would be based on the findings of the geotechnical studies (BMP-2). No adverse effects related to RTS or seiche would occur as the result of construction or operation of Alternative 2.

Impact GEO-3: Result in substantial soil erosion or the loss of topsoil

No Project

Under the No Project Alternative, no operations or construction would occur that would cause increased soil erosion or the loss of topsoil. Existing land uses such as grazing and rural agricultural activities could result in soil erosion or the loss of topsoil; these activities would continue to occur under the No Project Alternative.

Significance Determination

The No Project Alternative would not result in a substantial increase in soil erosion or the loss of topsoil because no new facilities would be constructed and operated. There would be no impact/no effect.

Alternatives 1, 2, and 3

This section addresses potential impacts associated with accelerated soil erosion, permanent topsoil loss, and soil degradation as a result of construction and operation of Alternative 1, 2, or 3. The discussions of Alternatives 1, 2, and 3 are combined here because they would have similar impact mechanisms and would involve extensive ground-disturbing activities. Further, the differences in impacts between the alternatives would be minor.

Construction

Temporary soil disturbance that would occur from construction in level to gently sloping areas, such as the alignments for the pipelines and roads to be improved in the Sacramento Valley and the TRR East footprint, is expected to result in little or no accelerated water erosion because of the lack of runoff energy to entrain and transport soil particles. Graded and otherwise disturbed soils in areas with moderate to steep slopes, such as those where the main dams, saddle dams, saddle dikes, I/O Works, and TRR West would be constructed, would be more prone to accelerated water erosion. Soil eroded within the Sites Reservoir's watershed would generally be deposited and retained in the inundation area through the temporary diversions of Funks Creek during construction. On Funks Creek, the coffer dam would provide enough residence time for sediment settling to occur for typical flows in Funks Creek. Soil eroded within the Sites Reservoir watershed may continue to be released on Stone Corral Creek as a result of the use of a coffer dam and diversion tunnel. The 12 foot-diameter diversion tunnel would convey flows directly from the creek into the tunnel and into Stone Corral Creek on the east side of the Sites Dam work area.

Alternatives 1, 2, and 3 include BMP-12 to address increased erosion rates that could occur as a result of construction activities. This BMP would ensure that erosion rates would not be excessive. The erosion control measures would protect soils that have been exposed during excavation, filling, and stockpiling operations from eroding at rates greater than pre-construction conditions. The sediment control measures would capture sediment that is generated from exposed soils. The runoff management measures would be implemented to reduce runoff rates and prevent concentrated runoff from causing scour, such as at culvert outfall points.

There would be some permanent loss of topsoil in the inundation area and permanent overcovering by fill soil in other areas. Most topsoil loss (14,800 acres under Alternatives 1 and 3 and 14,400 acres under Alternative 2) would be in uncultivated and unirrigated rangeland areas, resulting primarily from reservoir inundation.

As described in BMP-10, topsoil would be salvaged, stockpiled, and replaced to reduce the extent of topsoil loss. Other areas of topsoil would be temporarily disturbed but not permanently lost, including pipeline installation areas, staging/laydown areas, temporary soil stockpile areas, and other areas where the vegetation would be stripped or flattened by heavy equipment, such as adjacent to the main dam footprints, saddle dams, saddle dikes, pipelines, and new roadways. Such disturbances could degrade the condition (i.e., soil health) and productivity of the topsoil due to compaction and being overcovered during extended periods in stockpiles. Approximately 1,227 acres of topsoil would be temporarily disturbed under Alternatives 1 and 3 and 1,414 acres of topsoil would be disturbed under Alternative 2. Alternatives 1, 2, and 3 include BMPs to address erosion (BMP-12) and the loss of topsoil as a result of construction (BMP-10). Implementation of BMP-10 to salvage, stockpile, and replace topsoil and prepare a topsoil storage and handling plan will minimize the extent of topsoil loss as a result of excavation and overcovering. This BMP prescribes the installation of temporary construction barrier to ensure heavy equipment is confined to as small an area as possible, thereby minimizing the extent to which topsoil is compacted or otherwise disturbed. The detailed design of the construction activities will incorporate an evaluation, based on review of soil survey maps supplemented by field investigations and prepared by a qualified soil scientist, that documents existing soil properties, specifies the thickness of the topsoil that should be salvaged, and identifies areas in which no topsoil should be salvaged. The soil scientist will prepare a plan that specifies how topsoil will be salvage, stored, and replaced. For certain Project components such as the Dunnigan Pipeline (which extends through farmland), the topsoil storage and handling plan would specify segregating the topsoil layer(s) from subsoil materials during trenching, then backfilling the soil materials in reverse order so as to return the area to the pre-existing condition. Measures to avoid degradation of soil health may also include decompaction of areas adjacent to pipeline trenches after backfilling is complete. Adherence to the guidance in the topsoil storage and management plan would minimize topsoil degradation and maintain the agricultural productivity of the soil.

Operation

Under Alternatives 1, 2, and 3, areas would be revegetated or otherwise stabilized at the end of the construction phase and continued or accelerated erosion would be reduced or minimized. This is because stabilization would be part of the post-construction erosion control measures implemented for the Project. Releases that enter Funks Reservoir and are conveyed to the TC Canal would not cause substantial erosion because the canal is concrete-lined. Releases that enter into GCID Main Canal would not cause substantial erosion because of energy dissipation structures. Releases from the Dunnigan Pipeline would not cause erosion because energy dissipation structures would be in place to prevent erosion at the CBD. Emergency releases could cause scour of Funks Creek and Stone Corral Creek, as discussed in Chapter 7, *Fluvial Geomorphology*.

No losses of topsoil would occur during operation because all topsoil excavation, overcovering, and inundation would occur during construction. Similarly, no degradation of soil health would occur during operation because all vegetation clearing, temporary soil disturbances and temporary soil stockpiling would occur during construction.

CEQA Significance Determination and Mitigation Measures

Alternatives 1, 2, and 3 include BMPs to address erosion and the loss of topsoil as a result of construction. Implementation of BMP-10 to salvage, stockpile, and replace topsoil and prepare a topsoil storage and handling plan would minimize the extent of topsoil loss as a result of excavation and overcovering. Furthermore, erosion and sediment control measures would be designed, installed, and maintained as part of BMP-12 to minimize erosion during construction and to comply with the Stormwater Construction General Permit. Any remaining topsoil loss would be a result of inundation and because the BMPs would reduce the extent of topsoil loss as a result of excavation and inundation, the construction impact would be less than significant.

Operation of Alternative 1, 2, or 3 would not result in substantial soil erosion or loss of topsoil because facilities would be designed to have energy dissipation structures or apparatuses to reduce water pressure into existing receiving waters. Furthermore, soil stabilization and revegetation would be part of the post-construction measures. Operation impacts would be less than significant.

NEPA Conclusion

Construction and operation effects would be the same as described above for CEQA. Construction and operation of Alternative 1, 2, or 3 would not result in a substantial soil erosion or loss of topsoil as compared to the No Project Alternative. Implementation of construction BMPs (BMP-10 and BMP-12) and design requirements for operation (e.g., energy dissipation structures) related to soil erosion and topsoil loss are required. No adverse effects related to increased soil erosion rates or loss of topsoil would occur as the result of construction or operation of Alternatives 1, 2, and 3.

Impact GEO-4: Be located in a geologic unit or soil that is unstable, or that would become unstable as a result of the Project, and potentially result in onsite or offsite landslide, lateral spreading, subsidence, liquefaction, or collapse

No Project

Under the No Project Alternative, the operations of the existing TC Canal, RBPP, and GCID Main Canal would continue. Although these facilities could be affected by strong ground shaking, they are designed to accommodate the effects of shaking, such as lateral spreading and other ground failures, and procedures are in place to shut off operations if necessary. These facilities are not expected to be affected by landslides because they are located in areas with flat terrain. No new facilities would be built.

Significance Determination

The No Project Alternative would not involve construction or operation of new facilities in a geologic unit or soil that is unstable and could potentially result in onsite or offsite landslide, lateral spreading, subsidence, liquefaction, or collapse. The existing facilities are designed to accommodate the effects of shaking and are in flat terrain. There would be no impact/no effect.

Alternatives 1 and 3

As described in Impact GEO-1c, facilities that would be more susceptible to liquefaction and lateral spread are those located in areas underlain by Holocene sediments (Qa, Qb, and Qsc) and have groundwater within 50 feet of the surface. The areas that have these conditions are the same as those that the alternatives may increase the potential for liquefaction and lateral spread to occur.

As described in Impact GEO-1d, the facilities that could be susceptible to seismically induced landsliding, as well as landsliding related to saturated soils caused by high rainfall, are those located on moderate to steep slopes with poor strengths, such as Holocene colluvium and alluvium and weathered bedrock on slopes. The areas that have these conditions are the same as those that the alternatives may increase the potential for landslides to occur.

Construction

As described for Impacts GEO-1c and GEO-1d, construction of some components, such as roads in the Sacramento Valley, facilities at Funks Reservoir and TRR East, and the Sites Lodoga Road realignment could be susceptible to liquefaction, lateral spread, or landslides. Additionally, if improperly designed and implemented, cuts and other excavations could cause slope instability. However, as described for Impacts GEO-1c and GEO-1d, Alternatives 1 and 3 facilities would be designed and constructed to conform to seismic design criteria and in accordance with geotechnical design recommendations.

Operation

As described for Impacts GEO-1c and GEO-1d, the risk of liquefaction could increase near the TRR East as a result of shallow groundwater conditions, and the risk of landslides could increase along steep slopes adjacent to Sites Reservoir due to the risk of saturation. However, the TRR East would be designed to conform with all applicable design criteria, and a reservoir rim study would be conducted to evaluate seepage and stability.

CEQA Significance Determination and Mitigation Measures

The impacts from the construction and operation of Alternatives 1 and 3 would be the same as those described for Impacts GEO-1c and GEO-1d under Alternatives 1 and 3. Overall, the impact would be less than significant.

NEPA Conclusion

Construction and operation effects would be the same as described above for CEQA. The geologic and soil stability conditions would be the same as the No Project Alternative. Facilities that could be susceptible to seismically induced landsliding, as well as landsliding related to saturated soils, would be designed as described in Impacts GEO-1c and GEO-1d. No adverse effects related to onsite or offsite landslide, lateral spreading, subsidence, liquefaction, or collapse would occur as a result the of construction or operation of Alternatives 1 and 3. No adverse effects related to onsite or offsite landslide, lateral spreading, subsidence, liquefaction, or collapse would occur as the result of construction or operation of Alternatives 1 and 3.

Alternative 2

The impact discussions for Alternative 2 under Impacts GEO-1c and GEO-1d describe the potential for seismically induced ground failure and the risk of landslides, respectively.

The impact of operation of Alternative 2 would be the same as under Alternative 1 or 3 because Alternative 2 would not increase the potential for seismically induced ground failure as compared to Alternatives 1 and 3. As discussed for Impact GEO-1c, the construction of the South Road due to the realignment of Sites Lodoga Road would result in a greater number of cuts and fills, which could become unstable. As described under Impact GEO-1d, the construction of TRR West and the South Road would entail much more excavation related to cut slope excavation, ditch excavation, benching, and embankment construction in hilly terrain. The risk of landslides for both construction and operation would therefore be greater under Alternative 2. However, as described in Impact GEO-1c, all facilities, including the TRR West and South Road would be designed, constructed, and operated to meet applicable design criteria.

CEQA Significance Determination and Mitigation Measures

The impacts associated with seismically induced ground failure during construction and operation of Alternative 2 and those related to landslides would be the same as those described for Impacts GEO-1c and GEO-1d, respectively. All facilities would be in the same seismic setting and designed, constructed, and operated to meet applicable design criteria. Impacts from onsite or offsite landslide, lateral spreading, subsidence, liquefaction, or collapse would be less than significant.

<u>*NEPA Conclusion*</u>

Construction and operation effects would be the same as described above for CEQA. The geologic and soil stability conditions would be the same as the No Project Alternative. Facilities that could be susceptible to seismically induced landsliding, as well as landsliding related to saturated soils, would be designed as described in Impacts GEO-1c and GEO-1d. No adverse effects related to onsite or offsite landslide, lateral spreading, subsidence, liquefaction, or collapse would occur as the result of construction or operation of Alternative 2. No adverse effects related to onsite or offsite landslide, lateral spreading, subsidence, liquefaction, or collapse would occur as the result of construction or operation of Alternative 2.

Impact GEO-5: Be located on expansive soil, as defined in Table 18-1-B of the Uniform Building Code (1994), creating substantial direct or indirect risks to life or property

No Project

Under the No Project Alternative, no construction would occur that could be affected by expansive soils. Existing facilities such as the TC Canal, GCID Main Canal, and GCID head gates have existed for well over 50 years; the RBPP has also existed for a long time. If there were expansive soils under existing facilities, these facilities would show evidence of damage. Regular maintenance of these facilities occurs and would continue to occur under the No Project Alternative, and, if deterioration of the facilities occurs because of expansive soils or otherwise, the owners and operators would fix the facilities.

<u>*Significance Determination*</u>

The No Project Alternative would not involve construction or operation of new facilities on expansive soil and therefore there would be no substantial direct or indirect risks to life or property. There would be no impact/no effect.

Alternatives 1, 2, and 3

Expansive soils are subject to shrinking and swelling with seasonal changes in moisture content. Soil expansion and contraction can cause damage or failure of foundations, utilities, and pavements. Soil below the depth of the permanent water table or that is inundated is not subject to shrinking and swelling.

<u>*Construction*</u>

As described in BMP-3, the presence of expansive soils would be identified prior to construction and Project facilities designed to accommodate or improve soil conditions (see *Operation*). However, the effects of expansive soils would be evident only after construction is complete at a given facility. In other words, expansive soils affect buildings and facilities through potential damage or cracking. Therefore, construction impacts are not discussed further.

<u>*Operation*</u>

As described in Section 12.2.3, *Soils*, with the exception of the existing concrete foundation and other facilities not underlain by soil material (i.e., GCID head gate and GCID Main Canal siphons) and the sediment in Funks Reservoir, expansive soils as mapped by NRCS underlie part or all of the Alternatives 1, 2, and 3 components. The expansive soils exist as either as a particular layer or throughout the entire profile to a depth of 5–6 feet. Expansive soil material could also occur at depths greater than 6 feet.

Activities that could be affected by expansive soils would be the same under Alternative 2 as under Alternative 1 or 3. For example, even though the dams would be smaller and fewer under Alternative 2, the other components that could be affected by expansive soils (e.g., pipelines, roads, facilities with concrete foundations) would be similar. As described in BMP-3, the presence of expansive soils would be identified prior to construction. Appropriate standard design/engineering approaches would be implemented to limit the risk of adverse effects related to expansive soil and to comply with the California Building Standards Code and other applicable standards, guidelines, and code requirements. Commonly applied measures such as water infiltration management, lime treatment, structural stiffening, increased foundation embedment, and over-excavation and replacement with suitable material would be implemented as appropriate to avoid excessive expansion and contraction (and therefore facility damage). The footings of the bridge (Alternatives 1 and 3) would always be under water, so they would not be subject to soil expansion/contraction. Use of the South Road, longer Dunnigan Pipeline, and Sacramento Discharge would not be affected by expansive soils because they would be underlain by non-expansive fill soil or concrete foundations.

CEQA Significance Determination and Mitigation Measures

There would be no construction impacts caused by expansive soils for Alternatives 1, 2, and 3 because the soils' seasonal shrinking and swelling would not affect or be affected by construction but rather would be evident only after construction is complete at a given facility.

Operation of the GCID system upgrades (Alternatives 1, 2 and 3) would not be subject to expansive soils because they do not exist at the facility. There would be no impact.

All other facilities constructed on expansive soils would be designed to withstand the effects of soil expansion, consistent with California Building Standards Code requirements and other design and construction requirements relevant to specific Project components. Overall, the operation impacts of Alternatives 1, 2, and 3 for expansive soils would be less than significant.

NEPA Conclusion

Construction and operation effects would be the same as described above for CEQA. Construction and operation of Alternatives 1, 2, and 3 would not alter the soils conditions as compared to the No Project Alternative. Structures constructed under Alternative 1, 2, or 3 would be required to be designed to withstand the effects of soil expansion, consistent with California Building Standards Code requirements. No adverse effects related to expansive soils would occur as the result of construction or operation of Alternatives 1, 2, and 3.

Impact GEO-6: Have soils incapable of adequately supporting the use of septic tanks or alternative wastewater disposal systems where sewers are not available for the disposal of wastewater

No Project

Under the No Project Alternative, no onsite wastewater disposal system would be constructed as part of the Project. Wastewater disposal would continue to exist in the Project area through various means, including septic tanks, and would continue to follow existing regulations if/when maintaining and installing septic tanks.

Significance Determination

Septic systems would continue to exist under the No Project Alternative and soils would continue to adequately support them. There would be no impact/no effect.

Alternatives 1, 2, and 3

Construction and Operation

Under Alternatives 1, 2, and 3, onsite wastewater disposal system(s) would be constructed to serve structures intended for human occupation, including an administration and operations building and a maintenance and storage building. The recreation areas would be served by vault toilets, which by design do not require waste disposal/leach fields. If a conventional disposal system were built on soils that are incapable of adequately supporting the use of septic tanks or alternative wastewater disposal systems, use of the system could cause surface water quality impacts, groundwater contamination, and objectionable odors.

The administration and operations building and the maintenance and storage building would be built on soil mapped as Capay clay, 5 to 9% slopes. This soil is rated as being “Very limited” for an onsite wastewater disposal system as a result of slow water movement and shallow depth to a saturated zone (Soil Survey Staff 2020) (i.e., shallow groundwater). As identified in BMP-9, the final design of these structures would involve soil testing for wastewater disposal system suitability. An alternative wastewater disposal system, such as a mound system or pressure dose system, would be implemented if needed to overcome the likely limiting soil and shallow groundwater conditions at the Funks Reservoir facility. Among these alternative treatment systems is sand fill media laid on top of the prepared original soil surface, allowing for the use of a septic system where native soil conditions preclude the use of a traditional design.

CEQA Significance Determination and Mitigation Measures

Soil characteristics at the administration and operations building and the maintenance and storage building appear to be limited to accommodate a conventional onsite wastewater disposal system. As part of final design, alternative wastewater disposal systems would be designed and constructed to overcome potentially limiting soil and groundwater conditions (BMP-9). Impacts under operating conditions would be less than significant for Alternative 1, 2, or 3.

<u>*NEPA Conclusion*</u>

Operation effects would be the same as described above for CEQA. Alternatives 1, 2, or 3 would not have soils incapable of adequately supporting the use of septic tanks or alternative wastewater disposal systems as compared to the No Project Alternative. Alternative wastewater disposal systems may be required for the administration building to overcome potentially limited soil and groundwater conditions. These conditions would be addressed through implementation of BMP-9. No adverse effects related to soils that are incapable of adequately supporting the use of septic tanks or alternative wastewater disposal systems as the result of operation of Alternative 1, 2, or 3 would occur.

Impact GEO-7: Directly or indirectly destroy a unique paleontological resource or site or unique geologic feature

No Project

Under the No Project Alternative, no major excavation that could damage or destroy paleontological resources would occur.

<u>*Significance Determination*</u>

The No Project Alternative would not directly or indirectly destroy a unique paleontological resource or site or unique geologic feature because no new facilities would be constructed and operated. There would be no impact/no effect.

Alternatives 1 and 3

Activities that could damage paleontological resources are those involving ground disturbance. Table 12-7 lists the depth and extent of ground-disturbing activities that would occur by component, the geologic units that would be affected, and the paleontological sensitivity of those units. Project components have been grouped based on the geologic units affected by Alternatives 1 and 3 and the type of ground disturbance, where possible.

Table 12-7. Ground-Disturbing Construction Activities and the Geologic Units Affected

Component Grouping	Geologic Units Affected	Project Activity That Could Affect Resource	Extent of Activity for Alternatives 1 and 3	Extent of Activity for Alternative 2	Depth of Activity for Alternatives 1 and 3	Depth of Activity for Alternative 2	Paleontologically Sensitivity of Units Affected
Sacramento River Diversion and Conveyance to Regulating Reservoirs	GCID—Holocene unit (Qb), Pleistocene units (Qml, Qmu, Qrl, Qru)	GCID system upgrades, including the new head gate and siphons	Approximately 30 acres, mainly along the canal and temporary construction easement	Same as Alternative 1 or 3	GCID—Head Gate excavation depth would be 3 to 10 feet below existing canal invert. The siphons would have an excavation depth of 15 to 30 feet below existing field elevation.	Same as Alternative 1 or 3	Qa: low Qb: low Qru: high Qml: high Qru: high Qrl: high
Regulating Reservoirs and Conveyance Complex	Funks facilities—Holocene unit (Qb), Cretaceous unit (pTms-assumed to be Kb or Kc), and recently deposited sediments in the reservoir TRR East facilities—Holocene unit (Qb), Pleistocene	Construction of Funks Reservoir, Funks pipelines, TRR East or West, Funks and TRR East or West PGPs, TRR East or West pipelines, Electrical transmission connection, Transition manifold, Buildings	Approximately 1,000 acres	Approximately 1,000 acres	Pipelines—12 feet in diameter would range in depth of cover from 6 to 40 feet below ground surface I/O Works—hillside excavation for the downstream and upstream tunnel portals 80 feet and 100 feet deep respectively TRR East—excavation to depths generally ranging from 3 to 6 feet, excavation	Generally, the same as Alternative 1 or 3 except: TRR West—excavation 20 to 60 feet deep for much of reservoir area and 90 to 120 feet deep near the PGP. A short tunnel would be excavated between the Main and	Qb: low Qmu: high Qrl: high Qrb: high Kb and Kc: low

Component Grouping	Geologic Units Affected	Project Activity That Could Affect Resource	Extent of Activity for Alternatives 1 and 3	Extent of Activity for Alternative 2	Depth of Activity for Alternatives 1 and 3	Depth of Activity for Alternative 2	Paleontologically Sensitivity of Units Affected
	unit (Qrl); (Pleistocene Qmu may underlie Qb) TRR West facilities—Holocene unit (Qb), Pleistocene units (Qrb), Cretaceous unit (pTms-assumed to be Kb or Kc)				ranging from 10 to 12 feet for the control structures and cement deep soil mixing treatment from 40 to 50 feet deep under embankment, PGP, and substation. PGP—excavation up to 40 feet deep along the edge of the reservoirs. Funks Reservoir—dredging of a maximum of 4–7 feet of accumulated sediment to return reservoir to its original depths and storage volume.	Extension reservoirs. No cement deep soil mixing would be required. Shorter pipelines to the transmission manifold.	
Inundation Area, bridge, Sites Lodoga Road Realignment, Huffmaster Road	Inundation area—primarily Cretaceous unit (Kb) Saddle Dams 1, 2, 3 rock	Construction staging, dam quarrying, bridge excavation	Approximately 13,500 acres	Approximately 13,350 acres	Bridge Column Footings—12 feet deep Bridge Abutments—7 feet deep Bridge	Smaller inundation area and no bridge construction. South Road construction	Qml: high Qrl and Qru: high Kb or Kc: low

Component Grouping	Geologic Units Affected	Project Activity That Could Affect Resource	Extent of Activity for Alternatives 1 and 3	Extent of Activity for Alternative 2	Depth of Activity for Alternatives 1 and 3	Depth of Activity for Alternative 2	Paleontologically Sensitivity of Units Affected
(Realigned), South Road	processing haul roads—Pleistocene units (Qml, Qrl, Qru) Huffmaster Road and South Road: Cretaceous unit (pTms-assumed to be Kb or Kc)				Drilled Shafts—80 feet deep Staging areas—up to 2 feet deep Haul Roads—up to 5 feet deep Borrow Areas—up to 30 feet deep Quarries—up to 180 feet deep Rock Processing—up to 5 feet deep Sites Lodoga Road—average estimated depth of 26 feet and maximum depth of 108 feet Huffmaster Road (Realigned)— average estimated depth of 26 feet	similar to Huffmaster Road but 20 miles longer.	
I/O Works; Sites Dam and Golden Gate Dam; Saddle	Dams, Saddle Dams (except 5), I/O Works—Cretaceous	Construction staging, I/O tower foundation, tunnel, dam excavation,	Approximately 300 acres	Approximately 200 acres	I/O Works—Hillside excavation for the downstream and upstream tunnel portals 80 feet and	Generally, the same as Alternative 1 or 3 but without Saddle	Kb and Kc (underlie most of area): low Qb: low Qrl: high

Component Grouping	Geologic Units Affected	Project Activity That Could Affect Resource	Extent of Activity for Alternatives 1 and 3	Extent of Activity for Alternative 2	Depth of Activity for Alternatives 1 and 3	Depth of Activity for Alternative 2	Paleontologically Sensitivity of Units Affected
Dams and Dikes	unit (pTms-assumed to be Kb or Kc), minor Holocene unit (Qb) Saddle Dam 5—pTms, minor Pleistocene unit (Qrl)	saddle dam rock processing and haul roads			180 feet deep, respectively Sites Diversion Outlet—Hillside excavation for the downstream and upstream tunnel portals 30 feet and 50 feet deep respectively Golden Gate Diversion—Excavation included with dam excavation. Saddle Dams—Approximately 15 feet deep for upstream and downstream portals	Dams 1, 2, and 6. Saddle Dike 3 would be in same vicinity as Saddle Dam 1	
Conveyance to Sacramento River—Dunnigan Pipeline to CBD Outlet only	Holocene units (Qsc, Qa, Qb), Pleistocene units (Qml, Qmu), Pliocene- to Pleistocene unit (Tte)	Excavation for Dunnigan Pipeline	Approximately 100 acres	Approximately 250 acres	Pipelines 10 feet in diameter would range in depth of cover from 6 to 25 feet below ground surface	Generally, the same at Alternatives 1 and 3	Qsc: low Qa: low Qb: low Qml and Qmu: high Tte: high

Component Grouping	Geologic Units Affected	Project Activity That Could Affect Resource	Extent of Activity for Alternatives 1 and 3	Extent of Activity for Alternative 2	Depth of Activity for Alternatives 1 and 3	Depth of Activity for Alternative 2	Paleontologically Sensitivity of Units Affected
Comm Road South, Access Roads A, B1, B2, C1, C2	Holocene units (Qa, Qb), Cretaceous unit (pTms-assumed to be Kb or Kc)	Road improvements and construction	Approximately 150 acres	Same as Alternative 1 or 3	Saddle Dam Roads North and South average estimated depth of 10 feet, similar to North Road. Comm Road South average estimated depth of 10 feet Access Roads A1, B1, and B2 average depth of 10 feet Access Roads C1 and C2 average depth of 3 feet.	Same as Alternative 1 or 3	Qa: low Qb: low Kb and Kc: low
South Saddle Dam Road; Saddle Dam Road-North; McDermott Road; North Road; Roads D, F, 68, 69	Holocene unit (Qa, Qb), Pleistocene units (Qml, Qrl, Qru), Cretaceous unit (pTms-assumed to be Kb or Kc)	Road improvements and construction	Approximately 400 acres	Same as Alternative 1 or 3	Construction roads: Excavating for shoulders and compacting the subgrade, performing full-depth reclamation of the existing roadbed by in-place pulverization (assumed 14 inches deep). {Some excavation for minor cuts and fills.}	Same as Alternative 1 or 3	Qa: low Qb: low Qml: high Qru and Qrl: high pTms: unknown

Component Grouping	Geologic Units Affected	Project Activity That Could Affect Resource	Extent of Activity for Alternatives 1 and 3	Extent of Activity for Alternative 2	Depth of Activity for Alternatives 1 and 3	Depth of Activity for Alternative 2	Paleontologically Sensitivity of Units Affected
					Average estimated depth of 2 feet. North Road average estimated depth of 10 feet and maximum depth of 16 feet		
Recreation Areas	Cretaceous unit (pTms-assumed to be Kb or Kc)	Grading and shallow excavation for amenities	Approximately 800 acres	Same as Alternative 1 or 3	Likely shallow grading	Same as Alternative 1 or 3	Kb and Kc: low

Notes: See Figures 12-1a–c and 12-2 and Section 12.2.1.4, *Geologic Units*, for more information on the geologic units.

Construction

Under Alternatives 1 and 3, a wide variety of ground-disturbing activities would occur in areas of varying paleontological sensitivity throughout the study area. If fossils are present in these areas, they could be damaged by these construction activities (Table 12-7).

For the Sacramento River diversion and conveyance to regulating reservoirs (TC Canal, GCID Main Canal, GCID system upgrades), Alternatives 1 and 3 would involve installation of two pumps at the RBPP and improvements to the GCID Main Canal. At the RBPP, there would be no excavation and therefore no impact on paleontological resources. For the GCID Main Canal improvements, the new head gate would involve excavation and pile driving in the Riverbank Formation, replacement of the GCID Main Canal siphons would involve excavation in the Modesto Formation, and other improvements would involve minor excavation in previously disturbed soils. These activities would be unlikely to damage paleontological resources because they would involve shallow disturbance, small areas of disturbance, or geologic units that are generally too young to contain fossils.

A variety of ground-disturbing activities would be required in the regulating reservoir complex. Excavation would occur for the foundations of the transition manifold, the PGPs, and other buildings. Trenching or microboring and tunneling would occur for the pipelines. For the Funks PGP, these activities would take place in areas underlain by the Great Valley sequence and basin deposits, which are not sensitive for paleontological resources. The Funks Reservoir would also be dredged, but this would affect only recently deposited sediment. For the TRR East PGP, these activities would take place in the Riverbank Formation, which is sensitive for paleontological resources, and the basin deposits, which are not sensitive but overlie the paleontologically sensitive Modesto and Riverbank Formations. Construction of the TRR East would require extensive soil amendment using CDSM and excavation (Table 12-7), which would take place in the Riverbank Formation and basin deposits and likely extend into the Modesto Formation. The TRR East pipelines would extend through the basin deposits, Riverbank Formation, Red Bluff Formation, and Great Valley sequence. These activities could damage paleontological resources in those locations where paleontologically sensitive units are present.

Tunneling for the pipelines would occur in the Great Valley sequence, which is not sensitive for paleontological resources. Therefore, tunneling would be unlikely to damage paleontological resources.

The I/O Works, main and saddle dams, and saddle dikes would involve ground-disturbing activities associated with excavation and blasting for the dam and dike foundations and I/O Works foundations, tunnel, and diversions. These activities would occur primarily in the Great Valley sequence. The formations of this sequence in this area are the Cortina (the Yolo and Venado members) and Boxer Formations (Figure 12-2), which are not sensitive for paleontological resources. Excavation for Saddle Dam 5 would also occur in small areas of the Riverbank Formation. Most of the area affected by excavation of the I/O Works, dams, and saddle dikes would not be likely to affect paleontological resources, but the small areas of Riverbank Formation may contain fossils that could be damaged.

Construction in the inundation area for the dams, Sites Lodoga Road realignment (including the bridge), and Huffmaster Road realignment would involve extensive ground-disturbing activities. These activities include quarrying for dam-building materials, construction of bridge berms and foundations, and grading for staging and construction areas. However, these activities would occur primarily in the Boxer and Cortina Formations, which are not sensitive for paleontological resources. Even though excavation would be necessary for construction of the Huffmaster Road realignment, the excavation would also be confined to these units. These activities therefore would be unlikely to damage paleontological resources. The inundation area would cover some areas of Riverbank Formation on the eastern edge of the reservoir, but this would be unlikely to damage paleontological resources. Haul for Saddle Dams 1, 2, and 3 would occur in the Modesto and Riverbank Formations, but this excavation would be shallow and narrow.

Construction of the Dunnigan Pipeline would occur in units sensitive for paleontological resources: the Tehama Formation on the western end of the pipeline alignment and the Modesto Formation for the remainder of the alignment. Both of these units have produced many vertebrate fossils, and the Tehama Formation is known for the large number of early horse fossils found in the unit. Therefore, the entire Dunnigan Pipeline alignment is sensitive for paleontological resources and excavation for the pipeline could damage paleontological resources.

Work for access roads and other roads would occur both in areas that are and are not sensitive for paleontological resources. Comm Road South and Access Roads A, B1, B2, C1, and C2 would occur in units not sensitive for paleontological resources (Cortina and Boxer Formations and Quaternary alluvium and basin deposits). The other roads would involve much smaller and shallower areas of disturbance for construction and improvements and would also not be likely to damage paleontological resources.

Road work for Saddle Dam Roads North and South, McDermott Road, North Road, and Roads D, F, 68, and 69 would occur, at least in part, in the Modesto and Riverbank Formations, which are sensitive for paleontological resources. The road work would include construction of new paved roads, construction of new gravel roads, and improvements to existing roads. Although much of the work would occur in previously disturbed soil or deposits too young to contain fossils (Qa and Qb), deeper excavation could extend into undisturbed Modesto and Riverbank Formations and damage paleontological resources.

The recreation areas would be constructed in locations underlain by the Boxer or Cortina Formations and therefore construction would not likely damage paleontological resources.

Operation

The operation of Alternatives 1 and 3 would be the same relative to paleontological resources because the differences in water deliveries would not affect paleontological resources in the reservoir, which has the same inundation area between alternatives. Wave action in the reservoir could cause erosion along the shoreline that could expose paleontological resources. However, this erosion would be in the Boxer Formation and would therefore be unlikely to damage paleontological resources. The regulating reservoirs are surrounded by disturbed material and therefore wave action in these areas would not damage paleontological resources.

Other operation activities would involve only small areas of ground disturbance or disturbance in previously disturbed soil or units too young to contain fossils. As a result, operation activities would be unlikely to damage paleontological resources.

CEQA Significance Determination and Mitigation Measures

Under Alternative 1 or 3, construction activities that would have a less-than-significant impact on paleontological resources are those that would occur in geologic units not sensitive for paleontological resources (Holocene units and the Great Valley sequence, including the Boxer and Cortina Formations) and involve small or shallow ground-disturbing activities, such as GCID Main Canal improvements and road improvements. In addition, the Worker Environmental Awareness Program (WEAP) BMP, which requires training construction workers to recognize paleontological resources and stopping work if paleontological resources are encountered, would be in place should fossils be unexpectedly encountered during construction activities.

Construction activities that would have a significant impact on paleontological resources are those that involve excavation in sensitive units, such as most construction in the regulating reservoir complex and trenching and staging for the Dunnigan Pipeline.

Overall construction impacts would be significant. For most activities, implementation of Mitigation Measures GEO 7.1–GEO-7.5 would reduce this impact by requiring that a qualified paleontologist be retained and design a paleontological resources monitoring and mitigation plan (PRMMP) so that fossils in the construction areas would be preserved.

For soil amendment under the TRR East, the use of CDSM could destroy fossils in the Riverbank and Modesto Formations. The ground disturbance would be deep, and a paleontological monitor would not be able to observe the disturbance or halt construction. Therefore, this impact would be significant and unavoidable.

Under Alternative 1 or 3 operations, wave action along the reservoir shoreline would cause a less-than-significant impact. No other operations would cause an impact.

Mitigation Measure GEO-7.1: Retain a Qualified Paleontological Resource Specialist Prior to the Start of Construction

The Authority will retain a qualified Paleontological Resource Specialist once the construction footprint can be accessed and the engineering design is at sufficient level of detail but at least 90 days prior to the start of construction. The Paleontological Resource Specialist will meet the minimum or equivalent qualifications for a paleontological resources manager, as described in the SVP guidelines (2010).

The Authority will retain qualified Paleontological Resource Monitors with the assistance of the Paleontological Resource Specialist to monitor construction activities, as described in the PRMMP. Paleontological Resource Monitors will have the equivalent of the following qualifications:

- Bachelor of Science or Bachelor of Arts degree in geology or paleontology and 1 year of experience monitoring in California
- Associate of Science or Associate of Arts degree in geology, paleontology, or biology and 4 years of experience monitoring in California
- Enrollment in upper-division classes pursuing a degree in the fields of geology or paleontology and 2 years of monitoring experience in California

Mitigation Measure GEO-7.2: Consultation with the Paleontological Resource Specialist Prior to and During Project Construction

At least 30 days prior to the start of construction, the Authority will provide maps or drawings to the Paleontological Resource Specialist that show the planned construction footprint. Maps will identify all areas where ground disturbance is anticipated during Project implementation. The plan drawings will show the location, depth, and extent of all ground disturbances affecting paleontologically sensitive sediment. If construction proceeds in phases, maps and drawings may be submitted prior to the start of each phase. In addition, the proposed schedule of each Project phase will be provided to the Paleontological Resource Specialist. Before work commences on affected phases, the Authority will notify the Paleontological Resource Specialist of any construction phase scheduling changes.

Mitigation Measure GEO-7.3: Prepare and Implement a Paleontological Resources Monitoring and Mitigation Plan

Once the construction footprint can be accessed and the engineering design is at sufficient level of detail, the Authority will prepare a PRMMP to identify general and specific measures to minimize potential effects on significant paleontological resources. Approval of the PRMMP by the Authority will occur prior to any ground disturbance. The PRMMP will function as the formal guide for paleontological resources monitoring, collecting, and sampling activities, and may be modified by the Authority to accommodate new data or changes to the Project. This document will be used as the basis of discussion when onsite decisions or changes are proposed. Copies of the PRMMP will reside with the Authority, Paleontological Resource Specialist, each Paleontological Resource Monitor, and the Authority's onsite manager.

The PRMMP will be developed in accordance with professional guidelines and be consistent with those issued by SVP (2010) and will include the following:

- Procedures for the performance and sequence of resource-related tasks, such as any literature searches, preconstruction surveys, appropriate worker environmental training module, construction monitoring, mapping and data recovery, discovery situations, fossil preparation and collection, identification and inventory, preparation of final reports, transmittal of materials for curation, and final report will be provided in the PRMMP, including:

- A discussion of the geologic units expected to be encountered, the location and depth of the units relative to the Project footprint, when known, and the known paleontological sensitivity of those units
- A discussion of the locations of where the monitoring of construction activities is deemed necessary, and a proposed plan for monitoring and sampling
- An explanation of why, how, and how much sampling is expected to take place and in what units, including descriptions of different sampling procedures that may be used
- A discussion of procedures to be followed in the event of a significant fossil discovery, diverting construction away from a find, resuming construction, and how notifications will be performed
- A discussion of equipment and supplies necessary for collection of fossil materials and any specialized equipment needed to prepare, remove, load, transport, and analyze large-sized fossils or extensive fossil deposits
- Procedures for inventory, preparation, and delivery for curation into a retrievable storage collection in a repository or museum, which meet SVP standards and requirements for the curation of paleontological resources
- Identification of the institution(s) that will be approached to receive data and fossil materials collected, and requirements or specifications for materials delivered for curation

The PRMMP will also provide guidance for preparation of a Paleontological Resources Report by the designated Paleontological Resource Specialist at the conclusion of ground-disturbing activities that may affect paleontological resources. The Paleontological Resources Report will include an analysis of the collected fossil materials and related information, including a description and inventory of recovered fossil materials, a map showing the location of paleontological resources encountered, determinations of sensitivity and significance, and a statement by the Paleontological Resource Specialist that effects on paleontological resources have been mitigated to be not adverse.

Mitigation Measure GEO-7.4: Conduct Monitoring During Project Construction and Prepare Monthly Reports

The Authority will ensure that the Paleontological Resource Specialist and Paleontological Resource Monitor(s) monitor construction excavations consistent with the PRMMP in areas where potential fossil-bearing materials have been identified, both at reservoir sites and along any constructed linear facilities associated with the Project.

The Authority will ensure that the Paleontological Resource Specialist and Paleontological Resource Monitor(s) have the authority to halt or redirect construction if paleontological resources are encountered. The Authority will ensure that there is no interference with monitoring activities, as directed by the Paleontological Resource Specialist.

The Authority will ensure that the Paleontological Resource Specialist prepares and submits monthly summaries of monitoring and other paleontological resources management activities. The summary will include the name(s) of the Paleontological Resource Specialist or Paleontological Resource Monitor(s) active during the month; general descriptions of training and monitored construction activities; and general locations of excavations, grading, and other activities. A section of the report will include the geologic units or subunits encountered, descriptions of samplings, if any, and a list of identified fossils. A final section of the report will address any issues or concerns about the Project relating to paleontological resources mitigation activities, including any incidents of non-compliance or any changes to the monitoring plan by the Paleontological Resource Specialist. If no monitoring took place during the month, the report will include an explanation as to why monitoring was not conducted.

Mitigation Measure GEO-7.5: Ensure Implementation of the Paleontological Resources Monitoring and Mitigation Plan

The Authority, through the designated Paleontological Resource Specialist, will ensure that all components of the PRMMP are performed during construction.

NEPA Conclusion

Construction and operation effects would be the same as described above for CEQA. For most components of Alternative 1 or 3, no adverse effects would occur as compared to the No Project Alternative with implementation of Mitigation Measures GEO-7.1–GEO-7.5 as the result of construction or operation. However, for soil amendment required for TRR East, the use of CDSM could destroy fossils in the Riverbank and Modesto Formations as compared to the No Project Alternative. The ground disturbance would be deep, and a paleontological monitor would not be able to observe the disturbance or halt construction. Therefore, this effect would be a substantial adverse effect.

Alternative 2

Construction

Most construction activities that could affect paleontological resources would be the same under Alternative 2 as under Alternative 1 or 3 because most components would the same. For example, although the dams would be smaller and fewer under Alternative 1 or 3, extensive excavation would still occur and that excavation would occur in geologic units not sensitive for paleontological resources. Similarly, though no bridge would be built under Alternative 2, extensive excavation would still occur and that excavation would occur in geologic units not sensitive for paleontological resources.

Three components that would differ under Alternative 2 are the TRR West, Dunnigan Pipeline, and South Road.

TRR West would be constructed in slightly different geologic units, would require a smaller area but greater depth of excavation, and would involve different construction techniques. Construction of the TRR West would require deep excavation in Quaternary basin deposits and the Great Valley sequence, which are not sensitive for paleontological resources, but also in the Red Bluff Formation, which is sensitive for paleontological resources. Because of the deep excavation, CDSM would not be required to stabilize the soil. The TRR West pipelines would be shorter but an additional tunnel between the Main and Extension reservoirs would be required. The other components of TRR West would be the same as for TRR East.

The Dunnigan Pipeline would differ because it extends beyond the CBD to the Sacramento River. This additional excavation would occur in Quaternary basin deposits, which are not sensitive for paleontological resources but that overlie the sensitive Modesto Formation. As with Alternative 1 or 3, this excavation could damage paleontological resources. Excavation through the levee would not disturb paleontological resources because levees do not contain in situ fossils.

The Sites Lodoga Road realignment would differ because there would be no bridge. The South Road would be constructed connecting to the realigned Huffmaster Road. Activities associated with the South Road would occur in geologic units not sensitive for paleontological resources.

Operation

Impacts related to wave action would be the same under Alternatives 1 and 3 as under Alternative 2 because wave action would occur in the same geologic units under all alternatives.

CEQA Significance Determination and Mitigation Measures

Most construction impacts would be the same under Alternative 2 as under Alternative 1 or 3 because most components would the same.

The CDSM required for construction of the TRR East under Alternative 1 or 3, which would result in a significant and unavoidable impact, would not be required for construction of the TRR West under Alternative 2. Although more extensive excavation would be required for the Main and Extension reservoirs that comprise TRR West, all ground-disturbing activities could be accessed by paleontological monitors. Therefore, implementation of Mitigation Measures GEO-7.1–GEO-7.5 would reduce the impacts of excavation related to TRR West construction on paleontological resources to a less-than-significant level.

Although two impacts that would differ would be for the Dunnigan Pipeline and the Sites Lodoga Road and South Road, the finding of less than significant with mitigation would remain the same. For the Dunnigan Pipeline, the finding remains less than significant because the additional excavation would occur in the same geologic units. Implementation of Mitigation Measures GEO-7.1–GEO-7.5 would reduce these impacts to a less-than-significant level. For the Sites Lodoga Road and South Road, the excavation would still occur in geologic units not sensitive for paleontological resources.

NEPA Conclusion

Construction and operation effects would be the same as described above for CEQA. Implementation of Mitigation Measures GEO-7.1–GEO-7.5 is required, and implementation would prevent paleontological resources from being directly or indirectly destroyed as compared to the No Project Alternative. No adverse effects would occur with implementation of Mitigation Measures GEO-7.1–GEO-7.5 as the result of construction or operation of Alternative 2.

12.5 References

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