

9.1 Affected Environment/Environmental Setting

This section of Chapter 9 describes the existing geologic and seismologic conditions and the associated potential geologic, seismic, and geotechnical hazards in the Sacramento–San Joaquin Delta (Delta) and Suisun Marsh area (Figure 1-9 in Chapter 1, *Introduction*). The information presented is based on existing information from published and unpublished sources. Specifically, the regional and site information was compiled from maps and reports published by various agencies, researchers, and consultants, including the California Department of Water Resources (DWR), CALFED Bay-Delta Program (CALFED), U.S. Army Corps of Engineers (USACE), U.S. Geological Survey (USGS), and California Geological Survey (CGS, formerly California Division of Mines and Geology). This section describes the environmental setting for the following areas, each of which has the potential to be affected by BDCP activities.

- Geologic setting focuses on the subsurface soils and the underlying bedrock units, including existing natural levee and channel deposits. Near-surface soils are fully discussed in Chapter 10, *Soils*, which describes surface erosion, subsidence processes, and other soil hazards. Mineral resources that could be affected by construction and operation of the BDCP alternatives are fully discussed in Chapter 26, *Mineral Resources*.
- Seismologic setting describes historical seismic events and the ground shaking potential during earthquakes.
- Geologic and seismic hazards, including surface fault rupture, seismic-induced liquefaction, and slope instability and ground failure, are identified. Potential levee instability and breaches related to geologic processes that could result in flooding are also described. See Chapter 6, *Surface Water* and Appendix 3E, *Potential Seismic and Climate Change Risks to SWP/CVP Water Supplies*, for additional discussion of levee stability.

Additionally, the federal and state regulatory settings for the identified geologic and seismic hazards are presented with a listing of applicable design codes.

The setting information for geology and seismicity, except where otherwise noted, is derived from the geology and seismicity appendix that was included in the conceptual engineering reports (CERs) prepared for the BDCP.

- *Conceptual Engineering Report—Isolated Conveyance Facility—All Tunnel Option* (California Department of Water Resources 2010a).
- *Conceptual Engineering Report—Isolated Conveyance Facility—Pipeline/Tunnel Option—Addendum* (California Department of Water Resources 2010b).
- *Conceptual Engineering Report—Isolated Conveyance Facility—East Option* (California Department of Water Resources 2009a).
- *Conceptual Engineering Report—Isolated Conveyance Facility—East Option—Addendum* (California Department of Water Resources 2010c).

- 1 • *Conceptual Engineering Report—Isolated Conveyance Facility—West Option* (California Department
2 of Water Resources 2009b).
- 3 • *Conceptual Engineering Report—Isolated Conveyance Facility—West Option—Addendum* (California
4 Department of Water Resources 2010d).
- 5 • *Option Description Report—Separate Corridors Option* (California Department of Water Resources
6 2010e).

7 **9.1.1 Potential Environmental Effects Area**

8 The Plan Area (the area covered by the BDCP) consists of the Delta and Suisun Marsh which lie within
9 California’s Central Valley, which is approximately 465 miles long and 40–60 miles wide. The valley is
10 bound by the Sierra Nevada on the east and the Coast Ranges on the west (Figure 9-1). Paleogeographic
11 reconstructions of this region indicate that Miocene sedimentation was similar to a modern fore-arc
12 basin (a sea floor depression between a subduction zone and an associated volcanic arc), shedding
13 arkosic (granular quartz and feldspar or mica) and volcanoclastic sediment westward from the
14 continent. (Figure 9-2 presents a geologic time scale.) In the mid-Pliocene Epoch, a shift in plate
15 tectonics triggered uplift of the Coast Ranges, which gradually closed the southern marine outlet to the
16 basin. By the late Pliocene, sub-aerial conditions prevailed throughout the valley, resulting from marine
17 regression (i.e., where shoreline shifts oceanward, exposing formerly submerged areas) and
18 sedimentation from the west. During Pleistocene Epoch, the valley separated from the Pacific Ocean
19 and developed internal drainage, the modern outlet being the Carquinez Strait, through which the
20 Sacramento River flows to the San Francisco Bay (Lettis and Unruh 1991, pp. 164–176).

21 The historical Delta formed approximately 5,000 years ago at the inland margin of the San Francisco
22 Bay Estuary as two overlapping geomorphic units. The Sacramento River Delta comprises about 30% of
23 the total area and was influenced by the interaction of rising sea level and river floods that created
24 channels, natural levees, and marsh plains. During large river flood events, silt and sand were deposited
25 adjacent to the river channel, forming natural levees above the marsh plain. In contrast, the larger San
26 Joaquin River Delta, located in the central and southern portions of the Delta and having relatively
27 small flood flows and low sediment supply, formed as an extensive, levee free freshwater tidal marsh
28 dominated by tidal flows and organic soil (peat and muck) accretion (Atwater and Belknap 1980).
29 Because the San Joaquin River Delta had less well-defined levees, sediment were deposited more
30 uniformly across the floodplain during high water, creating an extensive tule marsh with many small
31 branching tributary channels. As a result of the different amounts of inorganic sediment supply, the
32 peat and muck of the San Joaquin River Delta grade northward into peaty mud and then into mud as it
33 approaches the natural levees and flood basins of the Sacramento River Delta (Atwater and Belknap
34 1980).

35 **9.1.1.1 Regional Geology**

36 The Great Valley is a northwest-trending structural basin, separating the primarily granitic rock of the
37 Sierra Nevada from the primarily Franciscan Formation rock of the California Coastal Range (Norris
38 and Webb 1990). The basin is filled with an approximately 3- to 6-mile-thick layer of sedimentary
39 deposits deposited by streams originating in the Sierra Nevada, Coast Ranges, and South Cascade
40 Range, and flowing to the San Francisco Bay. Figure 9-3 is a geologic map of the Plan Area and vicinity.
41 (Detailed geologic mapping is not available for the entire Plan Area. Figure 9-3 is primarily based on
42 relatively detailed mapping derived from Atwater [1982] and covers most of the Delta. The geology of
43 the remaining areas [e.g., Suisun Marsh and southern end of the Delta] is based on regional geologic

1 mapping derived from the California Division of Mines and Geology. Figure 9-3 also shows the primary
 2 conveyance alignments subdivided into segments; these segments provide the basis for the discussion
 3 of potential effects in Section 9.3, *Environmental Consequences*. Figure 9-4, which is based on boring
 4 logs, shows a cross-section of the stratigraphy of the sediment generally oriented along the Alternative
 5 1A tunnel alignment.

6 The Delta received thick accumulations of sediment from the Sierra Nevada to the east and the Coast
 7 Ranges to the west after the Cretaceous and most of Tertiary Periods. The Delta has experienced
 8 several cycles of deposition, nondeposition, and erosion that has resulted in the accumulation of thick,
 9 poorly consolidated to unconsolidated sediment overlying the Cretaceous and Tertiary formations
 10 since late Quaternary Period. Shlemon and Begg (1975) believe that the peat and muck in the Delta
 11 began to form about 11,000 years ago at the start of the current phase of sea level rise, which started at
 12 the beginning of the Holocene Epoch. This rise created tule marshes that covered most of the Delta.
 13 These organic soils formed from the accumulated detritus of the tules and other marsh vegetation.

14 As the Suisun Marsh formed, plant detritus slowly accumulated, compressing the saturated underlying
 15 base material. Mineral sediment were added to the organic material by tidal action and during floods.
 16 Generally, mineral sediment deposition decreased with distance from the sloughs and channels (Miller
 17 et al. 1975). Suisun Marsh soils are termed “hydric” because they formed under prolonged saturated
 18 soil conditions. The soil adjacent to the sloughs is mineral soil with less than 15% organic matter
 19 content, and although classified as “poorly drained,” they are better drained than the more organic soil
 20 situated farther from the sloughs.

21 Suisun Marsh organic soil is found farthest from the sloughs and at the lowest elevations. They have
 22 greater than 50% organic matter content. Other common soils in the Suisun Marsh belong to the Valdez
 23 series, which formed on alluvial fans and contain very low amounts of organic matter. Valdez series
 24 soils are found primarily on Grizzly Island (Miller et al. 1975).

25 Suisun Marsh is bordered by upland soil that is non-hydric and contains very little organic matter.
 26 The marsh was originally formed by the deposition of silty alluvium from floodwaters of Suisun Slough,
 27 Montezuma Slough, and the Sacramento–San Joaquin Rivers network. The top layer in the Suisun
 28 Marsh area is mainly peat, muck, and young bay mud, underlain by a sand aquifer. The sand is a
 29 windblown dune deposit.

30 The surface geologic units over the Delta, Suisun Marsh, and adjoining areas include peaty and other
 31 organic soils, alluvium, levee and channel deposits, dune sand, older alluvium, and bedrock (Figure
 32 9-3).

33 **9.1.1.2 Local Geology**

34 A geologic map of the Plan Area is provided in Figure 9-3. It was necessary to use different sources to
 35 compile the geologic map and descriptions of the geologic map units (Tables 9-1 through 9-5)
 36 presented in this report. The primary map used in Figure 9-3 is the geologic map created by Atwater
 37 (1982), which provides the greater detail but does not cover the entire Plan Area. Regional geologic
 38 maps (Wagner et al. 1981; Wagner and Bortugno 1982; Wagner et al. 1991) were therefore used to fill
 39 in the remaining parts of the Plan Area. Except where noted, the text descriptions provided in Tables
 40 9-1 through 9-4 are taken directly (i.e., verbatim) from the work done by Graymer et al. (2002) because
 41 this work, although it did not cover as much of the Plan Area as Atwater, provides the most recent and
 42 relevant general descriptions of the geologic units that occur in the Plan Area. Because Graymer et al.

1 and Atwater used different names for geologic units, Tables 9-1 through 9-4 include approximate
2 correlations between the terminology in Graymer’s et al. and Atwater’s maps.

3 **9.1.1.2.1 Peat and Organic Soils**

4 The tule marshes created by sea level rise covered most of the Delta and led to the formation of peat
5 and muck. The thickness of organic soils in the Delta generally ranges from about 55 feet near Sherman
6 Island to almost nonexistent toward the southern part of the Delta (Real and Knudsen 2009). The
7 Suisun Marsh area is generally underlain by thick organic soils and peat (more than 40 feet thick in
8 some places near Grizzly Bay).

9 Over the years, these soils have been given various designations. For example, in 1935 the University of
10 California Agricultural Experiment Station mapped the surface soils using such names as Staten peaty
11 muck, Egbert muck, or Sacramento mucky loam. More recently, these organic and high organic matter
12 mineral soils were labeled on geologic maps as peaty muds and were mapped by the USGS (Graymer et
13 al. 2002) as Holocene Bay mud deposits and Delta mud deposits, as described in Table 9-1. Atwater
14 mapped the Delta mud deposits as “Peat and Mud of Delta Wetlands and Waterways” (map symbol
15 Qpm). Bay mud deposits do not appear within the limits of the Atwater map (Atwater 1982) (Figure 9-
16 3).

17 **Table 9-1. Mapped Peaty Mud**

Map Unit Name	Map Symbol	Description ^a	Approximate Correlation to Atwater ^b
Bay mud deposits (Holocene)	Qhbm	Water-saturated estuarine mud, predominantly gray, green, blue, and black clay and silty clay underlying marshlands and tidal mud flats of San Francisco Bay and Carquinez Strait. The mud also contains lenses of well-sorted, fine sand and silt, a few shelly layers (oysters), and peat. The mud interfingers with and grades into fine-grained fan deposits at the distal edge of Holocene fans. This unit is time-transgressive and generally occupies the area between the modern shoreline and the historical limits of tidal marsh	Not applicable
Delta mud deposits (Holocene)	Qhdm	Mud and peat with minor silt and sand deposited at or near sea level in the Sacramento/San Joaquin River Delta. Much of the area underlain by this unit is now dry because of construction of dikes and levees and below sea level due to compaction and deflation of the now unsaturated delta sediment.	Qpm

Source: Graymer et al. 2002.

^a Descriptions are taken directly from Graymer et al. 2002.

^b This correlation is only an approximation provided by the chapter author to aid the reader. It is not a scientific or peer-reviewed analysis.

19 **9.1.1.2.2 Alluvium**

20 Alluvium is sediment deposited by a river or other running water, and is typically composed of a
21 variety of materials, including fine particles of silt and clay and larger particles of sand and gravel.

22 A river continually picks up and drops solid particles of rock and soil from its bed throughout its length.

1 Where river flow is fast, more particles are picked up than dropped. Where the river flow is slow, more
 2 particles are dropped than are picked up. Areas where more particles are dropped are called *alluvial*
 3 *plains* or *floodplains*, and the dropped particles are called *alluvium*. Even small streams make alluvial
 4 deposits, but it is in the floodplains and deltas of large rivers where large, geologically substantial
 5 alluvial deposits are found. The mapped Holocene alluvial deposits found in the Delta and Suisun Marsh
 6 are described in Table 9-2.

7 **Table 9-2. Mapped Alluvium**

Map Unit Name	Map Symbol	Description ^a	Approximate Correlation to Atwater ^b
Younger Alluvium (late Holocene)	Qhay	Loose sand, gravel, silt, and clay deposited in active depositional environments and judged to be less than 1,000 years old based on geomorphic expression or historic records of deposition.	
Alluvium (Holocene)	Qha	Sand, silt, and gravel deposited in fan, valley fill, terrace, or basin environment. Mostly undissected by later erosion. Typically mapped in smooth, flat valley bottoms in medium-sized drainages and other areas where geomorphic expression is insufficient to allow differentiation of depositional environment.	Atwater mapped according to drainage basin and Graymer et al. according to type of alluvium, so correlation is very general: Qyp, Qym, Qya, Qymc
Terrace (Holocene)	Qht	Moderately well sorted sand, silt, gravel, and minor clay deposited in point bar and overbank settings. These deposits are as much as 10 m above the historic flood plain, but mostly undissected by later erosion.	
Alluvial Fan Deposits (Holocene)	Qhf	Moderately to poorly sorted and moderately to poorly bedded sand, gravel, silt, and clay deposited where streams emanate from upland regions onto more gently sloping valley floors or plains. Holocene alluvial fan deposits are mostly undissected by later erosion. In places, Holocene deposits may only form a thin layer over Pleistocene and older deposits.	
Fine-Grained Alluvial Fan Deposits (Holocene)	Qhff	Mostly silt and clay with interbedded lenses of sand and minor gravel deposited at the distal margin of large alluvial fan complexes.	
Alluvium (Holocene and late Pleistocene)	Qa	Sand, silt, and gravel deposited in fan, valley fill, terrace, or basin environments. Similar to unit Qha, this unit is mapped where deposition may have occurred in either Holocene or late Pleistocene time. In Yolo County, this unit includes the Modesto and Riverbank Formations as mapped by Helley and Barker (1979).	Same as above but also includes Qm, Qr, Qry, and Qro (Table 9-5)
Terrace Deposits (Holocene and late Pleistocene)	Qt	Moderately sorted to well-sorted, moderately bedded to well-bedded sand, gravel, silt, and minor clay deposited on relatively flat, undissected stream terraces. Similar to unit Qht, this unit is mapped where deposition may have occurred in either Holocene or late Pleistocene time.	Not mapped as a separate unit by Atwater (see Qht)
Alluvial Fan Deposits (Holocene and late Pleistocene)	Qf	Poorly sorted, moderately to poorly bedded sand, gravel, silt, and clay deposited in gently sloping alluvial fans. Similar to unit Qhf, this unit is mapped where deposition may have occurred in either Holocene or late Pleistocene time.	Atwater mapped according to drainage basin and

Map Unit Name	Map Symbol	Description ^a	Approximate Correlation to Atwater ^b
Alluvium (late Pleistocene)	Qpa	Poorly to moderately sorted sand, silt, and gravel in the Capay area (Esparto quadrangle). This unit is mapped on gently sloping to level alluvial fan or terrace surfaces where separate fan, terrace, and basin deposits could not be delineated. Late Pleistocene age is indicated by depth of stream incision, development of alfisols and lack of historical flooding.	Graymer et al. according to type of alluvium, so correlation is very general: Qo, Qom, Qoa, Qomc
Alluvial Fan Deposits (late Pleistocene)	Qpf	Poorly sorted, moderately to poorly bedded sand, gravel, silt, and clay deposited in gently sloping alluvial fans. Late Pleistocene age is indicated by erosional dissection and development of alfisols. These deposits are about 10% denser and have 50% greater penetration resistance than unit Qhf (California Department of Conservation 2000).	
Basin Deposits (late Pleistocene)	Qpb	As mapped by Atwater (1982), older alluvium widely but sparsely exposed at the toe of the Putah Creek fan (Dozier quadrangle), most commonly in basins between stream-built ridges of younger alluvium.	
Pediment Deposits (late and early Pleistocene)	Qop	Thin deposits of sand, silt, clay, and gravel on broad, planar erosional surfaces. These deposits are extremely dissected, have well-developed soils, and are mostly tens or hundreds of meters above the current depositional surface.	
Alluvium (late and early Pleistocene)	Qoa	Sand, silt, clay, and gravel deposits with little or none of the original geomorphic expression preserved. Moderately to extremely dissected, in places tens or hundreds of meters above the current depositional surface, and capped by well-developed soils. In Yolo County, this unit includes the Red Bluff Formation as mapped by Helley and Barker (1979).	

Source: Graymer et al. 2002.

Note: Geologic units are listed in order of age (youngest to oldest).

^a Descriptions are taken directly from Graymer et al. 2002.

^b This correlation is only an approximation provided by the chapter author to aid the reader. It is not a scientific or peer-reviewed analysis.

1
2 Atwater (1982) did not differentiate the alluvial deposits into alluvium, terrace, and fan deposits. As
3 shown on Figure 9-3, these deposits are instead collectively mapped as Quaternary alluvium named
4 according to the non-glaciated drainage basins from which the sediment was derived. Within each
5 basin, the alluvial deposits are called out by age: Qy indicating younger alluvium and Qo indicating
6 older alluvium. The Qy (Qyp, Qym, Qya, and Qymc) alluvial deposits on the Atwater map correspond to
7 the units listed in Table 9-2, which begin with Qh or Q to indicate Holocene to Holocene-to-Pleistocene-
8 aged deposits. Similarly, the Qo (Qop, Qom, Qoa, and Qomc) alluvial deposits are listed in Table 9-2,
9 with Qp indicating Pleistocene-aged alluvial deposits. Qch and Qcr, as mapped on the Atwater map,
10 consist of alluvial deposits from the Corral Hollow and Calaveras creek drainage basins, respectively,
11 and they are not broken out by age of deposits (Atwater 1982).

12 9.1.1.2.3 Levee and Channel Deposits

13 The ability of a river to carry sediment varies greatly with its flow volume and velocity. When a river
14 floods over its banks, the water spreads out, slows down, and deposits its load of suspended sediment.

1 Fine-grained sediment are deposited further from the channel, where coarser sediment are deposited
 2 nearer the channel. Over time, the river's banks are built up above the level of the rest of the floodplain.
 3 The resulting low ridges are called natural levees. Artificial, or human-made, levees are built to prevent
 4 flooding of lands along the river; these confine flow, resulting in higher and faster water flow than
 5 would occur naturally. Artificial levees impact sedimentation in the modern Delta. Natural and artificial
 6 levee deposits have been mapped and are described in Table 9-3. Atwater did not separately map
 7 artificial channel, levee, and stream deposits. The natural levee, floodplain, and flood basin deposits
 8 listed in Table 9-3 are designated as Ql, Qfp, and Qb, respectively, on the Atwater map (Atwater 1982).

9 **Table 9-3. Mapped Levee and Channel Deposits**

Map Unit Name	Map Symbol	Description ^a	Approximate Correlation to Atwater ^b
Artificial Channel Deposits (Historic)	ac	Modified stream channels, usually where streams have been straightened and realigned. Deposits in artificial channels range from concrete in lined channels to sand and gravel similar to natural stream channel deposits (Qhc).	Not applicable
Artificial Levee Fill (Historic)	alf	Man-made deposit of various materials and ages, forming artificial levees as much as 20 ft (6.5 m) high. Some are compacted and quite firm, but fills made before 1965 are almost everywhere not compacted and consist simply of dumped materials. Levees bordering waterways of the Sacramento/San Joaquin Delta, mudflats, and large streams were first emplaced as much as 150 years ago. The distribution of levee fill conforms to levees shown on the most recent U.S. Geological Survey 7.5-minute quadrangle maps	Not applicable
Stream Channel Deposits (Holocene)	Qhc	Loose sand, gravel, and cobbles with minor clay and silt deposited within active, natural stream channels.	Not mapped as a separate unit by Atwater.
Natural Levee Deposits (Holocene)	Qhl	Moderately- to well-sorted sand with some silt and clay deposited by streams that overtop their banks during flooding. Natural levees are often identified by their low, channel-parallel ridge geomorphology.	Ql
Floodplain Deposits (Holocene)	Qhfp	Medium- to dark-gray, dense, sandy to silty clay. Lenses of coarser material (silt, sand, and pebbles) may be locally present. Flood plain deposits usually occur between levee deposits (Qhl) and basin deposits (Qhb) and are prevalent in the Walnut Creek-Concord Valley, much of which is south of the map area.	Qfp
Floodbasin Deposits (Holocene)	Qhfb	Firm to stiff silty clay, clayey silt, and silt, commonly with carbonate nodules and locally with black spherules (Mn and (or) Fe oxides). The deposits laterally grade into peaty mud and mud of tidal wetlands (unit Qhdm). Locally, the deposits are veneered with silty, reddish-brown alluvium of historic age, some of which may have resulted from hydraulic mining in the Sierra Nevada during the late 1800s.	Qb

Source: Graymer et al. 2002.

Note: Geologic units are listed in order of age (youngest to oldest).

^a Descriptions are taken directly from Graymer et al. 2002.

^b This correlation is only an approximation provided by the chapter author to aid the reader. It is not a scientific or peer-reviewed analysis.

9.1.1.2.4 Dune Sand Deposits

Dune sand deposits consist of very well-sorted fine to medium grained eolian (wind deposited) sand. Holocene sand may discontinuously overlie the latest Pleistocene sand, both of which may form a mantle of varying thicknesses over older materials. Most of the deposits are thought to be associated with the latest Pleistocene to early Holocene periods of low sea level, during which large volumes of fluvial (i.e., pertaining to a river or stream) and glacially-derived sediment from the Sierra were blown into the dunes. Dune sand deposits are described in Table 9-4. The Atwater map refers to these dune sand as eolian deposits (Qe, Qm2e, and Qoe) (Atwater 1982).

Table 9-4. Mapped Dune Sand Deposits

Map Unit Name	Map Symbol	Description ^a	Approximate Correlation to Atwater ^b
Dune Sand (early Holocene and latest Pleistocene)	Qds	Very well sorted fine- to medium-grained eolian sand. They occur mainly in two large northwest-southeast trending sheets, as well as many small hills, most displaying Barchan morphology. Dunes display as much as 30 m of erosional relief and are presently being buried by basin deposits (Qhb) and delta mud (Qhdm). They probably began accumulating after the last interglacial high stand of sea-level began to recede about 79 ka (Imbrie et al., 1984; Martinson et al., 1987; Hendy and Kennett, 2000), continued to form when sea level dropped to its Wisconsin minimum about 18 ka, and probably ceased to accumulate after sea level reached its present elevation (about 6 ka). Atwater (1982) recognized buried paleosols in the dunes, indicating periods of nondeposition.	Qe, Qm2e, Qoe

Source: Graymer et al. 2002.

Note: ka = thousand years.

^a Descriptions are taken directly from Graymer et al. 2002.

^b This correlation is only an approximation provided by the chapter author to aid the reader. It is not a scientific or peer-reviewed analysis.

9.1.1.2.5 Older Alluvium

The older alluvium consists of the Pleistocene-aged Modesto and Riverbank formations that were deposited during separate episodes of glacially-derived sediment from the glaciated core of the Sierra Nevada (Lettis and Unruh 1991; Marchand 1977:39–50; Cherven and Graham 1983).

Lithologically, the two units are nearly identical arkosic fine-grained alluvium from the Sierra Nevada. However, the upper Modesto frequently has finer-grained silt and sand with a notable eolian component at the surface, capped by a weakly developed soil. The Riverbank is coarser gravel and sand capped by a very well developed soil. The timing of their deposition remains uncertain, but the Riverbank is probably Illinoian (roughly 300,000—130,000 years bp), while the Modesto is probably Late Wisconsin to early Holocene (roughly 21,000 to 10,000 years bp).

The Pleistocene Mokelumne River channels that deposited older alluvium show little relation to the present stream. Whereas the modern river channels meander in its floodplain and carry fine-grained sediment, the Pleistocene rivers cut deep, canyon-like channels into underlying, older fan deposits.

1 These ancient rivers had greater hydraulic force and carried glacially derived boulders and cobbles
 2 much farther downstream than the present river (Shlemon 1971). The older alluvial units are
 3 described in Table 9-5. These glacial deposits do not appear within the limits of the Graymer et al. map
 4 (2002).

5 **Table 9-5. Mapped Older Alluvium**

Map Unit Name	Map Symbol	Description
Modesto Formation	Qm	Material ranges from loose sand (probably eolian), to fluvial loose sand and silt, to compact silt and very fine sand.
Riverbank Formation	Qr	Riverbank Formation, undivided.
Riverbank Formation	Qry	Younger unit of Riverbank Formation.
Riverbank Formation	Qro	Older unit of Riverbank Formation.

Source: Atwater 1982.
 Note: Geologic units are listed in order of age (youngest to oldest).

6 **9.1.1.2.6 Bedrock Units**

7
 8 The above-described relatively poor-consolidated to unconsolidated Quaternary deposits overlie
 9 Cretaceous-to-Tertiary-age sedimentary bedrock, which is generally deeper than 1,000 feet in the Delta
 10 (Brocher 2005). These older sedimentary rocks consist primarily of interbedded marine sandstone,
 11 shale, and conglomerate. However, deposition of shallow marine, terrestrial, and volcanoclastic
 12 sediments predominated by the late Tertiary period. Immediately adjacent to the broader delta-fan-
 13 estuary system, rock outcrops of the early Pliocene Montezuma formation of the Vacaville Assemblage
 14 can be found in the Montezuma Hills, north of the western Delta area. This sedimentary rock comprises
 15 the easternmost outcrops of the northeastern Diablo Range south of the western Delta area (Graymer
 16 et al. 2002).

17 **9.1.1.3 Regional and Local Seismicity**

18 The California Coast Ranges physiographic province lies along the complex boundary between two
 19 tectonic plates: the North American Plate and the Pacific Plate. The geologic and tectonic conditions in
 20 the Delta and Suisun Marsh have been, and continue to be, controlled primarily by the interaction of
 21 these two massive blocks of the Earth's crust. Under the current tectonic regime, the Pacific Plate
 22 moves northwestward relative to the North American Plate at a rate of about 1.57 inches (40
 23 millimeters) per year (Working Group on California Earthquake Probabilities 2003). Although relative
 24 motion between these two plates is predominantly lateral (strike-slip), an increase in convergent
 25 motion along the plate boundary within the past few million years has resulted in the formation of
 26 mountain ranges and structural valleys of the Coast Ranges province (DeCourten 2008).

27 The San Andreas fault system dominates the seismicity of the region, and it comprises several major
 28 faults including the San Andreas, Hayward–Rodgers Creek, Calaveras, Concord–Green Valley, and
 29 Greenville faults. In addition to these major faults, many other named and unnamed regional faults
 30 accommodate relative motion between the plates and relieve compressional stresses that also act along
 31 the plate boundary.

1 The Delta and Suisun Marsh are in the eastern portion of the greater San Francisco Bay region, one of
 2 the most seismically active areas in the United States. Since 1800, several earthquakes with magnitudes
 3 greater than 6.5 have occurred in the immediate San Francisco Bay Area, including the 1868 magnitude
 4 6.8 earthquake on the Hayward fault, the 1906 magnitude 7.9 San Francisco earthquake on the San
 5 Andreas fault, and the more recent 1989 magnitude 6.9 Loma Prieta earthquake that occurred in the
 6 Santa Cruz Mountains. Figure 9-5 depicts the recorded historical seismicity in the San Francisco Bay
 7 region from 1800 to 2006.

8 **9.1.1.3.1 Delta**

9 Figure 9-5 indicates that the San Francisco Bay Area and Delta region have generally experienced low-
 10 level seismicity since 1800. No earthquakes with magnitude greater than 5.0 have been observed in the
 11 Delta. Buildings constructed in accordance with the California Building Code (CBC) are not expected to
 12 experience major damage caused by an earthquake with a magnitude smaller than 5.0.

13 As discussed in the following sections, the known active seismic sources located within the Delta area
 14 are mostly blind thrust faults (described below).

15 **9.1.1.3.2 Suisun Marsh**

16 Similar to the Delta, Suisun Marsh has experienced low-level seismicity since 1800. A few earthquakes
 17 with magnitudes between 3.0 and 4.9 were recorded in the proximity of the Pittsburgh–Kirby Hills fault
 18 (Figure 9-5). Some of these seismic events may have occurred on the fault.

19 Two earthquakes (the 1892 Vacaville-Winters and the 1983 Coalinga earthquakes) have been
 20 associated with the Coast Ranges-Sierran Block (CRSB) seismic zone, a complex-dipping thrust fault
 21 zone that goes through the Delta and Suisun Marsh area. The epicenter of the 1892 Vacaville-Winters
 22 earthquake was approximately 8 miles west of the Delta and Suisun Marsh. The epicenter of the 1983
 23 Coalinga earthquake was approximately 110 miles south of the Delta. Both of these seismic events had
 24 a magnitude greater than 6.5.

25 In 2003, the Working Group on California Earthquake Probabilities (WGCEP) calculated a 62%
 26 probability for one or more large earthquakes (magnitude 6.7 or greater) to occur in the San Francisco
 27 Bay region between 2002 and 2032). This estimate includes a 27% probability for one or more
 28 earthquakes of magnitude 6.7 or greater to take place along the nearby Hayward–Rodgers Creek fault
 29 over the same period. Because no major earthquakes have occurred in the San Francisco Bay region over
 30 the last several years, this probability will increase with time because of the strain that builds up along
 31 the faults (Working Group on California Earthquake Probabilities 2003).

32 The earthquake source model adopted by WGCEP in the 2003 study includes both the major regional
 33 faults and the background seismicity. Because of uncertainties associated with the source data, multiple
 34 earthquake source models were considered, and weights were assigned to these models based on
 35 expert opinion.

36 **9.1.1.3.3 Past Earthquake Ground Motion Intensity and Damage**

37 The San Francisco Bay region has been subjected to damaging ground shaking during past earthquakes.
 38 Table 9-6 lists the largest earthquakes that have affected the San Francisco Bay region since 1868 and
 39 the damage caused by these earthquakes, as described in the seismic study (California Department of
 40 Water Resources 2007a).

1 **Table 9-6. Largest Earthquakes Having Affected the San Francisco Bay Region**

Date	Intensity	Fault	Location	Damage Incurred
October 21, 1868	$M_L = 6.8$	Southern Hayward	San Francisco Bay Area, San Jose	Heavy damage sustained in towns along the Hayward fault in the eastern San Francisco Bay Area.
April 19 and 21, 1892	$M = 6.2$ to 6.5	CRSB Seismic Zone	Winters/Vacaville	Damage to the communities of Vacaville, Dixon, and Winters, and the surrounding rural areas. Brick buildings were damaged and one man was killed by falling bricks.
March 31, 1898	MMI = VIII or greater $M_L = 6.7$	(no data)	Mare Island in San Pablo Bay	Buildings damaged in areas around the San Francisco Bay Area.
April 18, 1906	$M = 7.9$	San Andreas	San Francisco	Widespread damage in northern California. Ground shaking and fire caused the deaths of more than 3,000 people and injured approximately 225,000 people.
May 2, 1983	$M = 6.4$	CRSB Seismic Zone	Coalinga	\$10 million in property damage and injured 94 people.
April 24, 1984	$M = 6.2$	Calaveras	Morgan Hill	\$7.5 million in damage. In San Jose, cracks formed in some walls, plaster fell, many items were thrown from store shelves, and some chimneys cracked.
October 17, 1989	$M = 6.9$	San Andreas	Santa Cruz Mountains	\$6 billion damage, 62 deaths, 3,500 injured, and 12,000 people displaced from homes.
October 30, 2007	$M = 5.6$	Calaveras	Northeast of San Jose	Strong shaking, no damage reported.

Source: California Department of Water Resources 2010a.

Notes:

CRSB = Coast Ranges–Sierran Block.

M_L = Richter Magnitude.

M = Moment Magnitude.

MMI = Modified Mercalli Intensity.

The Richter Magnitude is a measure of the total energy released during an earthquake. The Moment Magnitude Scale is more precise than the Richter scale because it is based on the area of the fault moving at the same moment as an earthquake. Because magnitude does not describe the extent of the damage, its usefulness is limited to an approximation of whether the earthquake is large, small, or medium-sized. Earthquakes can also be described by their intensity, or the degree of damage or observable effects caused by an earthquake at a particular location. The Modified Mercalli Scale is divided into 12 degrees, each identified by a Roman numeral.

- 2
- 3 Damage resulting from earthquake ground shaking is typically estimated by Modified Mercalli Intensity
- 4 (MMI). MMI is a measure of ground shaking that is based on the effects of earthquakes on people and
- 5 buildings at a particular location. An MMI VII or greater indicates damaging effects on people and
- 6 buildings.
- 7 Seismologists believe it is likely that the Delta and Suisun Marsh will experience periodic minor to
- 8 moderate earthquakes (magnitude 6.5 or greater) in the next 50 years. A magnitude 6.5 or greater
- 9 earthquake on the major seismic sources in the San Francisco Bay region would affect the Delta and
- 10 Suisun Marsh with moderate to strong ground shaking, and could potentially induce damage in these

1 areas. Strong ground shaking is typically expressed in terms of high peak ground accelerations (the
2 maximum acceleration by a soil particle at the ground surface during an earthquake).

3 **9.1.1.3.4 Active Seismic Sources**

4 Seismic sources or faults can generally be described by one of three activity classes as defined by CGS:
5 active, potentially active, or inactive. Active describes historical and Holocene faults that have had
6 displacements within the past 11,000 years. Potentially active describes faults showing evidence of
7 displacements during Quaternary time (the past 1.6 million years). Pre-Quaternary age faults with no
8 subsequent offset are classified as inactive. An inactive classification by CGS does not mean that a fault
9 will not rupture in the future, but only that it has not been shown to have ruptured within the past 1.6
10 million years. Seismologists assume that the probability of fault rupture by inactive faults is low. For
11 this reason, only the potential seismic impacts from active or potentially active faults are discussed in
12 this chapter.

13 A recent seismic study (California Department of Water Resources 2007a) considered four categories
14 of active and potentially active seismic sources.

- 15 • Crustal fault
- 16 • Thrust fault
- 17 • Seismic zone
- 18 • Subduction zone

19 The characterization of these seismic sources is based on the latest geologic, seismologic, and
20 paleoseismic data, and the current understanding of fault behaviors is based mainly on the works of the
21 Working Group on Northern California Earthquake Potential (WGNCEP), WGCEP, and CGS seismic
22 source model used in the USGS National Seismic Hazard Maps (Working Group on Northern California
23 Earthquake Potential 1996; Working Group on California Earthquake Probabilities 2003; Cao et
24 al. 2003).

25 Key characteristics of the seismic sources important to the Delta and Suisun Marsh earthquake hazard
26 potential are summarized as follows:

27 **Crustal Faults**

28 The time-independent and time-dependent source models of active and potentially active seismic
29 sources in the San Francisco Bay region were considered in the seismic study (California Department of
30 Water Resources 2007a). The time-independent model assumes a Poissonian process (i.e., a statistical
31 probability distribution that characterizes discrete events occurring independently of one another in
32 time) for earthquake occurrence that is independent of the time since the last earthquake. In contrast,
33 in a time-dependent model, the likelihood of having an earthquake at a specific future time depends on
34 the elapsed time since the last earthquake; the longer the elapsed time is, the greater the likelihood will
35 be. In this study, the time-dependent source models were applied to only seven major faults based on
36 the rates of characteristic (maximum) events developed by WGCEP (2003). These seven faults are the
37 San Andreas, Hayward–Rodgers Creek, Calaveras, Concord–Green Valley, San Gregorio, Greenville, and
38 Mt. Diablo Thrust.

39 The approximate locations of the active and potentially active seismic sources in the San Francisco Bay
40 region and the Delta and Suisun Marsh are plotted in Figure 9-5. The surficial crustal faults known to

1 cross the Delta and Suisun Marsh are the Pittsburgh–Kirby Hills and the Concord–Green Valley faults.
 2 The Pittsburgh–Kirby Hills fault is mapped crossing the Suisun Marsh from near the Fairfield at the
 3 north to the Pittsburg at the south. The Concord–Green Valley fault crosses along the western part of
 4 Suisun Marsh. The Cordelia fault terminates close to the northern boundary of the Suisun Marsh.

5 Other major crustal faults in the San Francisco Bay region that have the potential for generating
 6 substantial earthquake ground shaking in the Delta and Suisun Marsh include the San Andreas,
 7 Hayward–Rodgers Creek, Calaveras, Concord–Green Valley, and Greenville. The San Andreas,
 8 Hayward–Rodgers Creek, and Calaveras faults are regional seismic sources that, although large
 9 distances away from the Delta and Suisun Marsh, can induce considerable ground shaking because of
 10 their potential for generating large-magnitude earthquakes.

11 The maximum earthquake moment magnitudes, closest distances to the Delta and Suisun Marsh,
 12 long-term geologic slip rates, and faulting mechanism assigned to these major active faults are
 13 presented in Table 9-7. Earthquake moment magnitude is a measure of earthquake size based on the
 14 energy released. This definition was developed in the 1970s to replace the Richter magnitude scale, and
 15 it is considered a better representation of earthquake size. The geologic slip rate is the rate that the
 16 sides of fault move with respect to one another. It is used to predict the frequencies of future
 17 earthquakes. Faulting style describes the direction of movements and relative magnitudes of various
 18 forces acting along the fault. A strike-slip faulting style indicates lateral sliding of the sides of a fault
 19 past each other.

20 **Table 9-7. Characteristics of Major Seismic Sources in San Francisco Bay Region**

Fault (closest to farthest)	Distance from Delta and Suisun Marsh ^a (miles)	Slip Rate ^b (inch/year)	Maximum Earthquake ^b (moment magnitude)	Faulting Style
Concord–Green Valley	0.0	0.20 ± 0.12	6.7	Strike-slip
Pittsburgh–Kirby Hills	0.0	0.02 ± 0.08	6.7	Strike-slip
Greenville	6.2	0.16 ± 0.08	6.9	Strike-slip
Hayward–Rodgers Creek	12.4	0.35 ± 0.08	7.3	Strike-slip
Calaveras	16.8	0.16 ± 0.79	6.9	Strike-slip
San Andreas	30.0	0.94 ± 0.12	7.9	Strike-slip

Source: California Department of Water Resources 2007a.

^a Closest distance from fault trace to Delta and Suisun Marsh.

^b Largest values assigned by California Department of Water Resources 2007a.

22 **Thrust Faults**

23 The seismic sources underlying the Delta and Suisun Marsh are mostly “blind” thrusts (Table 9-8).
 24 A blind thrust is a seismic source that is not expected to rupture to the ground surface during an
 25 earthquake event, but is still capable of producing large and damaging ground shaking. The known
 26 blind thrusts in the Delta include the Midland, Montezuma Hills, Thornton Arch, West Tracy, and
 27 Vernalis faults. The Black Butte and Midway faults are thrust faults, with a discernible geomorphic
 28 expression/trace at the surface.

1 **Table 9-8. Characteristics of Thrust Faults in the Delta and Suisun Marsh**

Fault (closest to farthest)	Probability of Activity	Slip Rate (inch/year)	Maximum Earthquake (moment magnitude)	Faulting Style
Thornton Arch	0.2	0.002–0.006	6.0–6.5	Reverse-oblique*
Montezuma Hills	0.5	0.002–0.02	6.0–6.5	Reverse-oblique
Vernalis	0.8	0.003–0.02	6.25–6.75	Reverse-oblique
Southern Midland	0.8	0.004–0.04	6.6	Reverse-oblique
West Tracy	0.9	0.07–0.5	6.25–6.5	Reverse-oblique
Black Butte and Midway	1.0	0.004–0.04	6.25–6.75	Reverse-oblique
Northern Midland	1.0	0.004–0.04	6.0–6.5	Reverse-oblique

Source: California Department of Water Resources 2007a; Fugro Consultants 2011.

* A reverse-oblique faulting style describes fault movements where one side of a fault moves upward relative to the other side (up-dipping) with some components of lateral movement as a result of compression in the crust.

- 2
- 3 The Midland fault is an approximately north-striking fault that dips to the west and underlies the
4 central region of the Delta area. The fault is at least 37 miles long, and gas explorations conducted in the
5 area indicate that it is not exposed at the ground surface (California Division of Oil and Gas 1982). The
6 Midland fault is divided into a Northern Midland fault zone, which characterizes the northwest-striking
7 fault splays north of Rio Vista, and a Southern Midland fault, which extends southward to near Clifton
8 Court Forebay. (The area (rather than a defined trace) referred to as the Northern Midland fault zone is
9 so-named because it encompasses numerous right-stepping northwest-striking splays of the Midland
10 fault.)
- 11 The Montezuma Hills seismic source is modeled as a source zone between the Delta and Suisun Marsh
12 near Rio Vista. The zone extends southward to the Sherman Island area and has been defined to
13 capture the potential active structures that may be responsible for the uplift of the Montezuma Hills
14 (California Department of Water Resources 2007a).
- 15 The Thornton Arch seismic zone has been defined to represent the possible existence of active buried
16 structures near the Thornton and West Thornton-Walnut Grove gas field near the Delta Cross Channel
17 area. After considering the best available evidence to date, the seismic study adopted a low probability
18 of activity and a low slip rate for this zone. The probability of activity is a measure of certainty, based
19 on the available data, that a seismic source is active (California Department of Water Resources 2007a).
20 The probability scale ranges from 0 to 1.0, with a probability of 1.0 strongly suggesting an active fault.
- 21 The West Tracy, Vernalis, Black Butte, and Midway faults are parts of the CRSB seismic zone (California
22 Department of Water Resources 2007a). As described previously in this section, the CRSB is a complex
23 zone of thrust faulting that defines the boundary between the Coast Ranges block to the west and the
24 Sierran basement rocks of the Sacramento and San Joaquin Valleys. The West Tracy fault is mapped
25 beneath the southwestern part of the Clifton Court Forebay and western part of the Byron Tract
26 Forebay. It has a total length of about 9.5 miles. Multiple east-dipping splays of the fault may exist in the
27 hanging wall (i.e., upthrown block) west of the Clifton Court Forebay, some of which are underneath
28 the intake channel to the Banks Pumping Plant (Fugro Consultants 2011). The fault strikes in a
29 northwest–southeast direction and dips westward moderately to steeply to the west. The Vernalis fault
30 is mapped at the southern end of the Delta area, extending between Tracy and Patterson, at a minimum
31 length of about 19.2 miles. Similar to the West Tracy fault, the Vernalis fault is a moderately to steeply

1 west-dipping fault (California Department of Water Resources 2007a). The Black Butte fault is a
 2 northwest-southeast striking fault approximately 6 miles southeast of Tracy. It dips moderately to
 3 steeply to the west. The Midway fault similarly strikes northwest-southeast and is separated from the
 4 northwest end of the Black Butte fault by an *en echelon* step across a small west-northwest-trending
 5 anticline. The seismic study (California Department of Water Resources 2007a) characterized the Black
 6 Butte and Midway faults as a single structure.

7 The probabilities of activity, maximum earthquake magnitudes, and long-term geologic slip rates
 8 assigned to these blind thrusts are presented in Table 9-8.

9 **Seismic Zones**

10 To account for seismicity not associated with known faults, such as random or floating earthquakes,
 11 two regional seismic zones—the Coast Ranges and Central Valley seismic zones—were developed
 12 for the seismic study. The maximum earthquake magnitudes assigned to these seismic zones are
 13 6.5 ± 0.3 moment magnitude. The recurrences of various earthquake magnitudes were estimated using
 14 the historical seismicity recorded in each of the two seismic zones after removing events within
 15 10-kilometer-wide corridors along known faults (to avoid double counting seismic events that
 16 occurred on the faults). Both the uniform and gridded seismicity source models were used to model the
 17 uncertainty associated with earthquake location. In the uniform model, earthquakes are assumed to
 18 occur everywhere within the zone with equal probability. For the gridded seismicity model, the rates of
 19 earthquakes at a particular location within the zone are estimated using the seismicity recorded
 20 around the location. A Gaussian (normal) filter was used to “smooth” the data and to assign greater
 21 weights to nearby seismicity (California Department of Water Resources 2007a).

22 **Subduction Zone**

23 A subduction zone consists of interface and intraslab seismic sources. The interface seismic source is
 24 along the convergent plate boundary, while the intraslab is a deeper seismic source on the subducting
 25 plate.

26 The Cascadia subduction zone extends from Cape Mendocino, California, to Vancouver Island, British
 27 Columbia. Although this seismic zone is a large distance from the Delta and Suisun Marsh,
 28 its contributions to the ground shaking cannot be ignored because of its potential for generating very
 29 large-magnitude earthquakes (earthquakes with moment magnitudes of about 9.0).

30 A large-magnitude earthquake tends to produce strong, long-period motions even at large distances
 31 from the energy source. Long-period ground motions are important for assessments of linear
 32 structures, such as tunnels and levee deformations.

33 Because of the distances from the Delta and Suisun Marsh, only the very large (megathrust) events of
 34 the interface were considered in the seismic study (California Department of Water Resources 2007a).
 35 The Wong and Dober (2007) megathrust model was adopted, with a maximum moment magnitude of 9
 36 ± 0.5 and a recurrence interval of 450 ± 150 years. An alternative model was considered by USGS for
 37 the Cascadia interface (Peterson et al. 2008). The 2007 USGS model considers two weighted fault
 38 rupture scenarios.

- 39 ● Megathrust events (magnitude 9.0 ± 0.2) that rupture the entire interface zone every 500 years
 40 (weight of 0.67).
- 41 ● Smaller events (magnitude 8.0 to 8.7) that float over the interface zone and rupture the entire zone
 42 over a period of about 500 years (weight of 0.33).

1 **9.1.1.4 Geologic and Seismic Hazards**

2 The geologic and seismic hazards discussed in this section include surface fault rupture, earthquake
3 ground shaking, seismic-induced liquefaction and its related soil instability, and slope instability.

4 **9.1.1.4.1 Surface Fault Ruptures**

5 **Fault Trace and Rupture Zones**

6 The Alquist-Priolo (AP) Earthquake Fault Zoning Act, passed in 1972, required the establishment of
7 earthquake fault zones (known as *Special Studies Zones* prior to January 1, 1994) along known active
8 faults in California. The state guidelines for assessing fault rupture hazards are explained in CGS Special
9 Publication 42, which is discussed in detail under Section 9.2, *Regulatory Setting*. Strict regulations for
10 development in these fault zones are enforced to reduce the potential for damage resulting from fault
11 displacement.

12 Special Publication 42 shows that the only AP fault zones occurring in the Plan Area are those for the
13 Green Valley and Cordelia faults. The active Green Valley fault crosses the southwestern corner of the
14 Suisun Marsh Restoration Opportunity Area (ROA) and the active Cordelia fault extends approximately
15 1 mile into the northwestern corner of the Suisun Marsh ROA.

16 As discussed previously, the Delta is underlain by blind thrusts that are considered active or potentially
17 active, but they are not expected to rupture to the ground surface. Blind thrust fault ruptures generally
18 terminate before they reach the surface. They may produce ground manifestations (i.e., below ground
19 shear zone and/or ground surface bulging) during breaking, but in most cases, no clear surface
20 ruptures.

21 Those faults that could cause ground deformation at the surface but not surface rupture are discussed
22 in the following section.

23 **Fault Offsets**

24 An estimate of fault offset (displacement during a seismic event) is important for assessing possible
25 future effects. The amount of fault offset depends mainly on earthquake magnitude and location along
26 the fault trace. Fault offset can take place on a single fault plane, or displacements can be distributed
27 over a narrow zone. Fault rupture can also be caused by rupture on a neighboring fault (secondary fault
28 rupture).

29 Empirical relationships are typically used to estimate fault offsets. The relationships provide estimates
30 of fault displacements, such as average and maximum offsets, as a function of fault parameters. The
31 average and maximum fault offsets for the Concord and Pittsburgh–Kirby Hills faults (Table 9-9) were
32 estimated using the relationships of Wells and Coppersmith (1994).

1 **Table 9-9. Estimated Fault Rupture Offsets for Concord and Pittsburgh Hills Faults**

Fault	Maximum Earthquake (moment magnitude)	Average Offset ^a (inch)	Maximum Offset ^a (inch)	Faulting Style
Concord ^b	6.7	10.6–38.6	13.4–63	Strike-slip
Pittsburgh–Kirby Hills	6.7	10.6–38.6	13.4–63	Strike-slip

Source: Estimated using the relationships of Wells and Coppersmith (1994).

^a The range represents values ± 1 standard deviation.

^b The maximum magnitude of the Concord–Green Valley fault system was used.

2

3 Although the Midland fault is characterized as a blind thrust, there seems to be anomalous relief near
4 the base of the peat (or top of the sand layer) across the fault traces. The available data indicate a
5 modest 6.6–9.8 foot west-side-up step at the base of the peat across the surface trace of the Midland
6 fault (California Department of Water Resources 2007a).

7 Fault offset characteristics of the West Tracy fault are provided in Table 9-8. The West Tracy fault
8 appears to contain secondary east-dipping splays (branches) in the hanging wall (i.e., overhanging
9 block) of the fault, positioned west of the Clifton Court Forebay, some of which are beneath the intake
10 channel to the Banks Pumping Plant. The CGS and USGS show the West Tracy fault as not being active.
11 However, Fugro Consultants (2011) indicate that the fault may have experienced movement within the
12 past 35,000 years and therefore would be potentially active. If movement occurred along the fault,
13 uplift of the hanging wall of the fault could cause surface deformation in the western part of the Clifton
14 Court Forebay and the Byron Tract Forebay. Additionally, slippage of the fault splays could cause
15 surface rupture immediately west of the Clifton Court Forebay and the Byron Tract Forebay (Fugro
16 Consultants 2011).

17 **9.1.1.4.2 Earthquake Ground Shaking**

18 The potential of earthquake ground shaking in the Delta was evaluated in the seismic study using the
19 Probabilistic Seismic Hazard Analysis (PSHA) method (California Department of Water Resources
20 2007a). This method permits the explicit treatment of uncertainties in source geometry and
21 parameters, as well as ground motion estimation. In a PSHA, the probabilities of exceeding various
22 levels of ground motion at a site are calculated by considering seismic source locations and geometry,
23 rates of various earthquake magnitudes, and ground motion attenuation from the energy source to the
24 site. The uncertainties associated with source parameters and ground motion estimation are
25 incorporated in the analysis using a logic tree approach that uses multiple parameter values.

26 The standard PSHA assumes a Poissonian process for earthquake occurrences or a time-independent
27 earthquake recurrence model. In the seismic study, however, a time-dependent recurrence model was
28 used to calculate the earthquake potential (California Department of Water Resources 2007a). The
29 time-independent PSHA analysis was also performed for comparison purposes.

30 In a time-dependent model, the time of the last earthquake is used to estimate earthquake recurrence
31 interval or frequency (a non-Poissonian process). Because many of the San Francisco Bay region
32 seismic sources do not have sufficient information on the times of last earthquakes, only seven of the
33 major faults were characterized using the time-dependent model: the San Andreas, Hayward–Rodgers
34 Creek, Calaveras, Concord–Green Valley, San Gregorio, Greenville, and Mt. Diablo Thrust. Therefore, the
35 overall model used in the seismic study is not a pure time-dependent model.

1 Empirical earthquake ground motion attenuation relationship is used to estimate the horizontal Peak
2 Ground Acceleration (PGA) and the 5% damped spectral accelerations. The ground motion attenuation
3 relationship describes the attenuation of seismic waves with distance to the source as a function of
4 source parameters such as magnitude, rupture width, faulting style, and site condition. Multiple
5 relationships are commonly used to account for the uncertainty associated with ground motion
6 predictions. The PGA and spectral accelerations are engineering parameters representing the intensity
7 of seismic waves (ground motion) at various frequencies.

8 The seismic study used the Next Generation Attenuation (NGA) relationships developed for western
9 United States earthquakes for the crustal faults, blind thrusts, and seismic zones discussed previously
10 (California Department of Water Resources 2007a). At the time of the seismic study, only three of the
11 NGA relationship models were available, and these were used with equal weights (Chiou and Youngs
12 2006; Campbell and Bozorgnia 2007; Boore and Atkinson 2007). For the Cascadia subduction zone, the
13 seismic study used the relationships of Youngs et al. (1997) and Atkinson and Boore (2003).

14 The PSHA was conducted at six selected locations in the Delta area (Clifton Court, Delta Cross Channel,
15 Montezuma Slough, Sacramento, Sherman Island, and Stockton) for four different years: 2005, 2050,
16 2100, and 2200. The selected sites represent the north, south, east, west and central regions of the
17 Delta and the western-most section of the Plan Area. The results are expressed in terms of hazard
18 curves that relate the intensity of ground motion (PGA and response spectral accelerations) to annual
19 exceedance probability (probability that a specific value of ground motion intensity will be exceeded).
20 The distributions of hazard curve (the 5th, 15th, mean, median [50th], 85th, and 95th percentile hazard
21 curves) were calculated at the six selected locations for PGA and 1.0-second spectral acceleration. The
22 seismic hazard analysis was performed for a stiff soil site condition, with an average shear-wave
23 velocity of 1,000 feet per second (ft/sec) in the top 100 feet, or 30 meters (V_{s100ft}).

24 The results of PSHA indicate that ground shaking hazards in the Delta area are not sensitive to the
25 assumed recurrence model (whether a time-dependent or time-independent model is used). This is
26 true because the hazards are dominated by the nearby Delta seismic sources (time-independent
27 sources), and not by the time-dependent major seismic source in the region.

28 **Controlling Seismic Sources**

29 The seismic sources expected to dominate the ground motions at a specific location (known as
30 *controlling seismic sources*) vary depending on the location, ground motion probability level (or return
31 period), and ground motion frequency (or period). Table 9-10 summarizes the controlling seismic
32 sources at the six selected sites in 2005 for PGA and 1.0-second spectral acceleration at ground motion
33 return periods of 100 and 2,475 years.

1 **Table 9-10. Controlling Seismic Sources in 2005**

Location	PGA	1.0-second Spectral Acceleration
<i>100-Year Return Period</i>		
Clifton Court	Southern Midland Mt. Diablo	Mt. Diablo Hayward–Rodgers Creek
Delta Cross Channel	Southern Midland Northern Midland Zone	Mt. Diablo
Montezuma Slough	Concord–Green Valley	Concord–Green Valley
Sacramento	Northern Midland Zone	Mt. Diablo San Andreas
Sherman Island	Southern Midland	Southern Midland Hayward–Rodgers Creek San Andreas
Stockton	Southern Midland Hayward–Rodgers Creek Calaveras	Hayward–Rodgers Creek San Andreas
<i>2,475-Year Return Period</i>		
Clifton Court	Southern Midland	Southern Midland
Delta Cross Channel	Southern Midland Northern Midland Zone	Cascadia Subduction Zone Southern Midland
Montezuma Slough	Pittsburg–Kirby Hills	Pittsburg–Kirby Hills
Sacramento	Northern Midland Zone	Cascadia Subduction Zone
Sherman Island	Southern Midland Montezuma Hills Zone	Southern Midland
Stockton	Southern Midland	Cascadia Subduction Zone
Source: California Department of Water Resources 2007a. Note: PGA = Peak Ground Acceleration		

2

3 Additionally, the controlling seismic sources in 2200 are similar to those in 2005 except for the 1.0-
4 second spectral acceleration; the San Andreas fault becomes a major contributor to the site hazards
5 because of the high potential for a repeat of a 1906-type major earthquake event. The controlling
6 seismic sources in 2050 and 2100 are similar to the sources identified for 2005 and 2200.

7 **Site Soil Amplifications**

8 Thick deposits of peaty and soft soil tend to amplify earthquake ground motions, especially for the
9 long-period motions such as the 1.0-second spectral acceleration. The earthquake ground motions
10 developed for the Delta and Suisun Marsh as part of the seismic study are applicable for a stiff soil site
11 condition. Therefore, these motions are expected to change as they propagate upward through the
12 peaty and soft soil from the stiffer alluvium underlying the Delta and Suisun Marsh. Based on CALFED
13 Bay-Delta Program (2000), the acceleration amplification factor from the stiff base layer to the levee
14 crown is in the order of 1 to 2.

15 **72-Year Return Period Peak Ground Motion**

16 The calculated mean PGA and 1.0-second spectral acceleration values for a 72-year ground motion
17 return period (or an annual frequency of 0.01388) in 2005 and 2200 are presented in Table 9-11.

The calculated ground motions in 2050 and 2100 are between these values. The 72-year return period corresponds to approximately a 50% probability of exceedance in 50 years. The ground motions were calculated for a stiff soil condition with an average shear-wave velocity of 1,000 ft/sec in the top 100 feet.

Table 9-11. Calculated Mean Peak Ground Motions at Selected Sites for Various Return Periods (for Stiff Soil Site, $V_{s100ft} = 1,000$ ft/sec)

Location	Return Period									
	72 years		144 years		475 years		975 years		2,475 years	
	2005	2200	2005	2200	2005	2200	2005	2200	2005	2200
<i>Mean Peak Ground Acceleration in g</i>										
Clifton Court	0.18	0.21	0.24	0.27	0.39	0.41	0.49	0.51	0.66	0.67
Delta Cross Channel	0.13	0.14	0.16	0.18	0.24	0.25	0.29	0.29	0.36	0.36
Montezuma Slough	0.23	0.27	0.31	0.34	0.46	0.49	0.57	0.60	0.74	0.75
Sacramento	0.11	0.12	0.14	0.14	0.20	0.20	0.24	0.24	0.29	0.29
Sherman Island	0.20	0.23	0.27	0.29	0.41	0.43	0.49	0.52	0.64	0.66
Stockton	0.12	0.13	0.15	0.17	0.22	0.23	0.25	0.27	0.31	0.33
<i>Mean 1.0-second Spectral Acceleration in g (5% damping)</i>										
Clifton Court	0.20	0.24	0.28	0.32	0.46	0.50	0.60	0.63	0.83	0.85
Delta Cross Channel	0.15	0.17	0.20	0.23	0.30	0.33	0.37	0.40	0.48	0.50
Montezuma Slough	0.24	0.29	0.33	0.38	0.53	0.57	0.66	0.71	0.89	0.93
Sacramento	0.13	0.15	0.17	0.19	0.26	0.28	0.32	0.34	0.42	0.44
Sherman Island	0.22	0.26	0.29	0.34	0.46	0.50	0.59	0.62	0.78	0.80
Stockton	0.14	0.17	0.19	0.22	0.28	0.31	0.34	0.38	0.44	0.47

Source: California Department of Water Resources 2007a.

Note: g = acceleration due to gravity, 32.2 ft/sec²

144-Year Return Period Ground Motion

The calculated mean PGA and 1.0-second spectral acceleration values for a 144-year ground motion return period (or an annual frequency of 0.00694) in 2005 and 2200 are presented Table 9-11. The calculated ground motions in 2050 and 2100 are between these values (not shown in the table). The 144-year return period corresponds to approximately 30% probability of exceedance in 50 years.

475-Year Return Period Ground Motion

The calculated mean PGA and 1.0-second spectral acceleration values for a 475-year ground motion return period (or an annual frequency of 0.0021) in 2005 and 2200 are presented in Table 9-11. The calculated ground motions in 2050 and 2100 are between these values (not shown in the table). The 475-year return period corresponds to approximately 10% probability of exceedance in 50 years.

975-Year Return Period Ground Motion

The calculated mean PGA and 1.0-second spectral acceleration values for a 975-year ground motion return period (or an annual frequency of 0.00102) in 2005 and 2200 are presented in Table 9-11. The calculated ground motions in 2050 and 2100 are between these values (not shown in the table). The 975-year return period corresponds to approximately 5% probability of exceedance in 50 years.

2,475-Year Return Period Ground Motion

The calculated mean PGA and 1.0-second spectral acceleration values for a 2,475-year ground motion return period (or an annual frequency of 0.0004) in 2005 and 2200 are presented in Table 9-11. The calculated ground motions in 2050 and 2100 are between these values (not shown in the table). The 2,475-year return period corresponds to approximately 2% probability of exceedance in 50 years.

The data in Table 9-11 indicate that ground motion decreases from west to east as the distance to the San Andreas fault system increases. Also, the calculated ground motions are not sensitive (they only increase slightly) to the assumed time interval from the last major earthquake (from 2005 to 2200).

The 2008 USGS National Seismic Hazard Maps provide the values of PGA and 1.0-second spectral acceleration for the 475- and 2,475-year return periods. Table 9-12 compares the ranges of PGA and 1.0-second spectral acceleration calculated in the seismic study (California Department of Water Resources 2007a) to those estimated from the USGS maps (U.S. Geological Survey 2009).

Table 9-12. Comparison of Ground Motions Calculated in the Seismic Study to Estimated 2008 USGS Mapped Values

Ground Motion Return Period	Range of Mean Peak Ground Acceleration in g		Range of Mean 1.0-second Spectral Acceleration in g (5% damping)	
	DWR (2007a) ^a	USGS 2008 Maps ^b	DWR (2007a) ^a	USGS 2008 Maps ^b
475 years	0.20–0.46	0.20–0.40	0.26–0.53	0.14–0.30
2,475 years	0.29–0.74	0.30–0.70	0.42–0.89	0.25–0.50

Source: California Department of Water Resources 2007a; U.S. Geological Survey 2009.

DWR = California Department of Water Resources

g = acceleration due to gravity, 32.2 ft./sec²

USGS = U.S. Geological Survey

^a Ranges of calculated ground motion at the six selected sites in the Delta ($V_{s100ft} = 1,000$ ft/sec)

^b Approximate ranges of ground motion over the Delta ($V_{s100ft} = 2,500$ ft/sec)

The 2008 USGS maps were developed for a reference site condition with an average shear-wave velocity of 2,500 ft/sec (about 760 meters per second) in the top 100 feet (Petersen et al. 2008). Consequently, the mapped values cannot be directly compared to those calculated in the seismic study, which assumed a site condition with an average shear-wave velocity of 1,000 ft/sec (California Department of Water Resources 2007a).

9.1.1.4.3 Liquefaction

Liquefaction is a process whereby strong ground shaking causes loose and saturated soil sediment to lose strength and to behave as a viscous fluid. This process can cause excessive ground deformations, failures, and temporary loss of soil bearing capacity, resulting in damage to structures and levees. Ground failures can take the forms of lateral spreading, excessive differential and/or total compaction or settlement, and slope failure. Liquefaction can also increase the potential for buoyancy to buried structures (causing them to float to the ground surface) and cause an increase in lateral earth pressure. The Delta and Suisun Marsh are underlain at shallow depths by various channel deposits and recent silty and sandy alluvium. Some of the existing levee materials also consist of loose, silty, and sandy soil.

1 Where saturated, these soil of the levee embankment and the soil of their foundations locally may be
2 susceptible to liquefaction during earthquakes.

3 Soil liquefaction is also a function of ground motion intensity and shaking duration. Longer ground
4 shaking, even at a lower intensity, may cause liquefaction as the soil is subject to more repeated cycles
5 of loading. Longer duration shaking is typically associated with larger magnitude earthquakes, such as
6 earthquakes that occur on the San Andreas, Hayward, and Calaveras faults.

7 **Historical Occurrences of Liquefaction**

8 Ground manifestation associated with liquefaction during the 1906 San Francisco earthquake was
9 reported in three locations within and in the vicinity of the Plan Area. Youd and Hoose (1978) reported
10 settlements up to 11 feet, south of Fairfield along the Southern Pacific Railway through the Suisun
11 Marsh; ground settlement of several inches was reported at the Southern Pacific Bridge Crossing over
12 the San Joaquin River in Stockton; and settlement of 3 feet was reported at a bridge crossing over
13 Middle River approximately 10 miles west of Stockton (Youd and Hoose 1978). No ground
14 manifestations were reported in the Delta and Suisun Marsh during the more recent 1989 Loma Prieta
15 earthquake (Knudsen et al. 2000).

16 **Conditions Susceptible to Liquefaction**

17 Along the Delta and Suisun Marsh levees, loose silty and sandy soil are present in the levee
18 embankments and in the underlying foundation soil. When saturated, such soil is susceptible to
19 liquefaction during earthquake events. Since the levees are constructed (not naturally occurring), the
20 loose, silty and sandy soil comprising the levees are likely to be more continuous than those present in
21 the foundation of the levee (CALFED Bay-Delta Program 2000). Areas with larger lateral continuity of
22 liquefied soil are expected to experience more ground failure. The available data also indicate that the
23 levees protecting Sherman Island have extensive layers of liquefiable sandy soil, more so than other
24 levees in the Delta and Suisun Marsh (CALFED Bay-Delta Program 2000). See Chapter 6, *Surface Water*,
25 for more information.

26 **Liquefaction Hazard Mapping**

27 No official Seismic Hazard Zone maps for liquefaction potential have been developed by CGS or the
28 USGS for the Delta. Also, maps of liquefaction hazard (i.e., the susceptibility of the geologic or soil
29 materials and ground water levels to liquefaction combined with shaking levels anticipated for a given
30 earthquake scenario) have not been prepared for the entire Delta area. However, a preliminary analysis
31 of the risk of levee failure caused by liquefaction-induced seismic shaking was prepared for the CALFED
32 Levee System Integrity Program (Torres et al. 2000). Torres et al. (2000) estimated the magnitude and
33 recurrence intervals of peak ground accelerations throughout the Delta. Then, based on local
34 knowledge and limited geotechnical information, they identified and mapped Damage Potential Zones
35 (Figure 9-6). The Damage Potential Zones specifically are based on the “fragility” of existing levees as
36 affected by seismically induced liquefaction considering levee characteristics, levee foundation soil
37 characteristics, and seismic shaking factors. Consequently, the map should not be construed as a
38 liquefaction hazard map. The map shows that the highest potential levee damage could occur in the
39 central Delta and Sherman Island.

40 Liquefaction hazard maps prepared by the Association of Bay Area Governments have been prepared
41 for the greater San Francisco Bay Area, including the Suisun Marsh and the western and northwestern
42 parts of the Delta. Figure 9-6 shows that the liquefaction hazard in the Suisun Marsh ROA is mostly

1 medium to high, the southern half of the west conveyance option is mostly medium to low, and part of
 2 the Cache Slough ROA is medium to low (Association of Bay Area Governments 2011). Areas not
 3 assigned a hazard/damage potential class on Figure 9-6 either were not evaluated or are assumed to
 4 have less than low hazard/damage potential.

5 **9.1.1.4.4 Areas Susceptible to Slope Instability**

6 A landslide is a mass of rock, soil, and/or debris that has been displaced downslope by sliding, flowing,
 7 or falling. Landslides include cohesive block glides and disrupted slumps that have formed by the
 8 translation or rotation of slope materials along one or more planar or curve-planar surfaces. Soil creep
 9 is the slow, imperceptible downslope movement of weak soil and soft rock under the force of gravity.

10 Landslides occur when shear stresses within a soil or rock mass exceed the available shear strength of
 11 the mass. Failure may occur when stresses that act on a slope increase, internal strength of a slope
 12 decreases, or a combination of both. Increased stresses can be caused by an increase in weight of the
 13 overlying slope materials (by saturation), addition of material (surcharge) to the slope, application of
 14 external loads (foundation loads, for example), or seismic loading (application of an earthquake-
 15 generated agitation to a structure).

16 Slope soil shear strength (the internal resistance of a soil to shear stress) can be reduced through
 17 erosion and/or undercutting or removal of supporting materials at the slope toe as a result of scouring
 18 (concentrated erosion by streamflow), increased pore water pressure within the slope, and weathering
 19 or decomposition of supporting soil. Zones of low shear strength within the slope are generally
 20 associated with the presence of certain clay, bedding, or fracture surfaces. The various factors and
 21 processes that contribute to an unstable slope or levee in the Delta and Suisun Marsh are explained in
 22 Chapter 6, *Surface Water*.

23 Strong earthquake ground shaking often causes landslides, particularly in areas already susceptible to
 24 landslides because of other non-seismic factors, including the presence of existing landslide deposits
 25 and water-saturated slope materials. Failure of steep slopes, collapse of natural streambanks, and
 26 reactivation of existing landslides may occur extensively during a major earthquake.

27 **Historical Occurrences of Landslides and Levee Failure**

28 Since 1900, at least 158 levee failures or breaches have been reported that resulted in flooding the
 29 Delta and Suisun Marsh islands and tracts. (California Department of Water Resources 2010f)
 30 Earthquake ground shaking is not linked to any of these levee breaches. The dominant causes of the
 31 levee breaches are believed to have been water overtopping levees during high tides, erosion, piping
 32 and seepage through the levee embankment and foundation soil, and burrowing animals. (California
 33 Department of Water Resources 2007b)

34 Because the topography of the Delta and Suisun Marsh is nearly level, the potential of landslides at
 35 locations outside the levees is considered low. No maps or records on the historical occurrences of
 36 slope failure are readily available for areas outside the levees.

37 **Areas Susceptible to Landslides and Debris Flows**

38 The known areas susceptible to slope failure within the Delta and Suisun Marsh primarily are along the
 39 levee system and channel banks. Maps of those levees and channel banks that are particularly subject
 40 to mass failure have not been prepared.

1 Because of their steep slopes, the Potrero Hills, the area west of Interstate I-680, and the western
 2 slopes of the Montezuma Hills within the Suisun Marsh ROA likely have a greater relative potential for
 3 landslides and debris flows (a shallow, moving mass of rock fragments, soil, and mud) than the
 4 remainder of the Plan Area, although it is not known if any significant landslides or debris flows have
 5 occurred in these areas.

6 A map in the Solano County General Plan, Public Health and Safety Element (Solano County 2008)
 7 shows landslide susceptibility for the western part of the county. The landslide susceptibility ranges
 8 from “least susceptible” to “most susceptible” in the part of the Plan Area west of I-680. The area east of
 9 I-680 in the northwestern part of the Suisun Marsh is rated as “least susceptible”. The other parts of the
 10 county, including the Montezuma Hills and Potrero Hills, appear not to have been evaluated for
 11 landslide susceptibility.

12 Existing landslides (but not landslide susceptibility/hazard) have been mapped for all of Alameda
 13 County (Roberts et al. 1999). Within and adjoining the Plan Area, the map shows one relatively small
 14 landslide located east of the Delta Mendota Canal and southwest of Mountain House Creek.

15 In San Joaquin County, the sloping areas in the vicinity of the Plan Area exist southwest of the Plan
 16 Area. The San Joaquin County General Plan (San Joaquin County 1992) shows no areas that are subject
 17 to landslides within the Plan Area.

18 **Landslide Hazard Maps Prepared by California Geological Survey**

19 No official Seismic Hazard Zone maps for earthquake-induced landslide potential have been developed
 20 by CGS for the Delta and Suisun Marsh. The closest available maps are those for the Las Trampas Ridge
 21 USGS 7.5' quadrangle, southwest of the Delta and Suisun Marsh, and the Livermore and Altamont USGS
 22 7.5' quadrangles, south of the Delta and Suisun Marsh. The coverage areas of these maps are outside of
 23 the Plan Area.

24 **9.1.1.4.5 Ground Failure and Seismic-Induced Soil Instability**

25 **Compaction and Settlement**

26 Earthquake ground motions can cause compaction and settlement of soil deposits because of
 27 rearrangement of soil particles during shaking. The amount of settlement depends on ground motion
 28 intensity and duration and degree of soil compaction; looser soil subjected to higher ground shaking
 29 will settle more. Empirical relationships are commonly used to provide estimates of seismic-induced
 30 settlement. In these relationships, ground shaking can be represented by PGA and magnitude, and soil
 31 compaction is typically measured by Standard Penetration Test (SPT) (i.e., an *in-situ* dynamic
 32 penetration test that measures the density of granular soil) blow-counts or N-values. Excessive total
 33 and differential settlements can cause damage to buried structures, including utilities, which in turn
 34 may initiate larger failure to levees and other above-ground facilities.

35 **Loss of Bearing Capacity**

36 Liquefaction can also result in temporary loss of bearing capacity in foundation soil, which has the
 37 potential to cause foundation, pipeline, and tunnel failures during and immediately after an earthquake
 38 event.

1 **Lateral Spreading**

2 Soil lateral spreading, or horizontal movement, can be initiated during an earthquake event.
 3 Liquefaction-induced lateral spreading could occur even on gently sloping grounds or flat ground with
 4 a nearby free face (e.g., a steep stream bank or other slope) when the underlying soil liquefies. The
 5 amount of horizontal movement depends on ground motion intensity, the ground's slope, soil
 6 properties, and conditions of lateral constraint (free-face or non-free-face condition).

7 **Increased Lateral Pressures**

8 Liquefaction can increase lateral earth pressures on walls and buried structures. As soil liquefies, earth
 9 lateral pressure will approach that of a fluid-like material.

10 **Buoyancy**

11 Liquefaction can cause buried pipes and structures to become buoyant. The potential for buoyancy
 12 caused by liquefaction is typically determined using site-specific data at the planned locations of buried
 13 pipes and structures.

14 **9.1.1.4.6 Tsunami and Seiche**

15 No known maps of tsunami hazard are available for the Delta or Suisun Marsh areas. Tsunami hazard
 16 mapping closest to the Plan Area appears to be the tsunami inundation maps prepared by the California
 17 Department of Conservation (2009) that extend east to about the Benicia Bridge. That mapping shows
 18 at tsunami inundation area on the shores of the Sacramento River, extending east of the Benicia Bridge
 19 to the edge of the base map (i.e., the Benicia 7.5' quadrangle). The hazard maps show the "maximum
 20 considered tsunami runup from a number of extreme, yet realistic tsunami sources". On the Benicia
 21 quadrangle, the inundation areas extend over mud flats and tidal marshes, which are presumed to have
 22 an elevation at or within approximately 3 feet above sea level. Because the inundation zone is close to
 23 sea level, it appears that substantial tsunami effects extending into the Suisun Marsh and Delta are
 24 mostly attenuated in the San Francisco Bay. Tsunami effects to the east of the Benicia Bridge are
 25 presumed to be further attenuated in the Suisun and Grizzly bays.

26 Historic records of the Bay Area indicate that 19 tsunamis were recorded in San Francisco Bay during
 27 the period of 1868 to 1968. The maximum wave height recorded at the Golden Gate tide gage was 7.4
 28 feet (Contra Costa County 2009).

29 Based on a tsunami wave runup of 20 feet at the Golden Gate, the 2009 (Contra Costa) Countywide
 30 Comprehensive Transportation Plan indicates that tsunami attenuation in the San Francisco Bay would
 31 diminish the height of the wave to approximately 10 feet along the Richmond shoreline. East of Point
 32 Pinole, the wave height would diminish to approximately one-tenth of that (i.e., 2 feet) at the Golden
 33 Gate (Contra Costa Transportation Agency 2009).

34 Based on the above information and on professional judgment, the effects of a tsunami in the Suisun
 35 Marsh and Delta are expected to be minimal.

36 A seismically induced seiche is a rhythmic standing wave in a partly or fully enclosed body of water
 37 caused by seismic waves generated by a landslide, earthquake-induced ground acceleration, or ground
 38 offset. Elongate and deep (relative to width) bodies of water seem most likely to be subject to seiches,
 39 and earthquake wave orientation may also play a role in seiche formation. The "sloshing" waves
 40 generated can reach tens of feet high and have devastating effects on people and property. Seiches can
 41 temporarily flood a shoreline in a manner similar to tsunami; however, their destructive capacity is not

1 as great. Seiches may cause overtopping of impoundments such as dams, particularly when the
 2 impoundment is in a near-filled condition, releasing flow downstream. Earthquakes occurring miles
 3 away can produce seiches in local bodies of water which could overtop and damage levees and dams
 4 and cause water to inundate surroundings (Contra Costa County 2009). In 1868, an earthquake along
 5 the Hayward fault in the San Francisco Bay Area generated a seiche along the Sacramento River
 6 (County of Sacramento 1993).

7 Based on professional judgment, with the exception of the Clifton Court Forebay and the Byron Tract
 8 Forebay, the hazard of a seiche occurring in the Plan Area is expected to be low because of the lack of
 9 existing and proposed (e.g., intermediate forebay) deep, narrow, and enclosed water bodies and
 10 distance from seismic sources capable of generating strong ground motions.

11 Fugro Consultants, Inc. (2011) identified the potential for strong ground motions along the West Tracy
 12 fault to cause a seiche of an unspecified wave height to occur in the Clifton Court Forebay, assuming
 13 that this fault is potentially active. Since the fault also extends under the Byron Tract Forebay, a seiche
 14 could also potentially occur in the Byron Tract Forebay.

15 **9.2 Regulatory Setting**

16 **9.2.1 Federal Plans, Policies, and Regulations**

17 **9.2.1.1 U.S. Geological Survey Quaternary Faults**

18 USGS maintains the database of Quaternary fault and fold parameters (U.S. Geological Survey 2009).
 19 The database is periodically updated to reflect the latest data available and current understanding of
 20 fault behaviors. These parameters were used to develop the National Seismic Hazard Maps.

21 **9.2.1.2 U.S. Geological Survey National Seismic Hazard Maps**

22 USGS provides probabilistic seismic hazard maps for the 48 conterminous states, including the
 23 Delta and Suisun Marsh area (U.S. Geological Survey 2009). These maps depict contour plots of PGA
 24 and spectral accelerations at selected frequencies for various ground motion return periods. The USGS
 25 National Seismic Hazard Maps are updated periodically and have been adopted by many building and
 26 highway codes as the minimum design requirements.

27 **9.2.1.3 U.S. Geological Survey Landslide Hazard Program**

28 USGS provides information regarding the causes of ground failure and mitigation strategies to reduce
 29 long-term losses from landslide hazards. The information is useful for understanding the nature and
 30 scope of ground failures and improving the mitigation strategies.

31 **9.2.1.4 U.S. Army Corps of Engineers EC 1165-2-211**

32 In July 2009, the Corps issued EC 1165-2-211, a water resource policy mandating that every Corps
 33 coastal activity influenced by tidal waters include potential relative sea-level change in the starting
 34 water surface elevation, where appropriate. To conform, projects must determine how sensitive plans
 35 and designs are to rates of future local mean sea-level change, how this sensitivity affects calculated

1 risk, and what design or operations and maintenance measures should be implemented to minimize
2 adverse consequences while maximizing beneficial effects.

3 The Project is not a Corps activity subject to EC 1165-2-211; however, the Project will include
4 maintenance operations that will require placement of levee materials as necessary to maintain
5 freeboard in response to actual sea-level rise rates.

6 **9.2.2 State Plans, Policies, and Regulations**

7 **9.2.2.1 Delta Plan**

8 The Delta Reform Act requires that the Delta Plan promote effective emergency response and
9 emergency preparedness and promote appropriate land use to attempt to reduce risks to people,
10 property, and State interest in the Delta (Water Code section 85305). The Delta Reform Act requires the
11 Delta Plan to recommend priorities for State investments in Delta levees. In response, the Delta Plan
12 has adopted policy RR P1, *Prioritization of Statement Investments in Delta Levees and Risk Reduction*.

13 The hope is that implementation of Policy RR P1 will provide adequate protection to freshwater
14 aqueducts passing through the Delta and the primary freshwater channel pathways through the Delta
15 against floods and other risks of failures as well as prevent water deliveries to East Bay Municipal
16 Utilities District, Contract Costa Water District, the CVP and the SWP from being interrupted by floods
17 or earthquakes.

18 **9.2.2.2 California Division of Safety of Dams**

19 The DSOD has oversight and approval authority for structures that are considered dams under the
20 Water Code. Some levees are “dams” as defined by California Water Code section 6002, and as such, are
21 required to meet DSOD’s standards and design review requirements. Dams under DSOD jurisdiction are
22 artificial barriers that are at least 25 feet high or have an impounding capacity of at least 50 acre feet.
23 Water Code section 6004(c) specifically excludes structures in the Sacramento-San Joaquin Delta “...if
24 the maximum possible water storage elevation of the impounded water does not exceed four feet above
25 mean sea level, as established by the United States Geological Survey 1929 Datum.”

26 Certain elements of various BDCP Alternatives could be subject to DSOD jurisdiction depending on the
27 size and volume of water stored (i.e., the intermediate forebay, the Byron Tract Forebay, repairs or
28 alterations to certain levees that might fall within DSOD jurisdiction).

29 **9.2.2.3 Liquefaction and Landslide Hazard Maps 30 (Seismic Hazards Mapping Act)**

31 The Seismic Hazards Mapping Act of 1990 (California Public Resources Code Sections 2690 to 2699.6)
32 was passed following the Loma Prieta earthquake to reduce threats to public health and safety by
33 identifying and mapping known seismic hazard zones in California. The act directs the CGS of the
34 Department of Conservation to identify and map areas prone to earthquake hazards of liquefaction,
35 earthquake-induced landslides, and amplified ground shaking. The purpose of the maps is to assist
36 cities and counties in fulfilling their responsibilities for protecting public health and safety. The Act
37 requires site-specific geotechnical investigations be conducted identifying the seismic hazard and
38 formulating mitigation measures prior to permitting most developments designed for human
39 occupancy within areas prone to liquefaction and earthquake-induced landslides (also known as a Zone

1 of Required Investigation). Cities and counties are required to incorporate the Seismic Hazard Zone
 2 Maps into their Safety Elements and the Act requires sellers of real property to disclose to buyers if
 3 property is in a seismic hazard Zone of Required Investigation.

4 As of January 2012, 119 official seismic hazard zone maps showing areas prone to liquefaction and
 5 earthquake-induced landslides had been published in California, and more are scheduled. Most of the
 6 mapping has been performed in southern California and the San Francisco Bay Area. Twenty-nine
 7 official maps for the San Francisco Bay Area have been released, with preparation of 10 additional
 8 maps for San Mateo, Santa Clara, Alameda, and Contra Costa Counties planned or in progress. None of
 9 these planned or in-progress maps will cover the Plan Area. Accordingly, the Seismic Hazards Mapping
 10 Act requirements will not affect the project unless and until the area is mapped.

11 Review by the local agency is required for proposed construction sites located in the mapped seismic
 12 hazard zones. Site-specific geologic investigations and evaluations are carried out to identify the extent
 13 of hazards, and appropriate mitigation measures are incorporated in the development plans to reduce
 14 potential damage.

15 **9.2.2.4 Alquist-Priolo Earthquake Fault Zones**

16 The AP Earthquake Fault Zoning Act was passed in 1972 (California Public Resources Code
 17 Section 2621 et seq.). Similar to the Seismic Hazards Mapping Act, its main purposes are to identify
 18 known active faults in California and to prevent the construction of buildings used for human
 19 occupancy on the surface trace of active faults. For the purpose of this act, a fault is considered active if
 20 it displays evidence of surface displacement during Holocene time (approximately during the last
 21 11,000 years).

22 The act directs CGS to establish the regulatory zones, called AP Earthquake Fault Zones, around the
 23 known surface traces of active faults and to publish maps showing these zones. Each fault zone extends
 24 approximately 200 to 500 feet on each side of the mapped fault trace to account for potential branches
 25 of active faults.

26 CGS Special Publication 42 (Bryant and Hart 2007) states that in the absence of a site-specific faulting
 27 study, the areas within 50 feet of the mapped fault should be considered to have the potential for
 28 surface faulting and, therefore, no structure for human occupancy should be in these areas.
 29 Construction of buildings intended for human occupancy within the fault zone boundaries is strictly
 30 regulated, and site-specific faulting investigations are required.

31 Title 14 of the California Code of Regulations, Section 3601(e), defines buildings intended for human
 32 occupancy as those that would be inhabited for more than 2,000 hours per year. If none of the facilities
 33 included within the proposed project design meet this definition, this act would not apply.

34 **9.2.2.5 Assembly Bill 1200 (Chapter 573, Statutes of 2005)**

35 Assembly Bill 1200 directed DWR and the California Department of Fish and Wildlife to prepare a
 36 report on evaluating the potential effects on water supplies derived from the Delta from a variety of
 37 stressors, including continuous land subsidence, earthquakes, floods, and climate change. The bill also
 38 requires the studies of possible improvements and options (ranking of possible options) for the water-
 39 related issues in the next 50, 100, and 200 years when determining effects on the Delta.

40 In response to the bill, DWR and the California Department of Fish and Wildlife have issued a report,
 41 Risks and Options to Reduce Risks to Fishery and Water Supply Uses of the Sacramento/San Joaquin

1 Delta, dated January 2008. This report summarizes the potential risks to water supplies in the
 2 Sacramento and San Joaquin Delta attributable to future subsidence, earthquakes, floods and climate
 3 change, and identifies improvements to reduce the effects and options to deliver water.

4 **9.2.2.6 Regulatory Design Codes and Standards for Project Structures**

5 State and federal design codes and standards will regulate construction of the many structures that are
 6 part of the BDCP. These codes and standards establish minimum design and construction
 7 requirements, including design and construction of concrete and steel structures, levees, tunnels,
 8 pipelines, canals, buildings, bridges and pumping stations. They also establish construction
 9 requirements for temporary activities such as shoring of excavations and site grading. The codes and
 10 standards are intended to ensure structural integrity and to protect public health and safety. The codes
 11 and standards are developed by federal and state agencies with the participation of engineering boards
 12 or associations, and professional engineering societies. They are based on the performance history of
 13 structures under real conditions, including surface and subsurface geologic conditions and variable
 14 regional conditions such as flooding and seismic events. The following state and federal codes and
 15 standards will dictate the minimum design and construction requirements for the various elements of
 16 the BDCP water conveyance facilities and the structural aspects of other conservation measures. The
 17 minimum design and construction requirements act as performance standards for engineers and
 18 construction contractors. Because the design and construction parameters of these codes and
 19 standards are intended to reduce the potential for structural damage or risks to human health due to
 20 the geologic and seismic conditions that exist within the Plan Area and the surrounding region, their
 21 use is considered an environmental commitment of the agencies implementing the BDCP. This
 22 commitment is discussed further in Appendix 3B, *Environmental Commitments*.

- 23 ● American Association of State Highway and Transportation Officials (AASHTO) Guide Specifications
 24 for LRFD [load and resistance factor] Seismic Bridge Design, 1st Edition, 2009.
 - 25 ○ Geotechnical seismic design guidelines are consistent with the philosophy for structure design
 26 that loss of life and serious injury due to structure collapse are minimized, to the extent
 27 possible and economically feasible.
 - 28 ○ These guide specifications adopt:
 - 29 ● 7 percent probability of exceedance in 75 years (i.e., the same as 5 percent probability of
 30 exceedance in 50 years and an approximately 1,000 year recurrence interval) for
 31 development of a design spectrum.
 - 32 ● the NEHRP Site Classification system and include site factors in determining response
 33 spectrum ordinates
 - 34 ● a 1.5 safety factor (how much extra load beyond what is intended a structure will actually
 35 take or be required to withstand) for minimum support length requirement to ensure
 36 sufficient conservatism.
- 37 ● American Railway Engineering and Maintenance-of-Way Association Manual for Railway
 38 Engineering, Volume 2, Chapter 9, *Seismic Design for Railway Structures*, 2008.
 - 39 ○ Provides recommended practices and guidelines for railway design in seismically active areas
 40 as well as recommended practices for post-earthquake response, including inspections.
 - 41 ○ Three performance limit states are given for seismic design of railroad bridges.

- 1 • The serviceability limit state requires that the structure remain elastic during Level 1
2 ground motion (motion that has a reasonable probability of being exceeded during the life
3 of the bridge). Only moderate damage and no permanent deformations are acceptable.
- 4 • The ultimate limit state requires that the structure suffer only readily detectable and
5 repairable damage during Level 2 ground motion (motion that has a low probability of
6 being exceeded during the life of the bridge).
- 7 • The survivability limit state requires that the bridge not collapse during Level 3 ground
8 motion (motion for a rare, intense earthquake). Extensive damage may be allowed. For
9 some structures, the railroad may elect to allow for irreparable damage, and plan to replace
10 the bridges following a Level 3 event.
- 11 ○ No seismic analysis is necessary for locations where a base acceleration of 0.1 g or less is
12 expected with a 475-year return period. However, it is good practice to detail structures for
13 seismic resistance if they are in potentially active areas.
- 14 ○ Structures classified as “important” (discussed in Section 1.3.3) should be designed to resist
15 higher seismic loads than nonimportant structures.
- 16 • American Society of Civil Engineers Minimum Design Loads for Buildings and Other Structures,
17 ASCE-7-05, 2005.
- 18 ○ Provides requirements for general structural design and includes means for determining dead,
19 live, soil, flood, wind, snow, rain, atmospheric ice, and earthquake loads, and their
20 combinations that are suitable for inclusion in building codes and other documents.
- 21 ○ The intent of the seismic provisions in ASCE 7-05 is to provide a low probability of collapse for
22 buildings experiencing the Maximum Considered Earthquake (MCE) shaking. MCE shaking is
23 defined either as that shaking having a 2% probability of exceedance in 50 years (2,475 year
24 mean recurrence interval) or at sites near major active fault, 150% of the median shaking
25 resulting from a characteristic magnitude earthquake on that fault, whichever is less.
- 26 ○ Nonstructural components (including architectural, mechanical, electrical, and plumbing
27 equipment) and their supports and attachments that are permanently attached to a structure
28 must be designed and constructed to resist the effects of the earthquakes motions in
29 accordance with the code.
- 30 ○ Provides Seismic Hazards Maps developed by USGS. Section 13.2.1 requires that mechanical
31 and electrical equipment manufacturers provide certification that components are seismically
32 qualified. Section 13.3.1 determines the magnitudes of horizontal and vertical seismic forces.
33 Use $I_p = 1.5$ for mechanical equipment and 1.75 for electrical equipment in Occupancy Category
34 IV for critical facilities as discussed in Section 4.3.5
- 35 • California Building Standards Code, 2010 (Title 24 California Code of Regulations).
- 36 ○ Provides seismic design requirements in the design and construction of buildings, associated
37 facilities and equipment. This code applies to all building occupancies, and related features and
38 equipment throughout the state, and contains requirements to the structural, mechanical,
39 electrical, and plumbing systems, and requires measures for energy conservation, green design,
40 construction and maintenance, fire and life safety, and accessibility.
- 41 • Caltrans (California Department of Transportation) Seismic Design Criteria (SDC), Version 1.6, Nov
42 2010.

- 1 ○ The SDC is a compilation of new and existing seismic design criteria for Ordinary bridges (a
2 bridge that spans less than 300 feet and is built on soil that is not susceptible to liquefaction,
3 lateral spreading, or scour. The document is an update of all the Structure Design (SD) design
4 manuals on a period basis to reflect the current state of practice for seismic bridge design.
- 5 ● These specifications are meant to guarantee that an Ordinary bridge will remain standing
6 but may suffer significant damage requiring closure when ground shaking (defined as
7 ground motion time histories or response spectrum), liquefaction, lateral spreading,
8 surface fault rupture, and tsunami occur.
- 9 ● The criteria contained within the SDC are the minimum requirements for seismic design.
- 10 ● California Code of Regulations, Title 8.
- 11 ○ Section 3203 (Cal/OSHA Workplace Injury and Illness Prevention Program) states that a
12 workplace or construction sites must devise and implement an Injury and Illness Prevention
13 Program (IIPP) for all employees within the organization. The 8 required IIPP elements are:
- 14 ● Responsibility (e.g., supervisors are responsible for all accidents on their job or under their
15 supervision, supervisors are responsible for the inspection of work areas, equipment and
16 other potential accident producing conditions daily, employees are responsible for
17 ensuring that machine guards are used and maintained in good condition and reporting to
18 the supervisor if a guard is in questionable condition, etc.)
- 19 ● Compliance (e.g., supervisors must take disciplinary action when necessary to enforce
20 safety rules and practices, etc.)
- 21 ● Communication (e.g., company policy to maintain open communication between
22 management and employees on matters pertaining to safety, company will provide current
23 safety news and activities, safety reading materials, signs, posters, and/or a bulletin board
24 and will hold regular safety meetings)
- 25 ● Hazard Assessment (e.g., Managers, supervisors, and employees will report any hazardous
26 conditions or activities noted as a result of a formal weekly and/or monthly inspections or
27 during daily routine operations to the appropriate job site foreman or superintendent.)
- 28 ● Accident/Exposure Investigation (e.g., each supervisor/foreman has a prominent role in
29 promptly conducting an accident investigation and must collect the facts, determine the
30 sequence of events that resulted in the accident, identify action to prevent recurrence, and
31 provide follow-up to ensure that corrective action was effective)
- 32 ● Hazard Correction (e.g., all hazards will be corrected as soon as identified and a record of
33 hazard abatement will be kept in the main office to track the steps taken to correct the
34 hazardous condition)
- 35 ● Training and Instruction (e.g., all new employees must undergo an initial orientation on job
36 site safety rules and code of safe work practices. All employees must participate in
37 scheduled safety meetings which are conducted weekly by the site foreman on all job sites
38 and additional training as job duties or work assignments are expanded or changed)
- 39 ● Recordkeeping (e.g., hazard reports, employee-training records, etc. will be kept at the
40 main office)
- 41 ○ Section 1509 requires that every employer shall adopt a written Code of Safe Practices (8 CCR
42 1938, Appendix A) which related to the employer's operations. Also, supervisory employees

- 1 must conduct Toolbox or Tailgate safety meetings, or equivalent, with their crews at least every
2 10 working days to emphasize safety.
- 3 • DWR (California Department of Water Resources) Division of Safety of Dams (DSOD) *Guidelines for*
4 *Use of the Consequence-Hazard Matrix and Selection of Ground Motion Parameters*, 2002.
- 5 ○ The loading criteria for jurisdictional dam facilities are determined using the DSOD criteria as
6 follows:
- 7 • The statistical level of ground motion for design (50th- or 84th-percentile) is determined
8 from the DSOD Hazard Matrix (Table 2-2) based upon the consequence of failure (Total
9 Class Weight obtained from DSOD) and the slip rate of the causative fault (obtained from a
10 Seismic Hazard Assessment).
- 11 • The Minimum Earthquake PGA parameter of 0.15g to 0.25g now applies to all new and
12 existing jurisdictional dams undergoing re-evaluation in California (new and existing dams
13 undergoing re-evaluation must resist a horizontal force of 0.15g to 0.25g).
- 14 • DWR Division of Flood Management FloodSAFE Urban Levee Design Criteria, May 2012.
- 15 ○ Provides engineering criteria and guidance for the design, evaluation, operation, and
16 maintenance of levees and floodwalls that provide an urban level of flood protection (i.e., 200-
17 year level of flood protection) in California, as well as for determining design water surface
18 elevations (DWSE) along leveed and unleveed streams. Flood Safety Plan is required for all
19 agencies working at or near levee
- 20 ○ Requires analysis of seismic vulnerability of the levee system for 200-year return period
21 ground motions to meet the urban level of flood protection.
- 22 ○ Frequently loaded levees (and floodwalls), such as many levees in the Sacramento-San Joaquin
23 Delta, are required to have seismic stability sufficient to maintain the integrity of the levee and
24 its internal structures without significant deformation. In most cases, for frequently loaded
25 levees with less than 5 feet of freeboard, earthquake-induced deformations should be limited to
26 less than 3 feet of total deformation and about 1 foot of vertical displacement.
- 27 ○ For intermittently loaded levees (and floodwalls), if seismic damage from 200-year-return-
28 period ground motions is expected after the urban level of flood protection is achieved, a post-
29 earthquake remediation plan is required as part of a flood safety plan that is developed in
30 coordination with pertinent local, State, and federal agencies.
- 31 • DWR Division of Engineering State Water Project—Seismic Loading Criteria Report, Sept 2012.
- 32 ○ Provides DWR design guidelines in selecting appropriate seismic loading criteria for a wide
33 variety of SWP facilities including dams, canals, pipelines, tunnels, check structures, bridges,
34 buildings, pumping and power plants, and utility overcrossings. The seismic design load shall
35 be selected based on the criticality of a facility and consequences of failure. Most critical
36 facilities are expected to be functional immediately after an earthquake and thereby should
37 experience very limited damage. Other facilities may be considered less critical such that they
38 are designed to incur some damage but still return to some level of function in a specified
39 timeframe.
- 40 • DWR Delta Seismic Design, June 2012.
- 41 ○ This report serves to provide literature search of Delta specific design criteria and application
42 of load to structures. It's a compilation of existing state of practice for the seismic design of the

1 type of hydraulic structures as well as recommended guidelines for design criteria associated
 2 with future hydraulic structures in the Delta.

- 3 ● Federal Highway Administration Seismic Retrofitting Manual for Highways Structures, Parts 1
 4 and 2, 2006.
 - 5 ○ The manual recommends a performance-based methodology for retrofitting highway bridges.
 6 It defines different performance expectations for bridges of varying importance while subject
 7 to four different levels of seismic hazard. The manual goes on and provides more details for
 8 defining minimal, significant, and sustained damages. It is worth noting that the performance
 9 levels are varying with level of earthquake ground motion, bridge importance and anticipated
 10 service life (ASL). Two ground motion levels (lower level – 100 year return period and upper
 11 level – 975 year return period), two importance classifications (Standard and Essential), and
 12 three service life categories (ASL 1, 2, and 3) are defined.
 - 13 ○ Minimum performance levels for retrofitted bridges:

Earthquake Ground Motion	Bridge Importance and Service Life Category					
	Standard			Essential		
	ASL1	ASL2	ASL3	ASL1	ASL2	ASL3
Lower Level Ground Motion 50 percent probability of exceedance in 75 years; return period is about 100 years.	PL0	PL3	PL3	PL0	PL3	PL3
Upper Level Ground Motion 7 percent probability of exceedance in 75 years; return period is about 1,000 years.	PL0	PL1	PL1	PL0	PL1	PL2

- Notes:
1. Anticipated Service Life categories are:
 - a. ASL 1: 0-15 years
 - b. ASL 2: 16-50 years
 - c. ASL 3: greater than 50 years
 2. Performance Levels are:
 - a. PL0 – No minimum level of performance is recommended.
 - b. PL1 – Life safety. Significant damage is sustained during an earthquake and service is significantly disrupted, but life safety is assured. The bridge may need to be replaced after a large earthquake.
 - c. PL2 – Operational. Damage sustained is minimal and full service for emergency vehicles should be available after inspection and clearance of debris. Bridge should be repairable with or without restrictions on traffic flow.
 - d. PL3 – Fully operational. Damage sustained is negligible and full service is available for all vehicles after inspection and clearance of debris. Any damage is repairable without interruption to traffic.
 3. Earthquake ground motion levels
 - a. The “lower level” earthquake ground motion is one that has a reasonable likelihood of occurrence within the life of the bridge (assume to be 75 years) (i.e., it represents a relatively small but likely ground motion)
 - b. The “upper level” earthquake ground motion has a finite, but remote, probability of occurrence within the life of the bridge; i.e., it represents a large but unlikely ground motion.
 4. An “essential” bridge is one that satisfies one or more of the following conditions:
 - a. Required to provide secondary life safety (provides access to local emergency services such as hospitals or cross routes that provide secondary life safety).
 - b. Loss of the bridge would create a major economic impact
 - c. Formally defined by a local emergency plan as critical (enables civil defense, fire departments, and public health agencies to respond immediately to disaster situations)
 - d. Serves as a critical link in the security and/or defense roadway network.
 - e. A “standard” bridge is everything not “essential”

14

- 1 ● State of California Sea-Level Rise Task Force of the Coastal and Ocean Working Group of the
2 California Climate Action Team (CO-CAT), Sea-Level Rise Interim Guidance Document, 2010
- 3 ○ This document provides guidance for incorporating sea-level rise (SLR) projections into
4 planning and decision making for projects in California. Using Year 2000 as a baseline, the Sea-
5 Level Rise Projections in California range between 10 to 17 inches by year 2050 and between
6 18 to 29 inches by year 2070.
- 7 ○ Underestimating SLR in the project design will result in harmful realized impacts such as
8 flooding. Harmful impacts are more likely to occur if the project design is based upon a low
9 projection of SLR and less likely if higher estimates of SLR are used. In situations with high
10 consequences (high impacts and/or low adaptive capacity), using a low SLR value involves a
11 higher degree of risk. (examples of harmful impacts that might result from underestimating
12 SLR include damage to infrastructure, contamination of water supplies due to saltwater
13 intrusion, and inundation of marsh restoration projects located too low relative to the tides).
- 14 ○ As of the date of the guidance document, the State Coastal Conservancy (SCC) and the State
15 Lands Commission (SLC) have adopted, and the Delta Vision Blue Ribbon Task Force
16 Independent Science Board has recommended, the use of 55 inches (140 cm) of SLR for 2100.
17 The SCC and the SLC also adopted a policy of using 16 inches (41 cm) as the estimate of SLR for
18 2050. Agencies may select other values depending on their particular guiding policies and
19 considerations related to risk, ability to incorporate phased adaptation into design and other
20 factors.
- 21 ● USACE (Corps, CESP-K-ED-G), Geotechnical Levee Practice, SOP EDG-03, 2004.
- 22 ○ This procedure covers the geotechnical practice for levee evaluation, analysis, design,
23 construction and maintenance of levees in accordance with Sacramento District and USACE
24 guidance and regulation. Sacramento District standard practice may differ from published
25 USACE guidance.
- 26 ○ Standard Levee Geometry – The minimum levee section should have a 3H:1V waterside slope, a
27 minimum 20 ft. wide crown for main line levees, major tributary levees, and bypass levees, a
28 minimum 12 ft. wide crown for minor tributary levees, a 3H:1V landside slope, a minimum 20
29 ft. wide landside easement, and a minimum 15 ft. waterside easement. Existing levees with
30 landside slopes as steep as 2H:1V may be used in rehabilitation projects if landside slope
31 performance has been good. Easements are necessary for maintenance, inspection, and
32 floodfight access.
- 33 ○ Typically a seepage berm should be designed as a semipervious berm with a drainage layer.
34 Seepage berms should have a minimum width of 4 times the maximum levee height in a reach.
35 The maximum seepage berm width should typically be 300 ft. A seepage berm will typically
36 vary from about 5 ft. thick at the levee toe to about 3 ft. thick at the berm toe.
- 37 ● USACE Design and Construction of Levees, EM 1110-2-1913, 2000.
- 38 ○ This document provides guidelines or methodology for the design and construction of earth
39 levees.
- 40 ○ The manual is general in nature and not intended to supplant the judgment of the design
41 engineer on a particular project.
- 42 ● USACE Engineering and Design, Earthquake Design and Evaluation for Civil Works Projects, ER 1110-
43 2-1806, 1995.

- 1 ○ The manual provides guidance in evaluating and assessing the ground motions, site
2 characterization, structural response, functional consequences, and potential hazards in the
3 design and construction of Civil Work projects including dams and levees.
- 4 ○ The seismic design for new projects and the seismic evaluation or reevaluation for existing
5 projects should be accomplished in accordance with this regulation. This regulation applies to
6 all projects which have the potential to malfunction or fail during major seismic events and
7 cause hazardous conditions related to loss of human life, appreciable property damage,
8 disruption of lifeline services, or unacceptable environmental consequences. The scope of each
9 seismic study should be aimed at assessing the ground motions, site characterization,
10 structural response, functional consequences, and potential hazards in a consistent, well-
11 integrated, and cost-effective effort that will provide a high degree of confidence in the final
12 conclusions.
- 13 ○ Survival of operating equipment and utility lines is as essential as survival of the structural and
14 geotechnical features of the project.
- 15 ● USACE Engineering and Design – Earthquake Design and Evaluation of Concrete Hydraulic Structures,
16 EM 1110-2-6053, 2007.
- 17 ○ This manual provides guidance for performance-based design and evaluation of concrete
18 hydraulic structures (CHS). It introduces procedures that show how to design or evaluate a
19 hydraulic structure to have a predictable performance for specified levels of seismic hazard.
20 Traditional design and evaluation procedures may still be used for feasibility and screening
21 purposes. However, for critical facilities, they should be followed by the procedures of this
22 manual to prevent sudden collapse even though the structure may suffer severe damage, to
23 limit damage to a repairable level, or to maintain functionality immediately after the
24 earthquake.
- 25 ○ This manual contains mandatory requirements at the end of each chapter. These requirements
26 usually pertain to critical elements of the design and evaluation, such as loads and load
27 combinations, to analytical procedures used to determine force and displacement demands,
28 and to methods used to determine member strength and displacement capacities. The purpose
29 of the mandatory requirements is to assure that the structure meets minimum safety and
30 performance objectives.
- 31 ○ Performance requirements for stability shall be in accordance with EM 1110-2-2100, *Stability*
32 *Analysis of Concrete Structures*.
- 33 ● USACE Engineering and Design—General Design and Construction Considerations for Earth and
34 Rock-Fill Dams, EM 1110-2-2300, 2004.
- 35 ○ This manual provides guidance on the design and construction, and performance monitoring of
36 and modifications to embankment dams. The manual presents general guidance and is not
37 intended to supplant the creative thinking and judgment of the designer for a particular
38 project.
- 39 ○ To meet the dam safety requirements, the design, construction, operation, and modification of
40 an embankment dam must comply with the following technical and administrative
41 requirements:
- 42 ● Technical requirements

- 1 ○ The dam, foundation, and abutments must be stable under all static and dynamic
2 loading conditions
- 3 ○ Seepage through the foundation, abutments, and embankment must be controlled and
4 collected to ensure safe operation. The intent is to prevent excessive uplift pressures,
5 piping of materials, sloughing, removal of material by solution, or erosion of this
6 material into cracks, joints, and cavities. In addition, the project purpose may impose a
7 limitation on allowable quantity of seepage. The design should include seepage control
8 measures such a foundation cutoffs, adequate and nonbrittle impervious zones,
9 transition zones, drainage material and blankets, upstream impervious blankets,
10 adequate core contact area, and relief wells.
- 11 ○ The freeboard must be sufficient to prevent overtopping by waves and include an
12 allowance for settlement of the foundation and embankment.
- 13 ○ The spillway and outlet capacity must be sufficient to prevent over-topping of the
14 embankment by the reservoir.
- 15 ● Administrative requirements
- 16 ○ Environmental responsibility
- 17 ○ Operation and maintenance manual
- 18 ○ Monitoring and surveillance plan
- 19 ○ Adequate instrumentation to monitor performance
- 20 ○ Documentation of all the design, construction, and operational records
- 21 ○ Emergency Action Plan: Identification, notification, and response subplan
- 22 ○ Schedule for periodic inspections, comprehensive review, evaluation, and
23 modifications as appropriate.
- 24 ○ The following criteria must be met to ensure satisfactory earth and rock-fill structures:
- 25 ● Technical requirements
- 26 ○ The embankment, foundation, and abutments must be stable under all conditions of
27 construction and reservoir operation including seismic
- 28 ○ Seepage through the embankment, foundation and abutments must be controlled and
29 collected to prevent excessive uplift pressures, piping, sloughing, removal of material
30 by solution, or erosion of this material into cracks, joints, and cavities. In addition, the
31 project purpose may impose a limitation on allowable quantity of seepage. The design
32 should include seepage control measures such a foundation cutoffs, adequate and
33 nonbrittle impervious zones, transition zones, drainage blankets, upstream impervious
34 blankets, and relief wells.
- 35 ○ The freeboard must be sufficient to prevent overtopping by waves and include an
36 allowance for settlement of the foundation and embankment as well as for seismic
37 effects where applicable.
- 38 ○ The spillway and outlet capacity must be sufficient to prevent over-topping of the
39 embankment.

- 1 ● USACE Engineering and Design—Response Spectra and Seismic Analysis for Concrete Hydraulic
2 Structures, EM 1110-2-6050, 1999.
- 3 ○ This manual describes the development and use of response spectra for the seismic analysis of
4 concrete hydraulic structures. The manual provides guidance regarding how earthquake
5 ground motions are characterized as design response spectra and how they are then used in
6 the process of seismic structural analysis and design. The manual is intended to be an
7 introduction to the seismic analysis of concrete hydraulic structures.
- 8 ○ The design and evaluation of hydraulic structures for earthquake loading must be based on
9 appropriate criteria that reflect both the desired level of safety and the nature of the design and
10 evaluation procedures (ER 1110-2-1806). The first requirement is to establish earthquake
11 ground motions to be used as the seismic input by considering safety, economics, and the
12 designated operational functions. The second involves evaluating the earthquake performance
13 of the structure to this input by performing a linear elastic dynamic analysis based on a realistic
14 idealization of the structure, foundation, and water.
- 15 ● For an operating basis earthquake (OBE) that can reasonably be expected to occur within
16 the service life of the project (that is, with a 50 percent probability of exceedance during
17 the service life), structures located in regions of high seismicity should essentially respond
18 elastically to the event with no disruption to services, but limited localized damage is
19 permissible and should be repairable. In such cases, a low to moderate level of damage can
20 be expected.
- 21 ● For a maximum design earthquake (MDE) which is a maximum level of ground motion for
22 which a structure is designed or evaluated, the associated performance requirement is the
23 that the project performs without catastrophic failure, such as uncontrolled release of a
24 reservoir, although severe damage or economic loss may be tolerated. The damage during
25 an MDE event could be substantial, but should not be catastrophic in terms of loss of life,
26 economics, and social and environmental impacts.
- 27 ● For critical structures (structures of high downstream hazard whose failure during or
28 immediately following an earthquake could result in loss of life), the MDE is set equal to the
29 MCE (the greatest earthquake that can reasonably be expected to be generated by a specific
30 source on the basis of seismological and geological evidence). For other than critical
31 structures, the MDE is selected as a lesser earthquake than the MCE.
- 32 ● USACE Engineering and Design—Stability Analysis of Concrete Structures, EM 1110-2-2100, 2005.
- 33 ○ This manual establishes and standardizes stability criteria for use in the design and evaluation
34 of the many various types of concrete structures common to Corps of Engineers civil works
35 projects. As used in this manual, the term “stability” applies to external global stability (sliding,
36 rotation, flotation and bearing), not to internal stability failures such as sliding on lift surfaces
37 or exceedance of allowable material strengths. The manual prescribes the safety factors, which
38 govern stability requirements for the structure for various load combinations.
- 39 ● USACE Engineering and Design—Structural Design and Evaluation of Outlet Works, EM 1110-2-2400,
40 2003.
- 41 ○ This manual provides guidance for the planning and structural design and analysis of intake
42 structures and other outlet works features used on US Army Corps of Engineers projects for the

- 1 purpose of flood control, water supply, water quality and temperature control, recreation, or
 2 hydropower.
- 3 ○ The following are minimum required safety factors for seismic sliding analysis:
- 4 ● OBE = 1.7 for critical structures, and 1.3 for other structures
- 5 ● MDE = 1.3 for critical structures, and 1.1 for other structures
- 6 ○ The associated performance level with the OBE is the requirement that the structure will
 7 function within the elastic range with little or no damage and without interruption of function.
- 8 ○ The MDE is the maximum level of ground motion for which the structure is designed or
 9 evaluated. The tower may be damaged but retains its integrity. The purpose of the MDE is to
 10 protect against economic losses from damage or loss of services. Ordinarily the MDE is defined
 11 for intake towers as a ground motion having a 10 percent probability of exceedance during the
 12 service life of 100 years.
- 13 ● USACE Engineering and Design—Structural Design and Evaluation of Outlet Works, EM 1110-2-2400,
 14 2003.
- 15 ○ This manual provides guidance for the planning and structural design and analysis of intake
 16 structures and other outlet works features used on the U.S. Army Corps of Engineers projects
 17 for the purpose of flood control, water supply, water quality and temperature control,
 18 recreation, or hydropower.
- 19 ○ Seismic design for new towers and the evaluation of existing towers must demonstrate that the
 20 tower has adequate strength, ductility, and stability to resist the specified earthquake ground
 21 motions. The ultimate strength or capacity of new and existing towers will be determined using
 22 the principles and procedures described in EM 1110-2-2104. Capacities are based on ultimate
 23 strength, or the nominal strength multiplied by a capacity reduction factor. Intake tower
 24 sections shall have the strength to resist load combinations involving dead load, live load, and
 25 earthquake load.
- 26 ● USACE Engineering and Design—Time-History Dynamic Analysis of Concrete Hydraulic Structure, EM
 27 1110-2-6051, 2003.
- 28 ○ This manual describes the procedures for the linear-elastic time-history dynamic analysis and
 29 development of acceleration time-histories for seismic design and evaluation of concrete
 30 hydraulic structures. It provides guidance on the formulation and performance of the linear-
 31 elastic time-history dynamic analyses and how the earthquake input time-histories are developed
 32 and applied.
- 33 ○ Design and safety evaluation earthquakes for concrete hydraulic structures are the OBE and the
 34 MDE as required by ER 1110-2-1806.
- 35 ● The OBE is defined in ER 1110-2-1806 as an earthquake that can reasonably be expected to
 36 occur within the service life of the project, that is, with a 50 percent probability of exceedance
 37 during the service life. The associated performance requirement is that the project function
 38 with little or no damage, and without interruption of function. The purpose of the OBE is to
 39 protect against economic losses from damage or loss of service.
- 40 ● The MDE is defined in ER 1110-2-1806 as the maximum level of ground motion for which a
 41 structure is designed or evaluated. The associated performance requirement is that the

project performs without catastrophic failure, such as uncontrolled release of a reservoir, although severe damage or economic loss may be tolerated.

- For critical structures, ER 1110-2-1806 requires the MDE to be set equal to the MCE. Critical structures are defined as structures whose failure during or immediately following an earthquake could result in loss of life. The MCE is defined as the greatest earthquake that can reasonably be expected to be generated by a specific source on the basis of seismological and geological evidence (ER 1110-2-1806)
- For other than critical structures the MDE is selected as a less severe earthquake than the MCE, which provides for an economical design meeting specified safety standards. In these cases, the MDE is defined as that level of ground motion having as a minimum a 10 percent probability in exceedance in 100 years.

- USACE Slope Stability, EM 1110-2-1902, 2003.

- This engineer manual (EM) provides guidance for analyzing the static stability of slopes of earth and rock-fill dams, slopes of other types of embankments, excavated slopes, and natural slopes in soil and soft rock. Methods for analysis of slope stability are described and are illustrated by examples in the appendixes. Criteria are presented for strength tests, analysis conditions, and factors of safety. The criteria in this EM are to be used with methods of stability analysis that satisfy all conditions of equilibrium. Methods that do not satisfy all conditions of equilibrium may involve significant inaccuracies and should be used only under the restricted conditions described herein. This manual is intended to guide design and construction engineers, rather than to specify rigid procedures to be followed in connection with a particular project.
- Minimum Required Factors of Safety: New Earth and Rock-Fill Dams

Analysis Condition	Required Minimum Factor of Safety	Slope
End-of-Construction (including staged construction)	1.3	Upstream and Downstream
Long-term (steady seepage, maximum storage pool, spillway crest or top of gates)	1.5	Downstream
Maximum surcharge pool	1.4	Downstream
Rapid drawdown	1.1–1.3	Upstream

- USACE Engineering and Design—Settlement Analysis, EM 1110-1-1904, 1990.

- This manual presents guidelines for calculation of vertical displacements and settlement of soil under shallow foundations (mats and footings) supporting various types of structures and under embankments.

- USACE Engineering and Design—Design of Pile Foundations, EM 1110-2-2906, 1991

- This manual provides information, foundation exploration and testing procedures, load test methods, analysis techniques, design criteria and procedures, and construction considerations for the selection, design, and installation of pile foundations. The guidance is based on the present state of technology for pile-soil-structure-foundation interaction behavior. This manual provides design guidance intended specifically for geotechnical and structural engineers and essential information for others interested in understanding construction techniques related to

- 1 pile behavior during installation. The understanding of pile foundation behavior is actively
 2 expanding by ongoing research, prototype, model pile, and pile group testing and development
 3 of more refined analytical models. However, this manual is intended to provide examples and
 4 procedures of proven technology. This manual will be updated as changes in design and
 5 installation procedures are developed.
- 6 ○ The pile foundation must perform as designed for the life of the structure. Performance can be
 7 described in terms of structural displacements which may be just as harmful to a structure as
 8 an actual pile failure. The load capacity should not degrade over time due to deterioration of
 9 the pile material.
 - 10 ○ For most hydraulic structures, designers should have a high level of confidence in the soil and
 11 pile parameters and the analysis. Therefore, uncertainty in the analysis and design parameters
 12 should be minimized rather than requiring a high factor of safety. For less significant
 13 structures, it is permissible to use larger factors of safety if it is not economical to reduce the
 14 uncertainty in the analysis and design by performing additional studies, testing, etc. Also
 15 factors of safety must be selected to assure satisfactory performance for service conditions.
 16 Failure of critical components to perform as expected can be as detrimental as an actual
 17 collapse.
 - 18 ○ It is normal to apply safety factors to the ultimate load predicted. In general, safety factors for
 19 hydraulic structures are as follows:

Method of Determining Capacity	Loading Condition	Minimum Factor of Safety	
		Compression	Tension
Theoretical or empirical prediction to be verified by pile load test	Usual ¹	2.0	2.0
	Unusual ²	1.5	1.5
	Extreme ³	1.15	1.15
Theoretical or empirical prediction to be verified by pile driving analyzer	Usual ¹	2.5	3.0
	Unusual ²	1.9	2.25
	Extreme ³	1.4	1.7
Theoretical or empirical prediction not verified by load test	Usual ¹	3.0	3.0
	Unusual ²	2.25	2.25
	Extreme ³	1.7	1.7

¹ Usual loads refer to conditions which are related to the primary function of a structure and can be reasonably expected to occur during the economic service life. The loading effects may be of either a long term, constant or an intermittent, repetitive nature. Pile allowable loads and stresses should include a conservative safety factor for such conditions.

² Unusual loads refer to construction, operation or maintenance conditions which are of relatively short duration or infrequent occurrence. Risks associated with injuries or property losses can be reliably controlled by specifying the sequence or duration of activities, and/or by monitoring performance. Only minor cosmetic damage to the structure may occur during these conditions.

³ Extreme loads refer to events which are highly improbable and can be regarded as emergency conditions. Such events may be associated with major accidents involving impacts or explosions and natural disasters due to earthquakes or hurricanes which have a frequency of occurrence that greatly exceeds the economic service life of the structure. The basic design concept for normal loading conditions should be efficiently adapted to accommodate extreme loading effects without experiencing a catastrophic failure. Extreme loadings may cause significant structural damage which partially impairs the operational functions and requires major rehabilitation or replacement of the structure.

- 1 • U.S. Department of the Interior and USGS Climate Change and Water Resources Management: A
2 Federal Perspective, Circular 1331.
- 3 ○ The purpose of this interagency report is to explore strategies to improve water management
4 by tracking, anticipating, and responding to climate change. This report describes the existing
5 and still needed underpinning science crucial to addressing the many impacts of climate change
6 on water resources management. With sea level rising, data obtain in this report will be used in
7 the planning and design of future hydraulic facilities and levees.
- 8 ○ Advocates for the National Research Council (2004) recommendation of adopting an adaptive
9 management framework that involves post-construction evaluations being standard for the
10 adaptive management of projects and systems as well as ensuring that operating plans build in
11 flexibility to adapt to potential climate conditions.

12 **9.3 Environmental Consequences**

13 This section describes the potential effects that could result from project construction, operation and
14 maintenance, and restoration due to geologic and seismic-related conditions and hazards. The types of
15 effects that are evaluated include the following.

- 16 • Exposure of people or structures to potential substantial adverse effects, including the risk of loss
17 of property, personal injury, or death, involving the below.
- 18 ○ Rupture of a known earthquake fault, as delineated on the most recent AP Earthquake Fault
19 Zoning Map issued by the state geologist for the area or based on other substantial evidence of
20 a known fault.
- 21 ○ Strong seismic ground shaking.
- 22 ○ Liquefaction.
- 23 ○ Seismic-related ground failure.
- 24 ○ Slope instability.
- 25 ○ Soft, loose, and compressible soils.
- 26 ○ Seiche, tsunami, or mudflow.
- 27 • Location relative to geologic units or soils that are unstable or that would become unstable as a
28 result of the project and potentially result in on- or off-site landslide, lateral spreading, subsidence,
29 liquefaction, or collapse.

30 Geologic and seismic effects on structures and construction activities associated with the BDCP would
31 be restricted to the Plan Area, but the Plan Area could be affected by seismic conditions well outside the
32 Plan Area. Because all conveyance and restoration activities related to the project would occur within
33 the Plan Area, geologic and seismic conditions Upstream of the Delta and within the SWP and CVP
34 Export Service Areas would not be affected by construction, operation, maintenance, or restoration
35 activities. Therefore, this section does not evaluate effects in those geographic areas.

36 Potential adverse effects associated with near-surface soils, including erosion; subsidence caused by
37 oxidation of organic matter; and expansive, corrosive, and compressible soils, are assessed in Chapter
38 10, *Soils*. Further discussion of levee stability and flooding is provided in Chapter 6, *Surface Water*.

Potential effects of irrigation-induced salt loading to soils are addressed in Chapter 8, *Water Quality*, and Chapter 14, *Agricultural Resources*. Potential effects on mineral resources are fully discussed in Chapter 26, *Mineral Resources*.

9.3.1 Methods for Analysis

This section describes the methods used to evaluate the potential for geologic and seismic hazards to affect the constructed and operational elements of the alternatives and the potential for the elements of the alternatives to increase human health risk and loss of property or other associated risks. Some of these effects would be temporary, associated with construction activities within the geographic footprint of disturbance of new facilities in the Plan Area. Other effects would be more regional in nature, associated with the presence of new structures and water operations throughout the Plan Area. Lands outside of the Plan Area are not being considered because there are no structures being proposed and because changed operations upstream and within the water user service areas do not increase geologic or seismic hazards in those areas. Both quantitative and qualitative methods were used to evaluate these effects, depending on the availability of data. Conservation and restoration activities were evaluated on a programmatic level using qualitative methods to estimate potential effects.

The impact analysis for geology and seismicity was performed primarily using information on soils and stratigraphy, area topography, subsurface conditions, and potential earthquake hazards developed for the BDCP CERs and Geotechnical Data Reports, as listed below.

- *Conceptual Engineering Report—Isolated Conveyance Facility—All Tunnel Option* (California Department of Water Resources 2010a).
- *Conceptual Engineering Report—Isolated Conveyance Facility—Pipeline/Tunnel Option—Addendum* (California Department of Water Resources 2010b).
- *Conceptual Engineering Report—Isolated Conveyance Facility—East Option* (California Department of Water Resources 2009a).
- *Conceptual Engineering Report—Isolated Conveyance Facility—East Option—Addendum* (California Department of Water Resources 2010c).
- *Conceptual Engineering Report—Isolated Conveyance Facility—West Option* (California Department of Water Resources 2009b).
- *Conceptual Engineering Report—Isolated Conveyance Facility—West Option—Addendum* (California Department of Water Resources 2010d).
- *Option Description Report—Separate Corridors Option* (California Department of Water Resources 2010e).
- *Draft Phase II Geotechnical Investigation—Geotechnical Data Report—Pipeline/Tunnel Option* (California Department of Water Resources 2011).
- *Draft Phase I Geotechnical Investigation—Geotechnical Data Report—Isolated Conveyance Facility West* (California Department of Water Resources 2010g).
- *Draft Phase I Geotechnical Investigation—Geotechnical Data Report—Isolated Conveyance Facility East* (California Department of Water Resources 2010h).

1 Other study results and applicable maps and information published by various regulatory agencies,
 2 researchers and consultants were also used (e.g., California Department of Water Resources 1992;
 3 CALFED Bay-Delta Program 2000; California Department of Water Resources and California
 4 Department of Fish and Wildlife 2008, Shlemon and Begg 1975; Fugro Consultants 2011). The
 5 emphasis in the impact analysis has been to identify where the existing data suggest that geologic or
 6 seismic conditions pose a potentially serious threat to structural integrity. The analysis determines
 7 whether these conditions and associated risk can be reduced to less than significant by conformance
 8 with existing codes, standards and the application of accepted, proven construction engineering
 9 practices. A range of specific design and construction approaches are normally available to address a
 10 specific circumstance. For example, the potential for liquefaction to affect structural integrity could be
 11 controlled using a range of engineering approaches, such as by removal and replacement of the
 12 liquefiable soil with engineered fill and construction of the structure on pilings founded on non-
 13 liquefiable material. Specific control measures have not been developed for all site conditions at this
 14 point in the BDCP planning process. Regardless of the control method used, the same stability criteria
 15 must be met to conform with code and standards requirements. Design solutions would be guided by
 16 relevant building codes and state and federal standards for constructing foundations, bridges, tunnels,
 17 earthworks, and all other project facilities, listed in Section 9.2.2.4, *Regulatory Design Codes and*
 18 *Standards for Project Structures*. This evaluation process is described in more detail below in Section
 19 9.3.1.1. Methodologies for evaluating specific geologic and seismic hazards are further defined in
 20 Section 9.3.1.3 below.

21 Indirect environmental effects related to levee failure and breaches that could result in flooding are
 22 described in Chapter 6, *Surface Water*. Other resources that may be affected by the geologic and seismic
 23 conditions of the Plan Area are addressed in Chapter 7, *Groundwater*, and Chapter 10, *Soils*. Potential
 24 effects on mineral resources are discussed in Chapter 26, *Mineral Resources*.

25 **9.3.1.1 Process and Methods of Review for Geologic and Seismic Hazards**

26 This section describes the sequence of planning, evaluation, review and design activities that identify
 27 geologic and seismic hazards and establish approaches to avoiding or minimizing those hazards. This is
 28 the process being implemented to avoid significant hazards to structures and human health associated
 29 with the BDCP. The description of the process and methods is intended to make it clear how site-
 30 specific hazard conditions are identified and fully addressed through data collection, analysis and
 31 conformance with existing design and construction requirements.

32 As the BDCP and its various conservation measures have been developed by DWR in anticipation of
 33 agency and public review through the CEQA/NEPA processes, the agency has developed geologic and
 34 geotechnical information for all of the conveyance alignment alternatives. This information has been
 35 developed under the supervision of professional engineers and documented in the geotechnical data
 36 reports prepared by DWR for the project. As is appropriate for a project of this scale, these documents
 37 show project and alternative feasibility by identifying site geotechnical conditions along with
 38 associated constraints and opportunities. The geology and seismicity analyses in this chapter include
 39 review of the geotechnical data reports and other existing reports and data to determine whether
 40 significant risks might occur from implementing the BDCP.

41 Seismic and geologic hazards are determined to be adverse under NEPA or significant under CEQA if
 42 their related effects pose a substantial risk of damage to structures or pose a substantial human health
 43 threat. The criteria used to evaluate significance do not require the elimination of the potential for
 44 structural damage from the site's geologic and seismic conditions. Rather, the criteria require

1 evaluation of whether site conditions can be overcome through engineering design solutions that
2 reduce the substantial risk to people and structures. The codes and design standards referred to above
3 ensure that buildings and structures are designed and constructed so that, while they may sustain
4 damage during a major earthquake, the substantial risk of loss of property, personal injury or death
5 due to structure failure or collapse is reduced. The CEQA/NEPA evaluation considers whether
6 conformance with existing codes and standards, and application of accepted, proven construction
7 engineering practices, would reduce the substantial risk to people and structures.

8 Configuration of the proposed BDCP alternatives will be determined when the CEQA/NEPA review is
9 completed. Development of final-level design and inclusion of more detailed information would not be
10 likely to substantially modify any CEQA/NEPA conclusions. After CEQA/NEPA document certification,
11 the final design of structures will be developed; this will require additional subsurface geotechnical
12 investigation to identify very localized conditions that must be reflected in the final engineering design.
13 These geotechnical investigations will characterize, log, and test soils and bedrock at selected
14 construction sites to further refine anticipated site responses to seismic activity and the various loads
15 created by structures. They will also refine the design parameters that must be met. The geotechnical
16 investigation and its recommendations will be presented in a report that is reviewed and approved by
17 a California-registered civil engineer or a certified engineering geologist who is competent in the field
18 of seismic hazard evaluation and mitigation. The requirements for evaluating seismic hazards other
19 than surface fault rupture and for recommending mitigation measures that the California-registered
20 civil engineer or certified engineering geologist or geologist must follow are specified in *Guidelines for*
21 *Evaluating and Mitigating Seismic Hazards in California* (California Geological Survey 2008). For the
22 BDCP, the proponents have made an environmental commitment that final design of all constructed
23 components will meet the standards listed in Section 9.2.2.4, *Regulatory Design Codes and Standards for*
24 *Project Structures* and contained in Appendix 3B, *Environmental Commitments*. The constructed
25 components may include canals, tunnels, intake structures, pipelines, transmission lines, levees,
26 temporary and permanent access roads, bridges, borrow areas, and spoils storage sites.

27 Based on the final geotechnical report and code and standards requirements, the final design of
28 structures will be developed by the aforementioned California-registered civil engineer or California-
29 certified engineering geologist with participation and review by the BDCP proponents, and in some
30 cases county building departments, to ensure that design standards are met. The design and
31 construction specifications will then be incorporated into a construction contract for implementation
32 and required to be implemented. During project construction, new or unexpected conditions may be
33 found that are different than shown in the detailed, site-specific geotechnical report that guides the
34 final design. Under these circumstances, the new condition will be evaluated and an appropriate
35 method to meet the design specification will be determined by the project's California-registered civil
36 engineer or California-certified engineering geologist and approved by the BDCP proponents. Although
37 new or unexpected conditions may be found, the design standards will not change.

38 **9.3.1.2 Evaluation of Construction Activities**

39 Construction activities for the water conveyance facilities as they are currently defined, were evaluated
40 on a project level for potential effects relating to existing geologic hazards and to conform with federal
41 and state regulations and guidance pertaining to geologic hazard mitigation. Construction activities in
42 the ROAs were evaluated on a programmatic level for potential effects relating to existing geologic
43 hazards. These effects will need to be discussed in greater detail in subsequent project-level
44 environmental documentation after specific restoration activities are finalized.

1 Geologic and seismic analysis of construction-related effects included these methodologies and
2 approaches.

- 3 • **Review of conveyance alternatives and construction methods and sequences.** The available
4 design drawings, reports, and memoranda were reviewed, including construction methods, borrow
5 areas, and dewatering systems.
- 6 • **Review of available site topography and conditions and soil and groundwater data.** The
7 available data within the Plan Area, as presented in the CERs and the Geotechnical Data Reports
8 (see list at the beginning of Section 9.3.1), were compiled and reviewed. Available soil boring logs,
9 subsurface cross sections, soil stratigraphy, and groundwater data from the CER were used.
10 Geology and soil maps (from the U.S. Geological Survey and Natural Resources Conservation
11 Service) for the Plan Area were also used, with particular focus on areas where soft, loose, and
12 compressible soils are present.
- 13 • **Evaluation of potential effects caused by geologic conditions.** Potential effects of construction
14 activities from geologic hazards and the potential for increased risk were evaluated. Engineering
15 design criteria were reviewed and assessed to evaluate how substantial effects were addressed.

16 **9.3.1.2.1 Surface Fault Rupture**

17 Two types of surface fault rupture were addressed: sudden rupture and offset during an earthquake
18 event, and slow offset caused by long-term fault creep in the absence of an earthquake. The potential
19 for near-surface ground disturbance was assessed for blind thrust faults because they are not expected
20 to rupture to the ground surface as a result of fault creep or sudden offset.

21 The methodology for assessing surface fault rupture was based primarily on the available AP Fault
22 Zone Maps. Additional information provided in the CERs and the available published information on
23 fault rupture risks were also used. Areas within the footprints of each alternative located within the AP
24 fault zones or having the potential of experiencing ground ruptures during future earthquakes were
25 identified. For each area having fault rupture potential, the median (50th percentile) and 84th
26 percentile fault offsets during earthquakes were determined using published empirical relationships.
27 The long-term offset attributable to fault creep was also estimated using fault slip rate and time frame
28 considered.

29 **9.3.1.2.2 Earthquake Ground Shaking**

30 For engineering design purposes, ground shaking is commonly quantified by a response spectrum,
31 which is a plot of peak responses (acceleration, velocity, or displacement) of a single-degree-of-
32 freedom oscillator of varying natural frequency or period. Peak acceleration response at a period of
33 zero seconds or PGA is also widely used to characterize the level of ground motion. Earthquake ground
34 shaking is influenced by local site topography and soil conditions. Thick deposits of soft soils (such as
35 peaty mud) tend to amplify long-period motions, such as the response at a period of 1.0 second.

36 The potential exposure to ground shaking during future earthquakes and the effects to facilities within
37 all Build Alternative footprints was evaluated using the results of the CERs. Specifically, the effects of
38 ground motions predicted for various probabilities of exceedance during the design life of the project
39 were addressed. Seismic study results were interpolated and extrapolated to estimate ground shaking
40 for time periods not presented in the CERs; no new seismic ground motion calculations were
41 performed. Comparisons to previous studies were also made to validate the ground motion estimates.

1 **9.3.1.2.3 Liquefaction**

2 Liquefaction hazard was assessed using the available soil data from the CERs. The assessment was
 3 performed primarily through correlations with basic soil characteristics (soil type, water content,
 4 depositional environment, and age). For areas where adequate soil engineering data were not available,
 5 additional analyses were performed, including assessments based on SPT sampler penetration blow-
 6 counts (SPT blow-counts), Cone Penetration Test (CPT) measurements, and shear-wave velocity of the
 7 soil. The liquefaction analysis (for areas where adequate soil engineering data were available) was
 8 performed for earthquake ground motions with return periods of 475 years and 975 years,
 9 corresponding to 10% and 5% probabilities of being exceeded in 50 years, respectively. The controlling
 10 earthquake magnitudes were determined from the results of the seismic study (California Department
 11 of Water Resources 2007a) and/or the U.S. Geological Survey National Seismic Hazard Mapping
 12 Program.

13 **9.3.1.2.4 Ground Failure and Seismic-Induced Soil Instability**

14 **Compaction and Settlement**

15 Seismic-induced ground compaction and settlements are caused by the rearrangement of soil particles
 16 during an earthquake. Soil experiencing liquefaction tends to produce an increased amount of
 17 compaction and settlement. Excessive ground compaction may lead to large differential and/or total
 18 settlement and cause damage to facilities, lifelines, and other utilities.

19 A study of the characteristics of the soil found along the footprint of the proposed project was
 20 performed to give a qualitative assessment as to the potential for seismic-induced soil compaction and
 21 settlement.

22 **Loss of Bearing Capacity**

23 Loss of soil bearing capacity results mainly from significant reduction in soil effective stresses during
 24 an earthquake. In the case of liquefaction, soil effective stresses drop to almost zero, and soil strength
 25 reaches its residual value (soil residual strength). When soil strength is not sufficient to maintain
 26 stability, large deformation occurs, leading to foundation failure and excessive soil settlements and
 27 lateral movements.

28 A study of the type of the soil found along the footprint of the proposed project was performed to give a
 29 qualitative assessment as to the potential for substantial loss of bearing capacity during earthquakes.

30 **Lateral Spreading**

31 Lateral spreading typically occurs when the soil underlying an earth slope or near a free face liquefies
 32 during an earthquake. It can occur on gently sloping ground and extend large distances from the slope's
 33 open face.

34 A study of the characteristics of the soil/sediment and site topography found along the footprint of the
 35 proposed project was performed to give a qualitative assessment as to the potential for soil lateral
 36 movement.

37 **Increased Lateral Soil Pressure**

38 When soil liquefies, it behaves as a heavy liquid and may induce increased soil lateral pressure to walls
 39 or buried pipes and tunnels. The increased soil lateral pressure was estimated using liquefied soil unit

1 weight, which is roughly twice the unit weight of water. Even when a soil does not liquefy during a
2 seismic event, lateral earth pressures will increase mainly because of inertia earthquake forces.

3 **Buoyancy**

4 As soil liquefies, it causes an increase in buoyancy pressure on buried structures or parts of facilities
5 below the ground, similar to increased soil lateral pressure. The buoyancy forces were estimated using
6 liquefied soil unit weight.

7 **9.3.1.2.5 Slope Instability**

8 Slope instability (e.g., landslides, soil creep, and debris flow) can occur as a result of gravity loads or in
9 combination with earthquake loads. Analysis focused on areas where past instability had occurred or
10 where water saturates slope materials to estimate the potential for slope instability. In areas where
11 facilities may be built, new cut-and-fill slopes were identified and evaluated for stability.

12 A qualitative slope stability evaluation was performed based on slope inclination, soil type, and
13 groundwater conditions. For areas where adequate soil and site data were available, slope stability was
14 evaluated using a two-dimensional slope model and the limit-equilibrium method. Impact assessments
15 for the existing levees are described in Chapter 6, *Surface Water*.

16 **9.3.1.2.6 Soft, Loose, and Compressible Soils**

17 The team used both geographic information system (GIS) data and available geology and soil maps to
18 identify areas with soft, loose, and compressible soil within the footprints of each of the alternatives.
19 The thicknesses of these soils were estimated using available geotechnical exploration data.

20 **9.3.1.2.7 Seismic-Induced Seiche and Tsunami**

21 The basis for determining the hazard for seismically induced seiche and tsunami is discussed Section
22 9.1.1.3.

23 **9.3.1.3 Evaluation of Operations**

24 The potential for operation of the proposed facilities to directly or indirectly affect geologic hazards or
25 increase risks associated with geologic hazards was evaluated. The potential for adverse effects caused
26 by operation of the conveyance facilities was identified, and maintenance plans to address the effects
27 were evaluated.

28 Analysis methodologies and approaches for operation-related effects include review of the facilities
29 and their operations and evaluation of effects (including erosion, soil/slope instability, groundwater
30 fluctuation, and facility failures) caused by operation.

31 **9.3.2 Determination of Effects**

32 The effects of the BDCP alternatives on geologic and seismic risks may result from both construction
33 and operation of project features. This effects analysis assumes that an action alternative would result
34 in an adverse effect (under NEPA) or a significant impact (under CEQA) if it exposes people or
35 structures to a substantially greater potential for loss of property, personal injury or death from the
36 following effects.

- 1 • Earthquake fault rupture.
- 2 • Strong seismic ground shaking.
- 3 • Liquefaction.
- 4 • Seismic-related ground failure.
- 5 • Slope instability (landslides).
- 6 • Soft, loose and compressible soils.
- 7 • Seiche, tsunami, or mudflow.

8 For the purposes of this analysis, “substantially greater potential for loss, injury or death” is defined as
 9 any circumstance in which construction or operational activities have an increased likelihood of
 10 resulting in direct property loss, personal injury or death of individuals. Potential effects caused by
 11 subsidence, expansive and corrosive soils, and other such hazards are described in Chapter 10, *Soils*.
 12 Potential flooding effects are described in Chapter 6, *Surface Water*.

13 **9.3.2.1 Compatibility with Plans and Policies**

14 Constructing the proposed water conveyance facility (CM1) and implementing CM2–CM22 could
 15 potentially result in incompatibilities with plans and policies related to geologic/seismic hazards.
 16 Section 9.2, *Regulatory Setting*, provides an overview of federal, state, regional and agency-specific
 17 plans and policies applicable to seismic safety and levee stability. This section summarizes ways in
 18 which BDCP is compatible or incompatible with those plans and policies. Potential incompatibilities
 19 with local plans or policies do not necessarily translate into adverse environmental effects under NEPA
 20 or CEQA. Even where an incompatibility “on paper” exists, it does not by itself constitute an adverse
 21 physical effect on the environment, but rather may indicate the potential for a proposed activity to have
 22 a physical effect on the environment. The relationship between plans, policies, and regulations and
 23 impacts on the physical environment is discussed in Chapter 13, *Land Use*, Section 13.2.3.

24 Government Code Section 65302(g)(1) requires a seismic safety and safety element in all city and
 25 county general plans. The effect of this section is to require cities and counties to take seismic and
 26 safety hazards into account in their planning programs. The basic objective is to reduce loss of life,
 27 injuries, damage to property, and economic and social dislocations resulting from future earthquakes
 28 or other natural disasters. Generally, these local plans require mitigation of potential impacts of
 29 geologic hazards through development and building review, maintaining compatible land uses and
 30 appropriate construction techniques. Additionally, development projects are to conform with state
 31 seismic and building standards in the design and siting of critical facilities. Implementing a selected
 32 BDCP alternative could require construction of structures on or near blind faults. However, as
 33 discussed below under Impacts GEO-1 through GEO-16, construction and operation of the BDCP
 34 alternatives are not expected to create any additional seismic or geologic risk to lives or property. The
 35 BDCP proponents would implement an environmental commitment to conform with relevant state
 36 codes and standards to avoid creating any additional impacts from geologic/seismic hazards.
 37 Additionally, prior to construction, a California-registered civil engineer or California-certified
 38 engineering geologist would conduct site-specific evaluation for potential hazards and recommend
 39 measures in a geotechnical report to address hazards such as ground settlement or collapse from
 40 dewatering and potential liquefaction. These environmental commitments ensure the BDCP is
 41 compatible with the mission and goals of relevant general plans.

1 The Delta Plan, discussed generally in Section 9.2.2.1, has adopted policy RR P1, *Prioritization of*
 2 *Statement Investments in Delta Levees and Risk Reduction*. This policy covers any proposed action that
 3 involves discretionary State investments in Delta flood risk management, including levee operations,
 4 maintenance, and improvements, such as BDCP. The Delta Stewardship Council, in consultation with
 5 DWR, the Central Valley Flood Protection Board, and the California Water Commission, developed
 6 priorities for interim funding that include emergency preparedness, response, and recovery, as well as
 7 Delta levees funding. This policy prioritizes localized flood protection for existing urban areas by
 8 providing 200-year flood protection; protecting water quality and water supply conveyance in the
 9 Delta, especially levees that protect freshwater aqueducts and the primary channels that carry fresh
 10 water through the Delta; and protecting existing and providing for a net increase in channel-margin
 11 habitat. All of the levee alterations required by the BDCP alternatives meet this description. Therefore,
 12 the BDCP alternatives are compatible with the Delta Plan policies relevant to this resource area.

13 **9.3.3 Effects and Mitigation Approaches**

14 **9.3.3.1 No Action Alternative**

15 The No Action Alternative is the future condition at 2060 that would occur if none of the action
 16 alternatives were approved and if no change from current management direction or the level of
 17 management intensity of existing programs by federal, state, and local agencies occurred. The No
 18 Action Alternative considers changes in risk from geology and seismicity that would take place as a
 19 result of the continuation of existing plans, policies, and operations, as described in Chapter 3,
 20 *Description of Alternatives*. The No Action Alternative includes projects and programs with defined
 21 management or operational plans, including facilities under construction as of February 13, 2009,
 22 because those actions would be consistent with the continuation of existing management direction or
 23 level of management for plans, policies, and operations by the BDCP proponents and other agencies.
 24 The No Action Alternative assumptions also include projects and programs that are permitted or are
 25 assumed to be constructed by 2060. The No Action Alternative would result in the following effects on
 26 geology and seismicity.

27 **9.3.3.1.1 Earthquake-Induced Ground Shaking, Liquefaction, and Slope Instability**

28 Under the No Action Alternative, it is anticipated that the current hazard resulting from earthquake-
 29 induced ground shaking from regional and local faults would persist. This would continue to present a
 30 risk of levee failure and subsequent flooding of Delta islands, with a concomitant influx of seawater into
 31 the Delta, thereby adversely affecting water quality and water supply. The effects of flooding of Delta
 32 islands and consequently on water quality and supply are described in Appendix 3E, *Potential*
 33 *Seismicity and Climate Change Risks to SWP/CVP Water Supplies* and Chapter 6, *Surface Water*.

34 It is also anticipated that the current hazard of earthquake-induced liquefaction triggered by regional
 35 and local faults would persist. Liquefaction would continue to present a risk of levee failure and
 36 subsequent flooding of Delta islands, with concomitant water quality and water supply effects from
 37 seawater intrusion as described in Appendix 3E, *Potential Seismicity and Climate Change Risks to*
 38 *SWP/CVP Water Supplies*.

39 The current hazard of earthquake-induced slope instability (e.g., levee failure) triggered by regional
 40 and local faults would continue under the No Action Alternative. Slope instability associated with non-
 41 engineered levees would continue to present a risk of levee failure and subsequent flooding of Delta
 42 islands. Ongoing and reasonably foreseeable future projects in parts of the Delta are expected to

1 upgrade the levees to a “flood-safe” condition under the 100-year return flood elevation. However,
 2 these projects would provide very little levee foundation strengthening and improvements directed at
 3 improving the stability of the levees to better withstand ground shaking, liquefaction, and slope
 4 instability.

5 **9.3.3.1.2 Tsunami and Seiche**

6 Under the No Action Alternative, it is anticipated that the current hazard resulting from tsunami and
 7 seismically induced seiche on Delta and Suisun Marsh levees would continue. As reported above, the
 8 hazard of a substantial tsunami affecting the Delta and the Suisun Marsh appears to be minor because
 9 of their distance from the Pacific Ocean and the attenuating effect of San Francisco and Suisun bays.
 10 With respect to the hazard of a seiche, the existing water bodies in the Delta and Suisun Marsh tend to
 11 be wide and shallow. This geometry and distance to seismic sources generally are not conducive to the
 12 occurrence of a substantial seismically induced seiche, as described in Section 9.1.1.3. However,
 13 because of its proximity to the potentially active West Tracy fault, there is a potential hazard for a
 14 seiche to occur in the Clifton Court Forebay (Fugro Consultants 2011).

15 **9.3.3.1.3 Ongoing Plans, Policies, and Programs**

16 The programs, plans, and projects included under the No Action Alternative are summarized in Table 9-
 17 13, along with their anticipated effects on geology and seismicity. Although not specifically directed at
 18 mitigating potential damage to levees caused by a tsunami and seiche, the ongoing and reasonably
 19 foreseeable future projects directed to upgrade levees to a “flood-safe” condition under the 100-year
 20 return flood elevation or projects involving other similar levee improvements identified in Table 9-13
 21 below may provide some benefit to withstanding the potential effect of a tsunami and seiche.

22 In total, the plans and programs would result in a beneficial effect on an undetermined extent of levees
 23 in the Delta. Under the No Action alternative, these plans, policies, and programs would be deemed to
 24 have an indirect and beneficial effect upon the potential hazard of tsunami and seiche in the Delta due
 25 to improvements in levee infrastructure as a part of implementation of these projects or programs.

26 **9.3.3.1.4 Climate Change and Catastrophic Seismic Risks**

27 The Delta and vicinity is within a highly active seismic area, with a generally high potential for major
 28 future earthquake events along nearby and/or regional faults, and with the probability for such events
 29 increasing over time. Based on the location, extent and non-engineered nature of many existing levee
 30 structures in the Delta area, the potential for significant damage to, or failure of, these structures during
 31 a major local seismic event is generally moderate to high. In the instance of a large seismic event, levees
 32 constructed on liquefiable foundations are expected to experience large deformations (in excess of 10
 33 feet) under a moderate to large earthquake in the region. There would potentially be loss, injury or
 34 death resulting from ground rupture, ground shaking and liquefaction, (See Appendix 3E, *Potential*
 35 *Seismic and Climate Change Risks to SWP/CVP Water Supplies* for more detailed discussion).

36 **CEQA Conclusion:** In total, the plans and programs would result in a beneficial effect on an
 37 undetermined extent of levees in the Delta. Under the No Action alternative, these plans, policies, and
 38 programs would be deemed to have an indirect and beneficial effect upon the potential hazard of
 39 tsunami and seiche in the Delta. These plans and programs, however, would not decrease the risks
 40 associated with climate change or a catastrophic seismic event, as discussed above and more
 41 thoroughly in Appendix 3E, *Seismic and Climate Change Risks to SWP/CVP Water Supplies*.

1 **Table 9-13. Effects on Geology and Seismicity from the Plans, Policies, and Programs for the No Action Alternative**

Agency	Program/Project	Status	Description of Program/Project	Effects on Geology and Seismicity
USACE	Delta Dredged Sediment Long-Term Management Strategy	Ongoing	Maintaining and improving channel function, levee rehabilitation, and ecosystem restoration.	No direct effect on eliminating risks from earthquakes, groundshaking, liquefaction and slope instability. Indirect effect of improving resistance to tsunami and seiche.
DWR	In-Delta Storage Project	Planning phase	Strengthening of existing levees and construction of embankments inside levees.	No direct effect on eliminating risks from earthquakes, groundshaking, liquefaction and slope instability. Indirect effect of improving resistance to tsunami and seiche.
West Sacramento Area Flood Control Agency and USACE	West Sacramento Levee Improvements Program	Planning phase	Improvements to levees protecting West Sacramento to meet local and federal flood protection criteria.	No direct effect on eliminating risks from earthquakes, groundshaking, liquefaction and slope instability. Indirect effect of improving resistance to tsunami and seiche.
DWR	Levee Repair-Levee Evaluation Program	Ongoing	Repair of state and federal project levees.	No direct effect on eliminating risks from earthquakes, groundshaking, liquefaction and slope instability. Indirect effect of improving resistance to tsunami and seiche.
DWR	Delta Levees Flood Protection Program	Ongoing	Levee rehabilitation projects in the Delta.	No direct effect on eliminating risks from earthquakes, groundshaking, liquefaction and slope instability. Indirect effect of improving resistance to tsunami and seiche.
DWR, DFW, USACE	CALFED Levee System Integrity Program	Planning phase	Levee maintenance and improvement in the Delta.	No direct effect on eliminating risks from earthquakes, groundshaking, liquefaction and slope instability. Indirect effect of improving resistance to tsunami and seiche.
DWR	Central Valley Flood Management Planning Program	Planning phase	Among other management actions, involves levee raising and construction of new levees for flood control purposes.	No direct effect on eliminating risks from earthquakes, groundshaking, liquefaction and slope instability. Indirect effect of improving resistance to tsunami and seiche.
SAFCA, Central Valley Flood Protection Board, USACE	Flood Management Program	Ongoing	South Sacramento Streams Project component consists of levee, floodwall, and channel improvements.	No direct effect on eliminating risks from earthquakes, groundshaking, liquefaction and slope instability. Indirect effect of improving resistance to tsunami and seiche.
NMFS/USFWS	2008 and 2009 Biological Opinion	Ongoing	The Biological Opinions issued by NMFS and USFWS establish certain RPAs and RPMs to be implemented. Some of the RPAs require habitat restoration which may require changes to existing levees and channel improvements.	No direct effect on eliminating risks from earthquakes, groundshaking, liquefaction and slope instability. Indirect effect of improving resistance to tsunami and seiche.

9.3.3.2 Alternative 1A—Dual Conveyance with Pipeline/Tunnel and Intakes 1–5 (15,000 cfs; Operational Scenario A)

Impact GEO-1: Loss of Property, Personal Injury, or Death from Structural Failure Resulting from Strong Seismic Shaking of Water Conveyance Features during Construction

Earthquakes could be generated from local and regional seismic sources during construction of the Alternative 1A water conveyance facilities. Seismically induced ground shaking could cause collapse of facilities at the construction sites.

The potential for experiencing earthquake ground shaking during construction in 2020 (during the project's near-term implementation stage) was estimated using the results of the seismic study (California Department of Water Resources 2007a). The seismic study also computed seismic ground shaking hazards at six locations in the Delta for 2005, 2050, 2100, and 2200. The results of these analyses show that the ground shakings in the Delta are not sensitive to the elapsed time since the last major earthquake (i.e., the projected shaking hazard results for 2005, 2050, 2100, and 2200 are similar).

Table 9-14 lists the expected PGA and 1.0-second spectral acceleration (S_a) values in 2020 at selected facility locations along the Alternative 1A alignment. For the construction period, a ground motion return period of 72 years was assumed, corresponding to approximately 50% probability of being exceeded in 50 years. Values were estimated for a stiff soil site, as predicted in the seismic study (California Department of Water Resources 2007a), and for the anticipated soil conditions at the facility locations. No computational modeling was conducted for 2020 in the seismic study, so the ground shaking that was computed for 2005 was used to represent the construction near-term period (i.e., 2020).

Table 9-14. Expected Earthquake Ground Motions at Locations of Selected Major Facilities during Construction (2020)—Alternative 1A

Major Facilities	72-Year Return Period Ground Motions (during construction)			
	Peak Ground Acceleration (g)		1.0-sec S_a (g)	
	Stiff Soil ^a	Local Soil ^b	Stiff Soil ^a	Local Soil ^b
Intake Locations ^c	0.11	0.14	0.13	0.21
Tunnel Location near Venice Island ^d	0.20	0.26	0.22	0.35
Clifton Court Forebay / Byron Tract Forebay	0.18	0.23	0.20	0.32

g = gravity

S_a = second spectral acceleration

^a Stiff soil site, with a V_{s100ft} value of 1,000 ft/s.

^b Site-adjusted factors of 1.3 and 1.6 were applied to PGA and 1.0-sec S_a values, respectively (adjustments from a stiff soil site to a soft soil site).

^c The results of California Department of Water Resources 2007a for the Sacramento site were used.

^d The results of California Department of Water Resources 2007a for the Sherman Island site were used.

NEPA Effects: The seismic study employed time-dependent seismic source models for several major faults in the region. These models were characterized based on the elapsed times since the last major seismic events on the faults. Therefore, the exposure risks predicted in the seismic study would

1 increase if no major events take place on these faults through 2020. The effect could be substantial
 2 because seismically-induced ground shaking could cause loss of property or personal injury at the
 3 Alternative 1A construction sites (including intake locations, pipelines from intakes to the intermediate
 4 forebay, the tunnel, and the Byron Tract Forebay) as a result of collapse of facilities. For example,
 5 facilities lying directly on or near active blind faults, such as the concrete batch plant and fuel station on
 6 Tyler Island and Byron Tract Forebay for Alternative 1A may have an increased likelihood of loss of
 7 property or personal injury at these sites in the event of seismically-induced ground shaking. Although
 8 these blind thrusts are not expected to rupture to the ground surface under the forebays during
 9 earthquake events, they may produce ground or near-ground shear zones, bulging, or both (California
 10 Department of Water Resources 2007a). For a map of all permanent facilities and temporary work
 11 areas associated with this conveyance alignment, see Figure M3-1 in the Mapbook Volume.

12 However, during construction, all active construction sites would be designed and managed to meet the
 13 safety and collapse-prevention requirements of the relevant state codes and standards listed earlier in
 14 this chapter and expanded upon in Appendix 3B, *Environmental Commitments*, for the above-
 15 anticipated seismic loads. In particular, conformance with the following codes and standards would
 16 reduce the potential risk for increased likelihood of loss of property or personal injury from structural
 17 failure resulting from strong seismic shaking of water conveyance features during construction:

- 18 ● DWR Division of Engineering State Water Project—Seismic Loading Criteria Report, Sept 2012.
- 19 ● USACE Engineering and Design, Earthquake Design and Evaluation for Civil Works Projects, ER 1110-
 20 2-1806, 1995.
- 21 ● USACE Engineering and Design—Earthquake Design and Evaluation of Concrete Hydraulic
 22 Structures, EM 1110-2-6053, 2007.
- 23 ● USACE Engineering and Design—Response Spectra and Seismic Analysis for Concrete Hydraulic
 24 Structures, EM 1110-2-6050, 1999.
- 25 ● USACE Engineering and Design—Stability Analysis of Concrete Structures, EM 1110-2-2100, 2005.
- 26 ● California Code of Regulations, Title 8, Sections 1509 and 3203, California Code of Regulations.

27 Generally, the applicable codes require that facilities be built so that they incur minimal damage in the
 28 event of a foreseeable seismic event and that they remain functional following such an event and that
 29 the facility is able to perform without catastrophic failure in the event of a maximum design earthquake
 30 (the greatest earthquake reasonably expected to be generated by a specific source on the basis of
 31 seismological and geological evidence). The safety requirements could include shoring, specified slope
 32 angles, excavation depth restrictions for workers, lighting and other similar controls. Conformance
 33 with these standards and codes are an environmental commitment of the project (see Appendix 3B,
 34 *Environmental Commitments*). The worker safety codes and standards specify protective measures that
 35 must be taken at construction sites to minimize the risk of injury or death from structural or earth
 36 failure (e.g., utilizing personal protective equipment, practicing crane and scaffold safety measures).
 37 The relevant codes and standards represent performance standards that must be met by contractors
 38 and these measures are subject to monitoring by state and local agencies. The California Department of
 39 Industrial Relations Division of Operational Safety and Health (Cal-OSHA) requirements for an IIPP and
 40 the terms of the IIPP to protect worker safety are the principal measures that would be enforced at
 41 construction sites. Conformance with these health and safety requirements and the application of
 42 accepted, proven construction engineering practices would reduce any potential risk such that
 43 construction of Alternative 1A would not create an increased likelihood of loss of property, personal
 44 injury or death of individuals. Therefore, there would be no adverse effect.

1 **CEQA Conclusion:** Seismically induced ground shaking that is estimated to occur and the resultant
 2 ground motion anticipated at Alternative 1A construction sites, including the intake locations, the
 3 tunnel, the pipelines and the forebays, could cause collapse or other failure of project facilities while
 4 under construction. For example, facilities lying directly on or near active blind faults, such as the
 5 concrete batch plant and fuel station on Tyler Island and the Byron Tract Forebay for Alternative 1A
 6 may have an increased likelihood of loss of property or personal injury at these sites in the event of
 7 seismically-induced ground shaking. However, DWR would conform with Cal-OSHA and other state
 8 code requirements, such as shoring, bracing, lighting, excavation depth restrictions, required slope
 9 angles, and other measures, to protect worker safety. Conforming with these standards and codes is an
 10 environmental commitment of the project (see Appendix 3B, *Environmental Commitments*). Conforming
 11 with these health and safety requirements and the application of accepted, proven construction
 12 engineering practices would reduce any potential risk such that construction of Alternative 1A would
 13 not create an increased likelihood of loss of property, personal injury or death of individuals. This risk
 14 would be less than significant. No mitigation is required.

15 **Impact GEO-2: Loss of Property, Personal Injury, or Death from Settlement or Collapse Caused**
 16 **by Dewatering during Construction of Water Conveyance Features**

17 Settlement of excavations could occur as a result of dewatering at Alternative 1A construction sites
 18 with shallow groundwater. Soil excavation in areas with shallow or perched groundwater levels would
 19 require the pumping of groundwater from excavations to allow for construction of facilities. This can be
 20 anticipated at all intake locations (Sites 1–5) and pumping plant sites adjacent to the Sacramento River,
 21 where 70% of the dewatering for Alternative 1A would take place. All of the intake locations and
 22 adjacent pumping plants for Alternative 1A are located on alluvial floodbasin deposits, alluvial
 23 floodplain deposits and natural levee deposits. Similar dewatering may be necessary where intake and
 24 forebay pipelines cross waterways and major irrigation canals east of the Sacramento River and north
 25 of the proposed intermediate forebay. The conveyance pipeline between Intake 1 and tunnel 1 crosses
 26 three canals or ditches. Two of these would be a half mile south of the facility grounds for Intake 1 (or
 27 nearer) and the other would be about 0.4 miles north northwest of Scribner Road. The conveyance
 28 pipeline between Intake 3 and the intermediate forebay crosses five canals or ditches. Three are 0.6
 29 miles southeast of the facility grounds for Intake 3 (or nearer). The other two are both less than 0.25
 30 miles north of the connection with the intermediate forebay. Conveyance pipelines constructed for
 31 Intakes 2, 4, and 5 would not be anticipated to intersect with waterways or major irrigation canals.

32 Dewatering can stimulate settlement in excavation and tunneling sites. The settlement could cause the
 33 slopes of excavations to fail. This potential effect could be substantial because settlement or collapse
 34 during dewatering could result in collapse of excavations at the construction sites.

35 **NEPA Effects:** The hazard of settlement and subsequent collapse of excavations would be evaluated by
 36 assessing site-specific geotechnical and hydrological conditions at intake locations and adjacent
 37 pumping plants, as well as where intake and forebay pipelines cross waterways and major irrigation
 38 canals. A California-registered civil engineer or California-certified engineering geologist would
 39 recommend measures in a geotechnical report to address these hazards, such as seepage cutoff walls
 40 and barriers, shoring, grouting of the bottom of the excavation, and strengthening of nearby structures,
 41 existing utilities, or buried structures. As described in Section 9.3.1, *Methods for Analysis*, the measures
 42 would conform to applicable design and building codes, guidelines, and standards, such as the
 43 California Building Code and USACE's *Engineering and Design—Structural Design and Evaluation of*
 44 *Outlet Works*. See Appendix 3B, *Environmental Commitments*. In particular, conformance with the
 45 following codes and standards would reduce the potential risk for increased likelihood of loss of

1 property or personal injury from structural failure resulting from settlement or collapse at the
2 construction site caused by dewatering during construction:

- 3 • DWR Division of Flood Management FloodSAFE Urban Levee Design Criteria, May 2012.
- 4 • USACE Engineering and Design - Settlement Analysis, EM 1110-1-1904, 1990.
- 5 • California Code of Regulations, Title 8, Sections 1509 and 3203, California Code of Regulations.

6 Generally, the applicable codes require that facilities be built in such a way that settlement is
7 minimized. DWR would ensure that the geotechnical design recommendations are included in the
8 design of project facilities and construction specifications to minimize the potential effects from
9 settlement and failure of excavations. DWR would also ensure that the design specifications are
10 properly executed during construction. DWR has made an environmental commitment to conform with
11 appropriate code and standard requirements to minimize potential risks (Appendix 3B, *Environmental*
12 *Commitments*).

13 The worker safety codes and standards specify protective measures that must be taken at construction
14 sites to minimize the risk of injury or death from structural or earth failure (e.g., utilizing personal
15 protective equipment, practicing crane and scaffold safety measures). The relevant codes and
16 standards represent performance standards that must be met by contractors and these measures are
17 subject to monitoring by state and local agencies. Cal-OSHA requirements for an IIPP and the terms of
18 the IIPP to protect worker safety are the principal measures that would be enforced at construction
19 sites.

20 Conformance with these health and safety requirements and the application of accepted, proven
21 construction engineering practices would reduce any potential risk such that construction of
22 Alternative 1A would not create an increased likelihood of loss of property, personal injury or death of
23 individuals from settlement or collapse caused by dewatering. Therefore, there would be no adverse
24 effect.

25 **CEQA Conclusion:** Settlement or failure of excavations during construction could result in settlement or
26 collapse caused by dewatering at construction sites. However, DWR would conform with Cal-OSHA and
27 other state code requirements, such as using seepage cutoff walls, shoring, and other measures, to
28 protect worker safety. DWR or their contractors would also ensure that the design specifications are
29 properly executed during construction. DWR has made an environmental commitment to use the
30 appropriate code and standard requirements to minimize potential risks (see Appendix 3B,
31 *Environmental Commitments*). Conforming with these requirements and the application of accepted,
32 proven construction engineering practices would reduce any potential risk such that construction of
33 Alternative 1A would not create an increased likelihood of loss of property, personal injury or death of
34 individuals from settlement or collapse caused by dewatering. This risk would be less than significant.
35 No mitigation is required.

36 **Impact GEO-3: Loss of Property, Personal Injury, or Death from Ground Settlement during** 37 **Construction of Water Conveyance Features**

38 Two types of ground settlement could be induced during tunneling operations: large settlement and
39 systematic settlement. Large settlement occurs primarily as a result of over-excavation by the
40 tunneling shield. The over-excavation is caused by failure of the tunnel boring machine to control
41 unexpected or adverse ground conditions (for example, running, raveling, squeezing, and flowing
42 ground) or operator error. Minor settlement occurrences may not be discernible while large settlement

1 can range from interruption of utilities to hindrance of road access. Below the surface, large settlement
2 can lead to the creation of voids and/or sinkholes above the tunnel. This settlement can also affect the
3 ground surface. While this could potentially cause property loss or personal injury above the tunneling
4 operation, instances of large settlement are extremely unlikely to occur due to pre-construction
5 measures and other protective strategies and safety practices during construction. Site-specific
6 geotechnical investigations are needed to design the extent and type of ground improvement that may
7 be required. Ground improvement would be required to facilitate support of tunnel shafts, control
8 groundwater at the locations of the shafts, prevent development of undesired tunnel-induced surface
9 settlements and provide pre-defined zones for TBM maintenance interventions. The types of ground
10 improvement that would be considered include jet-grouting, permeation or compaction grouting, and
11 ground freezing. The choice usually depends on ground conditions and the methods preferred by the
12 contractor. Additionally, the use of earth pressure balance (EPB) tunnel boring machines (TBMs)
13 decreases the potential for over-excavation. EPB machines hold the excavated tunnel spoils in a
14 pressurized chamber behind the cutter head. This chamber is used to counterbalance earth pressures.
15 Pressure is held at the tunnel face by carefully controlling the rate of spoils withdrawal from the
16 chamber using a screw auger while the machine is pushed forward. The use of an EPB TBM enables the
17 construction of tunnels in soft ground conditions and a high water table. The TBM shield supports the
18 walls and roof of the excavation until the precast segmental liner is erected at the end of the shield. The
19 pressure at the face is maintained by the controlled release of excavated material via a screw conveyor.
20 Reusable tunnel material (RTM) is discharged into cars or onto conveyors to be removed off site.
21 Proper use of the EPB technique allows only the removal of the theoretically correct amount of
22 material, thus greatly reducing the potential of surface settlement.

23 Systematic settlement usually results from ground movements that occur before tunnel supports can
24 exit the shield and the tunnel to make full contact with the ground. Soil with higher silt and clay content
25 tend to experience less settlement than sandy soil. A deeper tunnel induces less ground surface
26 settlement because a greater volume of soil material is available above the tunnel to fill any systematic
27 void space.

28 The geologic units in the area of the Alternative 1A pipeline/tunnel alignment are shown on Figure 9-3
29 and summarized in Table 9-15. The characteristics of each unit would affect the potential for
30 settlement during tunneling operations. Segments 1 and 3 contain higher amounts of sand than the
31 other segments, so they pose a greater risk of settlement.

32 Given the likely design depth of the tunnel, the potential for excessive systematic settlement expressed
33 at the ground surface caused by tunnel installation is thought to be relatively low. Operator errors or
34 highly unfavorable/unexpected ground conditions could result in larger settlement. Large ground
35 settlements caused by tunnel construction are almost always the result of using inappropriate
36 tunneling equipment (incompatible with the ground conditions), improperly operating the machine, or
37 encountering sudden or unexpected changes in ground conditions.

1 **Table 9-15. Surficial Geology Underlying Alternative 1A/Pipeline/Tunnel Alignment by Segments**

Segment ^a	Geologic Unit	Geologic Unit Description
Segment 1 and Segment 2	Ql	Natural levee deposits: moderately- to well-sorted sand, with some silt and clay.
	Qb	Flood basin deposits: firm to stiff silty clay, clayey silt, and silt
	Qro	Riverbank Formation: alluvial fans from glaciated basins that consist of moderately sorted to well sort sand, gravel, silt and minor clay
	Qm2e	Eolian sand: well-sorted fine- to medium-grained sand
Segment 3	Ql	Natural levee deposits: moderately- to well-sorted sand, with some silt and clay.
	Qpm	Delta mud: mud and peat with minor silt or sand
Segment 4	Ql	Natural levee deposits: moderately- to well-sorted sand, with some silt and clay.
	Qpm	Delta mud: mud and peat with minor silt or sand
	Qb	Flood basin deposits: firm to stiff silty clay, clayey silt, and silt.
Segment 5 and Segment 6	Qpm	Delta mud: mud and peat with minor silt or sand
Segment 7	Qpm	Delta mud: mud and peat with minor silt or sand
	Qfp	Floodplain deposits: dense, sandy to silty clay
Segment 8	Qfp	Floodplain deposits: dense, sandy to silty clay
	Qch	Alluvial fans and terraces from non-glaciated drainage basins: clay, silt, sand, and gravel.

Sources: Hansen et al. 2001 and Atwater 1982.

^a The segments are shown on Figure 9-3.

2

3 **NEPA Effects:** The potential effect could be substantial because ground settlement could occur during
4 the tunneling operation. However, during detailed project design, a site-specific subsurface
5 geotechnical evaluation would be conducted along the pipeline/tunnel alignment to verify or refine the
6 findings of the preliminary geotechnical investigation. The tunneling equipment and drilling methods
7 would be reevaluated and refined based on the results of the investigations, and field procedures for
8 sudden changes in ground conditions (e.g., excavate and replace soft soil; staged construction to allow
9 soft soil to gain strength through consolidation) would be implemented to minimize or avoid ground
10 settlement. A California-registered civil engineer or California-certified engineering geologist would
11 recommend measures to address these hazards, such as specifying the type of tunnel boring machine to
12 be used in a given segment. The results of the site-specific evaluation and the engineer's
13 recommendations would be documented in a detailed geotechnical report prepared in accordance with
14 state guidelines, in particular *Guidelines for Evaluating and Mitigating Seismic Hazards in California*
15 (California Geological Survey 2008). The geotechnical report will contain site-specific evaluations of the
16 seismic hazard affecting the project, and will identify portions of the project site containing seismic
17 hazards. The report will also identify any known off-site seismic hazards that could adversely affect the
18 site in the event of an earthquake and make recommendations for appropriate mitigation as required
19 by 14 CCR 3724(a).

20 As described in Section 9.3.1, *Methods for Analysis*, the measures would conform to applicable design
21 and building codes, guidelines, and standards, such as USACE design measures. See Appendix 3B,

1 *Environmental Commitments*. In particular, conformance with the following codes and standards would
 2 reduce the potential risk for increased likelihood of loss of property or personal injury from ground
 3 settlement above the tunneling operation during construction:

- 4 • DWR Division of Engineering State Water Project – Seismic Loading Criteria Report, Sept 2012.
- 5 • DWR Division of Flood Management FloodSAFE Urban Levee Design Criteria, May 2012.
- 6 • California Code of Regulations, Title 8, Sections 1509 and 3203, California Code of Regulations.

7 As described in Impacts GEO-1 and GEO-2, DWR would ensure that the geotechnical design
 8 recommendations are included in the design of project facilities and construction specifications to
 9 minimize the potential effects from settlement. DWR would also ensure that the design specifications
 10 are properly executed during construction. DWR has made this conformance and monitoring process
 11 an environmental commitment of the BDCP (Appendix 3B, *Environmental Commitments*).

12 Generally, the applicable codes require that facilities be built so that they are designed for a landside
 13 slope stability and seepage/underseepage factors of safety greater than 1.0 (i.e., stable) and would
 14 therefore be less impacted in the event of ground settlement. The worker safety codes and standards
 15 specify protective measures that must be taken at construction sites to minimize the risk of injury or
 16 death from structural or earth failure (e.g., utilizing personal protective equipment, practicing crane
 17 and scaffold safety measures). The relevant codes and standards represent performance standards that
 18 must be met by contractors and these measures are subject to monitoring by state and local agencies.
 19 Cal-OSHA requirements for an IIPP and the terms of the IIPP to protect worker safety are the principal
 20 measures that would be enforced at construction sites.

21 Conformance to these and other applicable design specifications and standards would ensure that
 22 construction of Alternative 1A would not create an increased likelihood of loss of property, personal
 23 injury or death of individuals from ground settlement. Therefore, there would be no adverse effect.

24 **CEQA Conclusion:** Ground settlement above the tunneling operation could result in loss of property or
 25 personal injury during construction. However, DWR would conform with Cal-OSHA, USACE, and other
 26 design requirements to protect worker safety. DWR would also ensure that the design specifications
 27 are properly executed during construction. DWR has made an environmental commitment to use the
 28 appropriate code and standard requirements to minimize potential risks (Appendix 3B, *Environmental*
 29 *Commitments*). Conformance with these requirements and the application of accepted, proven
 30 construction engineering practices would reduce any potential risk such that construction of
 31 Alternative 1A would not create an increased likelihood of loss of property, personal injury or death of
 32 individuals from ground settlement. This risk would be less than significant. No mitigation is required.

33 **Impact GEO-4: Loss of Property, Personal Injury, or Death from Slope Failure during** 34 **Construction of Water Conveyance Features**

35 Excavation of borrow material could result in failure of cut slopes and application of temporary spoils
 36 and RTM at storage sites could cause excessive settlement in the spoils at the construction sites leading
 37 to collapse of slopes. Soil and sediment, especially those consisting of loose alluvium and soft peat or
 38 mud, would be particularly prone to failure and movement. Additionally, groundwater is expected to be
 39 within a few feet of the ground surface in these areas; this may make excavations more prone to failure.

40 Borrow and spoils areas for construction of intakes, sedimentation basins, pumping plants, forebays,
 41 and other supporting facilities would be sited near the locations of these structures (generally within
 42 10 miles). Along the pipeline/tunnel alignment, selected areas would also be used for disposing of the

1 byproduct (RTM) of tunneling operations. Table 9-16 describes the geology of these areas as mapped
 2 by Atwater (1982) (Figure 9-3).

3 **Table 9-16. Geology Underlying Borrow/Spoils and Reusable Tunnel Material Storage Areas—Alternative 1A**

Segment ^a	Geologic Unit	Geologic Unit Description
Segment 1 Borrow/Spoils Area	Ql	Natural levee deposits: moderately to well-sorted sand, with some silt and clay
	Qb	Flood basin deposits: firm to stiff silty clay, clayey silt, and silt
Segment 2 Borrow/Spoils Area	Ql	Natural levee deposits: moderately to well-sorted sand, with some silt and clay.
	Qb	Flood basin deposits: firm to stiff silty clay, clayey silt, and silt
	Qpm	Delta mud: mud and peat with minor silt or sand
Segment 9 Borrow/Spoils Area	Qch	Alluvial fans and terraces from non-glaciated drainage basins: clay, silt, sand and gravel
Segment 2 Reusable Tunnel Material Area	Ql	Natural levee deposits: moderately to well-sorted sand, with some silt and clay
	Qb	Flood basin deposits: firm to stiff silty clay, clayey silt, and silt
Segment 4 Reusable Tunnel Material Area	Ql	Natural levee deposits: moderately to well-sorted sand, with some silt and clay
	Qpm	Delta mud: mud and peat with minor silt or sand
Segment 5 and Segment 6 Reusable Tunnel Material Area	Qpm	Delta mud: mud and peat with minor silt or sand
Segment 7 Reusable Tunnel Material Area	Qfp	Floodplain deposits: dense, sandy to silty clay

Source: Hansen et al. 2001; Atwater 1982.

^a The segments are shown on Figure 9-3.

4
 5 **NEPA Effects:** The potential effect could be substantial because excavation of borrow material and the
 6 resultant cutslopes and potential failure of spoils/RTM fill slopes could cause injury of workers at the
 7 construction sites.

8 Excavations in borrow areas would be designed to avoid excessive ground movements on adjacent
 9 areas and soil “boiling” (i.e., upwelling of groundwater) at the bottom of the excavation. Spoils would be
 10 placed in 12-inch lifts with proper compaction and stored no higher than 12 feet above preconstruction
 11 ground elevation with maximum side slopes of 5H:1V. During design, the potential for native ground
 12 settlement below the spoils would be evaluated by a geotechnical engineer using site-specific
 13 geotechnical and hydrological information. The use of shoring, seepage cutoff walls, and ground
 14 modifications to prevent slope instability, soil boiling, or excessive settlement would be considered in
 15 the design.

16 In addition to the risk of slope failure at borrow sites and spoils and RTM sites, there are also potential
 17 impacts on levee stability resulting from construction of Alternative 1A water conveyance facilities. The
 18 intakes would be sited along the existing Sacramento River levee system, requiring reconstruction of
 19 levees to provide continued flood management. At each intake pumping plant site, a new setback levee

1 (ring levee) would be constructed. The space enclosed by the setback levee would be filled up to the
2 elevation of the top of the setback levee, creating a building pad for the adjacent pumping plant.

3 As discussed in Chapter 3, *Description of the Alternatives*, the new levees would be designed to provide
4 an adequate Sacramento River channel cross section and to provide the same level of flood protection
5 as the existing levee and would be constructed to geometries that meet or exceed PL 84-99 standards.
6 CALFED and DWR have adopted PL 84-99 as the preferred design standard for Delta levees. Transition
7 levees would be constructed to connect the existing levees to the new setback levees. A typical new
8 levee would have a broad-based, generally asymmetrical triangular cross section. The levee height
9 considered wind and wave erosion. As measured from the adjacent ground surface on the landside
10 vertically up to the elevation of the levee crest, would range from approximately 20 to 45 feet to
11 provide adequate freeboard above anticipated water surface elevations. The width of the levee (toe of
12 levee to toe of levee) would range from approximately 180 to 360 feet. The minimum crest width of the
13 levee would be 20 feet; however, in some places it would be larger to accommodate roadways and
14 other features. Cut-off walls would be constructed to avoid seepage, and the minimum slope of levee
15 walls would be three units horizontal to one unit vertical. All levee reconstruction will conform with
16 applicable state and federal flood management engineering and permitting requirements.

17 Depending on foundation material, foundation improvements would require excavation and
18 replacement of soil below the new levee footprint and potential ground improvement. The levees
19 would be armored with riprap—small to large angular boulders—on the waterside. Intakes would be
20 constructed using a sheetpile cofferdam in the river to create a dewatered construction area that would
21 encompass the intake site. The cofferdam would lie approximately 10–35 feet from the footprint of the
22 intake and would be built from upstream to downstream, with the downstream end closed last. The
23 distance between the face of the intake and the face of the cofferdam would be dependent on the
24 foundation design and overall dimensions. The length of each temporary cofferdam would vary by
25 intake location, but would range from 740 to 2,440 feet. Cofferdams would be supported by steel sheet
26 piles and/or king piles (heavy H-section steel piles). Installation of these piles may require both impact
27 and vibratory pile drivers. Some clearing and grubbing of levees would be required prior to installation
28 of the sheet pile cofferdam, depending on site conditions. Additionally, if stone bank protection, riprap,
29 or mature vegetation is present at intake construction site, it would be removed prior to sheet pile
30 installation.

31 As described in Section 9.3.1, *Methods for Analysis*, the measures would conform to applicable design
32 and building codes, guidelines, and standards, such as the California Building Code and USACE's
33 *Engineering and Design—Structural Design and Evaluation of Outlet Works*. DWR has made the
34 environmental commitment (see Appendix 3B, *Environmental Commitments*) that the geotechnical
35 design recommendations are included in the design of project facilities and construction specifications
36 to minimize the potential effects from failure of excavations and settlement. DWR also has committed
37 to ensure that the design specifications are properly executed during construction. In particular,
38 conformance with the following codes and standards would reduce the potential risk for increased
39 likelihood of loss of property or personal injury from settlement/failure of cutslopes of borrow sites
40 and failure of soil or RTM fill slopes during construction:

- 41 • DWR Division of Engineering State Water Project – Seismic Loading Criteria Report, Sept 2012.
- 42 • DWR Division of Flood Management FloodSAFE Urban Levee Design Criteria, May 2012.
- 43 • California Code of Regulations, Title 8, Sections 1509 and 3203, California Code of Regulations.

1 Generally, the applicable codes require that facilities be built to certain factors of safety in order to
 2 ensure that facilities perform as designed for the life of the structure despite various soil parameters.
 3 The worker safety codes and standards specify protective measures that must be taken at construction
 4 sites to minimize the risk of injury or death from structural or earth failure (e.g., utilizing personal
 5 protective equipment, practicing crane and scaffold safety measures). The relevant codes and
 6 standards represent performance standards that must be met by contractors and these measures are
 7 subject to monitoring by state and local agencies. Cal-OSHA requirements for an IIPP and the terms of
 8 the IIPP to protect worker safety are the principal measures that would be enforced at construction
 9 sites.

10 Conformance to these and other applicable design specifications and standards would ensure that
 11 construction of Alternative 1A would not create an increased likelihood of loss of property or injury of
 12 individuals from slope failure at borrow sites and spoils and RTM storage sites. The reconstruction of
 13 levees would improve levee stability over existing conditions due to improved side slopes, erosion
 14 countermeasures (geotextile fabrics, rock revetments, riprap, or other material), seepage reduction
 15 measures, and overall mass. Therefore, there would be no adverse effect.

16 **CEQA Conclusion:** Settlement/failure of cutslopes of borrow sites and failure of soil/RTM fill slopes
 17 could result in loss of property or personal injury during construction. However, DWR would conform
 18 with Cal-OSHA and other state code requirements and conform to applicable geotechnical design
 19 guidelines and standards, such as USACE design measures. Conformance with these requirements and
 20 the application of accepted, proven construction engineering practices would reduce any potential risk
 21 such that construction of Alternative 1A would not create an increased likelihood of loss of property,
 22 personal injury or death of individuals from slope failure at borrow sites and spoils and RTM storage
 23 sites. The reconstruction of levees would improve levee stability over existing conditions due to
 24 improved side slopes, erosion countermeasures, seepage reduction measures, and overall mass. The
 25 impact would be less than significant. No mitigation is required.

26 **Impact GEO-5: Loss of Property, Personal Injury, or Death from Structural Failure Resulting**
 27 **from Construction-Related Ground Motions during Construction of Water Conveyance Features**

28 Pile driving and other heavy equipment operations would cause vibrations that could initiate
 29 liquefaction and associated ground movements in places where soil and groundwater conditions are
 30 present to allow liquefaction to occur. The consequences of liquefaction could be manifested in terms of
 31 compaction or settlement, loss of bearing capacity, lateral spreading (horizontal soil movement),
 32 increased lateral soil pressure, and buoyancy within zones of liquefaction. These consequences could
 33 cause loss of property or personal injury and could damage nearby structures and levees.

34 The lateral extent (or influenced distance) of damage potential caused by pile driving and heavy
 35 equipment operations depends on many factors, including soil conditions, the piling hammer used,
 36 frequency of piling, and the vibration tolerance of structures and levees.

37 Pile driving would be conducted at the intakes, where, based on boring logs, soil materials subject to
 38 liquefaction (e.g., saturated, poorly graded sand) are present. During project design, site-specific
 39 geotechnical and groundwater investigations would be conducted to build upon existing data (e.g.,
 40 California Department of Water Resources 2010a, 2010b, 2011) to identify and characterize the
 41 vertical (depth) and horizontal (spatial) variability in soil bearing capacity and extent of liquefiable soil.
 42 Engineering soil parameters that could be used to assess the liquefaction potential, such as (SPT) blow
 43 counts, (CPT) penetration tip pressure/resistance, and gradation of soil, would also be obtained. SPT
 44 blow counts and CPT tip pressure are used to estimate soil resistance to cyclic loadings by using

1 empirical relationships that were developed based on occurrences of liquefaction (or lack of them)
 2 during past earthquakes. The resistance then can be compared to cyclic shear stress induced by the
 3 design earthquake (i.e., the earthquake that is expected to produce the strongest level of ground
 4 shaking at a site to which it is appropriate to design a structure to withstand). If soil resistance is less
 5 than induced stress, the potential of having liquefaction during the design earthquakes is high. It is also
 6 known that soil with high “fines” (i.e., silt- and clay-sized particles) content are less susceptible to
 7 liquefaction.

8 **NEPA Effects:** The potential effect could be substantial because construction-related ground motions
 9 could initiate liquefaction, which could cause failure of structures during construction.

10 During design, the facility-specific potential for liquefaction would be investigated by a geotechnical
 11 engineer. The potential effects of construction vibrations on nearby structures, levees, and utilities
 12 would be evaluated using specific piling information (such as pile type, length, spacing, and pile-driving
 13 hammer to be used). In areas determined to have a potential for liquefaction, the California-registered
 14 civil engineer or California-certified engineering geologist would develop design strategies and
 15 construction methods to ensure that pile driving and heavy equipment operations do not damage
 16 facilities under construction and surrounding structures, and do not threaten the safety of workers at
 17 the site (e.g., compaction grouting, which consists of pumping a thick grout mixture into the soil under
 18 high pressure forming a grout bulb which compacts the surrounding soil by displacement; removal and
 19 replacement of liquefaction susceptible soil; etc.). As shown in Figure 9-6, the area south of the
 20 Sacramento River all the way across Woodward Island, which Alternative 1A crosses through, has
 21 medium to medium-high potential for levee liquefaction damage. Two fuel stations, a concrete batch
 22 plant, as well as a barge unloading facility are located in this medium to medium-high potential for
 23 levee liquefaction damage area. Design strategies may include predrilling or jetting, using open-ended
 24 pipe piles to reduce the energy needed for pile penetration, using cast-in-place-drill-hole (CIDH)
 25 piles/piers that do not require driving, using pile jacking to press piles into the ground by means of a
 26 hydraulic system, or driving piles during the drier summer months. Field data collected during design
 27 also would be evaluated to determine the need for and extent of strengthening levees, embankments,
 28 and structures to reduce the effect of vibrations. These construction methods would conform with
 29 current seismic design codes and requirements, as described in Appendix 3B, *Environmental*
 30 *Commitments*. Such design standards include USACE’s *Engineering and Design—Stability Analysis of*
 31 *Concrete Structures and Soil Liquefaction during Earthquakes*, by the Earthquake Engineering Research
 32 Institute.

33 DWR has made the environmental commitment (see Appendix 3B, *Environmental Commitments*) that
 34 the construction methods recommended by the geotechnical engineer are included in the design of
 35 project facilities and construction specifications to minimize the potential for construction-induced
 36 liquefaction. DWR also has committed to ensure that these methods are followed during construction.

37 In particular, conformance with the following codes and standards would reduce the potential risk for
 38 increased likelihood of loss of property or personal injury from structural failure resulting from
 39 construction-related ground motions:

- 40 • USACE Engineering and Design—Design of Pile Foundations, EM 1110-2-2906, 1991
- 41 • USACE Engineering and Design, Earthquake Design and Evaluation for Civil Works Projects, ER 1110-
 42 2-1806, 1995
- 43 • California Code of Regulations, Title 8, Sections 1509 and 3203, California Code of Regulations.

1 Generally, the applicable codes require that facilities be built so that if soil in the foundation or
 2 surrounding area are subject to liquefaction, the removal or densification of the liquefiable material
 3 should be considered, along with alternative foundation designs. Additionally, any modification to a
 4 federal levee system would require USACE approval under 33 USC 408 (a 408 Permit) and would have
 5 to pass quality assurance review by the Major Subordinate Command prior to being forwarded to
 6 USACE headquarters for final approval by the Chief of Engineers.

7 The worker safety codes and standards specify protective measures that must be taken at construction
 8 sites to minimize the risk of injury or death from structural or earth failure (e.g., utilizing personal
 9 protective equipment, practicing crane and scaffold safety measures). The relevant codes and
 10 standards represent performance standards that must be met by contractors and these measures are
 11 subject to monitoring by state and local agencies. Cal-OSHA requirements for an IIPP and the terms of
 12 the IIPP to protect worker safety are the principal measures that would be enforced at construction
 13 sites.

14 Conformance to construction method recommendations and other applicable specifications would
 15 ensure that construction of Alternative 1A would not create an increased likelihood of loss of property,
 16 personal injury or death of individuals due to construction-related ground motion and resulting
 17 potential liquefaction in the work area. Therefore, there would be no adverse effect.

18 **CEQA Conclusion:** Construction-related ground motions could initiate liquefaction, which could cause
 19 failure of structures during construction, which could result in injury of workers at the construction
 20 sites. However, DWR would conform with Cal-OSHA and other state code requirements and conform to
 21 applicable design guidelines and standards, such as USACE design measures. Conformance with these
 22 requirements and the application of accepted, proven construction engineering practices would reduce
 23 any potential risk such that construction of Alternative 1A would not create an increased likelihood of
 24 loss of property, personal injury or death of individuals from construction-related ground motion and
 25 resulting potential liquefaction in the work area and the hazard would be controlled to a level that
 26 would protect worker safety (see Appendix 3B, *Environmental Commitments*). The impact would be less
 27 than significant. No mitigation is required.

28 **Impact GEO-6: Loss of Property, Personal Injury, or Death from Structural Failure Resulting**
 29 **from Rupture of a Known Earthquake Fault during Operation of Water Conveyance Features**

30 According to the available AP Fault Zone Maps, none of the Alternative 1A facilities would cross or be
 31 within any known active fault zones. However, numerous AP fault zones have been mapped west of the
 32 conveyance alignment (Figure 9-5). The closest AP fault zone would be the Greenville fault, located
 33 approximately 7.6 miles west of the conveyance facilities. Because none of the Alternative 1A
 34 constructed facilities would be within any of the fault zones (which include the area approximately
 35 200 to 500 feet on each side of the mapped surface trace to account for potential branches of active
 36 faults), the potential that the facilities would be directly subject to fault offsets is negligible.

37 In the Delta, active or potentially active blind thrust faults were identified in the seismic study.
 38 Segments 3, 4, and 5 of the Alternative 1A conveyance alignment (Figure 9-3) would cross the
 39 Thornton Arch fault zone. The western part of the proposed Byron Tract Forebay adjacent to the Clifton
 40 Court Forebay is underlain by the West Tracy fault. Although these blind thrusts are not expected to
 41 rupture to the ground surface under the forebays during earthquake events, they may produce ground
 42 or near-ground shear zones, bulging, or both (California Department of Water Resources 2007a). If the
 43 West Tracy fault is potentially active, it could cause surface deformation in the western part of the
 44 Clifton Court Forebay. Because the western part of the Byron Tract Forebay is also underlain by the

1 hanging wall of the fault, this part of the forebay may also experience uplift and resultant surface
2 deformation (Fugro Consultants 2011). In the seismic study (California Department of Water Resources
3 2007a), the Thornton Arch and West Tracy blind thrusts have been assigned 20% and 90%
4 probabilities of being active, respectively. The depth to the Thornton Arch blind fault is unknown. The
5 seismic study indicates that the West Tracy fault dies out as a discernible feature within approximately
6 3,000 to 6,000 feet below ground surface (bgs) [in the upper 1- to 2-second depth two-way time,
7 estimated to be approximately 3,000 to 6,000 feet using the general velocity function as published in
8 the Association of Petroleum Geologists Pacific Section newsletter (Tolmachoff 1993)].

9 It appears that the potential of having any shear zones, bulging, or both at the depths of the
10 pipeline/tunnel is low because the depth to the blind thrust faults is generally deep and there is no
11 credible evidence to indicate that the faults could experience displacement within the depth of the
12 pipeline/tunnel.

13 **NEPA Effects:** The effect would not be adverse because no active faults extend into the Alternative 1A
14 alignment. Additionally, although the Thornton Arch and West Tracy blind thrusts occur beneath the
15 Alternative 1A alignment, they do not present a hazard of surface rupture based on available
16 information, including the AP Earthquake Fault Zone Map showing faults capable of surface rupture
17 (Figure 9-5).

18 However, because there is limited information regarding the depths of the Thornton Arch and West
19 Tracy blind thrusts, seismic surveys would be performed on the blind thrust during the design phase to
20 determine the depths to the top of the faults. More broadly, design-level geotechnical studies would be
21 prepared by a geotechnical engineer licensed in the state of California during project design. The
22 studies would further assess site-specific conditions at and near all the project facility locations,
23 including seismic activity, soil liquefaction, and other potential geologic and soil-related hazards. This
24 information would be used to verify assumptions and conclusions included in the EIR/EIS. The
25 geotechnical engineer's recommended measures to address adverse conditions would conform to
26 applicable design codes, guidelines, and standards. Potential design strategies or conditions could
27 include avoidance (deliberately positioning structures and lifelines to avoid crossing identified shear
28 rupture zones), geotechnical engineering (using the inherent capability of unconsolidated geomaterials
29 to "locally absorb" and distribute distinct bedrock fault movements) and structural engineering
30 (engineering the facility to undergo some limited amount of ground deformation without collapse or
31 significant damage).

32 As described in Section 9.3.1, *Methods for Analysis*, such design codes, guidelines, and standards are
33 considered environmental commitments by DWR (see also Appendix 3B, *Environmental Commitments*).
34 For construction of the water conveyance facilities, the codes and standards would include the
35 California Building Code and resource agency and professional engineering specifications, such as the
36 Division of Safety of Dams *Guidelines for Use of the Consequence Hazard Matrix and Selection of Ground*
37 *Motion Parameters*, DWR's Division of Flood Management *FloodSAFE Urban Levee Design Criteria*, and
38 USACE's *Engineering and Design—Earthquake Design and Evaluation for Civil Works Projects*. These
39 codes and standards include minimum performance standards for structural design, given site-specific
40 subsurface conditions.

41 DWR would ensure that the geotechnical design recommendations are included in the design of project
42 facilities and construction specifications to minimize the potential effects from seismic events and the
43 presence of adverse soil conditions. DWR would also ensure that the design specifications are properly
44 executed during construction.

1 In particular, conformance with the following codes and standards would reduce the potential risk for
 2 increased likelihood of loss of property or personal injury from structural failure resulting from surface
 3 rupture resulting from a seismic event during operation:

- 4 • DWR Division of Engineering State Water Project – Seismic Loading Criteria Report, Sept 2012.
- 5 • USACE Engineering and Design – Time-History Dynamic Analysis of Concrete Hydraulic Structure, EM
 6 1110-2-6051, 2003.
- 7 • USACE Engineering and Design – Response Spectra and Seismic Analysis for Concrete Hydraulic
 8 Structures, EM 1110-2-6050, 1999.
- 9 • American Society of Civil Engineers Minimum Design Loads for Buildings and Other Structures,
 10 ASCE-7-05, 2005.
- 11 • California Code of Regulations, Title 8, Section 3203, California Code of Regulations.

12 Generally, the applicable codes require that facilities be built so that they incur minimal damage in the
 13 event of a foreseeable seismic event and that they remain functional following such an event and that
 14 the facility is able to perform without catastrophic failure in the event of a maximum design earthquake
 15 (the greatest earthquake reasonably expected to be generated by a specific source on the basis of
 16 seismological and geological evidence).

17 The worker safety codes and standards specify protective measures that must be taken at construction
 18 sites to minimize the risk of injury or death from structural or earth failure (e.g., utilizing personal
 19 protective equipment). The relevant codes and standards represent performance standards that must
 20 be met by contractors and these measures are subject to monitoring by state and local agencies. Cal-
 21 OSHA requirements for an IIPP and the terms of the IIPP to protect worker safety are the principal
 22 measures that would be enforced at construction sites.

23 Conformance to these and other applicable design specifications and standards would ensure that
 24 operation of Alternative 1A would not create an increased likelihood of loss of property or injury in the
 25 event of ground movement in the vicinity of the Thornton Arch fault zone and West Tracy, blind thrust
 26 would not jeopardize the integrity of the surface and subsurface facilities along the Alternative 1A
 27 conveyance alignment or the proposed forebay and associated facilities adjacent to the Clifton Court
 28 Forebay. Therefore, there would be no adverse effect.

29 **CEQA Conclusion:** There are no active faults capable of surface rupture that extend into the
 30 pipeline/tunnel alignment. Although the Thornton Arch and West Tracy blind thrusts occur beneath
 31 the pipeline/tunnel alignment, they do not present a hazard of surface rupture based on available
 32 information. Conformance to applicable design specifications and standards would ensure that
 33 operation of Alternative 1A would not create an increased likelihood of loss of property or injury of
 34 individuals in the event of ground movement in the vicinity of the Thornton Arch fault zone and West
 35 Tracy, blind thrust would not jeopardize the integrity of the surface and subsurface facilities along the
 36 Alternative 1A conveyance alignment or the proposed forebay and associated facilities adjacent to the
 37 Clifton Court Forebay. There would be no impact. No mitigation is required.

38 **Impact GEO-7: Loss of Property, Personal Injury, or Death from Structural Failure Resulting** 39 **from Strong Seismic Shaking during Operation of Water Conveyance Features**

40 Earthquake events may occur on the local and regional seismic sources during operation of the
 41 Alternative 1A water conveyance facilities. The ground shaking could damage pipelines, tunnels, intake
 42 Table 9-17 shows that the proposed facilities would be subject to moderate-to-high earthquake ground

1 shaking through 2025. All facilities would be designed and constructed in accordance with the
 2 requirements of the design guidelines and building codes described in Appendix 3B. Site-specific
 3 geotechnical information would be used to further assess the effects of local soil on the OBE and MDE
 4 ground shaking and to develop design criteria that minimize damage potential facilities, pumping
 5 plants, and other facilities disrupting the water supply through the conveyance system. In an extreme
 6 event of strong seismic shaking, uncontrolled release of water from damaged pipelines, tunnels, intake
 7 facilities, pumping plants, and other facilities could cause flooding, disruption of water supplies to the
 8 south, inundation of structures, property loss, and injury. These effects are discussed more fully in
 9 Appendix 3E, *Potential Seismicity and Climate Change Risks to SWP/CVP Water Supplies*.

10 Table 9-17 lists the expected PGA and 1.0- S_a values in 2025 at selected facility locations. For early long-
 11 term, earthquake ground motions with return periods of 144 years and 975 years were estimated from
 12 the results presented in the seismic study (California Department of Water Resources 2007a). The
 13 144-year and 975-year ground motions correspond to the OBE (i.e., an earthquake that has a 50%
 14 probability of exceedance in a 100-year period (which is equivalent to a 144-year return period event)
 15 and the MDE (i.e., an earthquake that causes ground motions that have a 10% chance of being exceeded
 16 in 100 years) design ground motions, respectively. Values were estimated for a stiff soil site (as
 17 predicted in the seismic study), and for the anticipated soil conditions at the facility locations. No
 18 seismic study results exist for 2025, so the ground shaking estimated for the 2050 were used for Early
 19 Long-term (2025).

20 **Table 9-17. Expected Earthquake Ground Motions at Locations of Selected Major Facilities in the Early Long-**
 21 **Term (2025)—Alternative 1A**

Major Facilities	144-year Return Period Ground Motions (OBE)			
	Peak Ground Acceleration (g)		1.0-sec S_a (g)	
	Stiff Soil ^a	Local Soil ^b	Stiff Soil ^a	Local Soil ^b
Intake Locations ^c	0.14	0.15	0.19	0.30
Tunnel Location near Venice Island ^d	0.30	0.33	0.31	0.50
Clifton Court Forebay/Byron Tract Forebay	0.28	0.31	0.30	0.48
Major Facilities	975-year Return Period Ground Motions (MDE)			
	Peak Ground Acceleration (g)		1.0-sec S_a (g)	
	Stiff Soil ^a	Local Soil ^e	Stiff Soil ^a	Local Soil ^e
Intake Locations ^c	0.24	0.24	0.33	0.53
Tunnel Location near Venice Island ^d	0.50	0.50	0.60	0.96
Clifton Court Forebay/Byron Tract Forebay	0.50	0.50	0.61	0.98

g = gravity

MDE = maximum design earthquake

OBE = operating basis earthquake

PGA = Peak Ground Acceleration

S_a = second spectral acceleration

^a Stiff soil site, with a V_{s100ft} value of 1,000 ft/s.

^b Site-adjusted factors of 1.1 and 1.60 were applied to PGA and 1.0-sec S_a values, respectively.

^c The results of California Department of Water Resources 2007a for the Sacramento site were used.

^d The results of California Department of Water Resources 2007a for the Sherman Island were used.

^e Site-adjusted factors of 1.0 and 1.60 were applied to PGA and 1.0-sec S_a values, respectively.

1 This potential effect could be substantial because strong ground shaking could damage pipelines,
2 tunnels, intake facilities, pumping plants, and other facilities and result in loss of property or personal
3 injury. The damage could disrupt the water supply through the conveyance system. In an extreme
4 event, an uncontrolled release of water from the conveyance system could cause flooding and
5 inundation of structures. Please refer to Chapter 6, *Surface Water* and Appendix 3E, *Potential Seismicity*
6 *and Climate Change Risks to SWP/CVP Water Supplies*, for a detailed discussion of potential flood effects.

7 The structure of the underground conveyance facility would decrease the likelihood of loss of property
8 or personal injury of individuals from structural shaking of surface and subsurface facilities along the
9 Alternative 1A conveyance alignment in the event of strong seismic shaking. The conveyance pipeline
10 will be lined with precast concrete which will be installed continuously following the advancement of a
11 pressurized tunnel boring machine. The lining consists of precast concrete segments inter-connected to
12 maintain alignment and structural stability during construction. Reinforced concrete segments are
13 precast to comply with strict quality control. High performance gasket maintains water tightness at the
14 concrete joints, while allowing the joint to rotate and accommodate movements during intense ground
15 shaking. Precast concrete tunnel lining (PCTL) has been used extensively in seismically active locations
16 such as Japan, Puerto Rico, Taiwan, Turkey, Italy and Greece. The adoption of PCTL in the United States
17 started about 20 years ago, including many installations in seismically active areas such as Los Angeles,
18 San Diego, Portland and Seattle. PCTL provides better seismic performance than conventional tunnels
19 for several reasons:

- 20 • higher quality control using precast concrete
- 21 • better ring-build precision with alignment connectors
- 22 • backfill grouting for continuous ground to tunnel support
- 23 • segment joints provide flexibility and accommodate deformation during earthquakes
- 24 • high performance gasket to maintain water tightness during and after seismic movement

25 Reviewing the last 20 years of PCTL seismic performance histories, it can be concluded that little or no
26 damage to PCTL was observed for major earthquakes around the world. Case studies of the response of
27 PCTL to large seismic events have shown that PCTL should not experience significant damage for
28 ground acceleration less than 0.5g (Dean et al. 2006). The design PGA for a 975-year return period is
29 0.49g (California Department of Water Resources 2010i, Table 4-4). Based on this preliminary data, the
30 Delta tunnels can be designed to withstand the anticipated seismic loads.

31 Design-level geotechnical studies would be conducted by a licensed civil engineer who practices in
32 geotechnical engineering. The studies would assess site-specific conditions at and near all the project
33 facility locations and provide the basis for designing the conveyance features to withstand the peak
34 ground acceleration caused by fault movement in the region. The geotechnical report will contain site-
35 specific evaluations of the seismic hazard affecting the project, and will identify portions of the project
36 site containing seismic hazards. The report will also identify any known off-site seismic hazards that
37 could adversely affect the site in the event of an earthquake and make recommendations for
38 appropriate mitigation as required by 14 CCR 3724(a). The California-registered civil engineer or
39 California-certified engineering geologist's recommended measures to address this hazard would
40 conform to applicable design codes, guidelines, and standards. Design strategies could include
41 measures such as slope stabilization and removing or replacing liquefaction-prone soil during grading,
42 site strengthening through dynamic compaction methods, deep densification of the soil through
43 blasting, or other site improvement methods.

1 As described in Section 9.3.1, *Methods for Analysis*, and in Appendix 3B, *Environmental Commitments*,
 2 such design codes, guidelines, and standards include the California Building Code and resource agency
 3 and professional engineering specifications, such as the Division of Safety of Dams *Guidelines for Use of*
 4 *the Consequence Hazard Matrix and Selection of Ground Motion Parameters*, DWR's Division of Flood
 5 Management *FloodSAFE Urban Levee Design Criteria*, and USACE's *Engineering and Design—Earthquake*
 6 *Design and Evaluation for Civil Works Projects*. Conformance with these codes and standards are an
 7 environmental commitment by DWR to ensure that ground shaking risks are minimized as the water
 8 conveyance features are operated.

9 DWR would ensure that the geotechnical design recommendations are included in the design of project
 10 facilities and construction specifications to minimize the potential effects from seismic events and the
 11 presence of adverse soil conditions. DWR would also ensure that the design specifications are properly
 12 executed during construction. See Appendix 3B, *Environmental Commitments*.

13 In particular, conformance with the following codes and standards would reduce the potential risk for
 14 increased likelihood of loss of property or personal injury from structural failure resulting from strong
 15 seismic shaking of water conveyance features during operations:

- 16 • DWR Division of Engineering State Water Project–Seismic Loading Criteria Report, Sept 2012.
- 17 • USACE Engineering and Design–Time-History Dynamic Analysis of Concrete Hydraulic Structure, EM
 18 1110-2-6051, 2003.
- 19 • USACE Engineering and Design–Response Spectra and Seismic Analysis for Concrete Hydraulic
 20 Structures, EM 1110-2-6050, 1999.
- 21 • American Society of Civil Engineers Minimum Design Loads for Buildings and Other Structures,
 22 ASCE-7-05, 2005.
- 23 • California Code of Regulations, Title 8, Section 3203, California Code of Regulations.

24 Generally, the applicable codes require that facilities be built so that they incur minimal damage in the
 25 event of a foreseeable seismic event and that they remain functional following such an event and that
 26 the facility is able to perform without catastrophic failure in the event of a maximum design earthquake
 27 (the greatest earthquake reasonably expected to be generated by a specific source on the basis of
 28 seismological and geological evidence).

29 **NEPA Effects:** Conformance with the aforementioned standards and codes are an environmental
 30 commitment of the project (see Appendix 3B, *Environmental Commitments*). The worker safety codes
 31 and standards specify protective measures that must be taken at construction sites to minimize the risk
 32 of injury or death from structural or earth failure (e.g., utilizing personal protective equipment). The
 33 relevant codes and standards represent performance standards that must be met by contractors and
 34 these measures are subject to monitoring by state and local agencies. Cal-OSHA requirements for an
 35 IIPP and the terms of the IIPP to protect worker safety are the principal measures that would be
 36 enforced at project sites during operations.

37 Conformance to these and other applicable design specifications and standards would ensure that
 38 operation of Alternative 1A would not create an increased likelihood of loss of property, personal
 39 injury or death of individuals from structural shaking of surface and subsurface facilities along the
 40 Alternative 1A conveyance alignment in the event of strong seismic shaking. Therefore, there would be
 41 no adverse effect.

1 **CEQA Conclusion:** Seismically induced strong ground shaking could damage pipelines, tunnels, intake
 2 facilities, pumping plants, and other facilities and result in loss of property or personal injury. The
 3 damage could disrupt the water supply through the conveyance system. In an extreme event, an
 4 uncontrolled release of water from the damaged conveyance system could cause flooding and
 5 inundation of structures. However, through the final design process, measures to address this hazard
 6 would be required to conform to applicable design codes, guidelines, and standards. As described in
 7 Section 9.3.1, *Methods for Analysis*, and in Appendix 3B, *Environmental Commitments*, such design
 8 codes, guidelines, and standards include the California Building Code and resource agency and
 9 professional engineering specifications, such as the Division of Safety of Dams *Guidelines for Use of the*
 10 *Consequence Hazard Matrix and Selection of Ground Motion Parameters*, DWR's Division of Flood
 11 Management *FloodSAFE Urban Levee Design Criteria*, and USACE's *Engineering and Design—Earthquake*
 12 *Design and Evaluation for Civil Works Projects*. Conformance with these codes and standards is an
 13 environmental commitment by DWR to ensure that ground shaking risks are minimized as the
 14 Alternative 1A water conveyance features are operated and there would be no increased likelihood of
 15 loss of property, personal injury or death of individuals. The hazard would be controlled to a safe level.
 16 The impact would be less than significant. No mitigation is required.

17 **Impact GEO-8: Loss of Property, Personal Injury, or Death from Structural Failure Resulting**
 18 **from Seismic-Related Ground Failure (Including Liquefaction) during Operation of Water**
 19 **Conveyance Features**

20 Earthquake-induced ground shaking could cause liquefaction, resulting in soil slumping or lateral
 21 spreading and subsequent damage to or breaching of water conveyance structures and facilities. The
 22 consequences of liquefaction are manifested in terms of compaction or settlement, loss of bearing
 23 capacity, lateral spreading (soil movement), increased lateral soil pressure, and buoyancy within zones
 24 of liquefaction. Failure of tunnels, pipelines, levees, bridges, and other structures and facilities could
 25 result in loss of property or personal injury, and disrupt SWP and CVP water supply deliveries. The
 26 potential for adverse impacts from flooding as a result of levee or dam failure is also discussed in
 27 Chapter 6, *Surface Water*.

28 The native soil underlying Alternative 1A facilities consist of various channel deposits and recent silty
 29 and sandy alluvium at shallow depths. The available data along the southern portion of the conveyance
 30 (from approximately Potato Slough to Clifton Court Forebay) show that the recent alluvium overlies
 31 peaty or organic soil, which in turn is underlain by layers of mostly sandy and silty soil (Real and
 32 Knudsen 2009). Soil borings advanced by DWR along the northern portion of the conveyance (from
 33 approximately Potato Slough to Intake 1) show the surface soil as being similar to the range reported
 34 for the southern portion, but locally containing strata of clayey silt and lean clay. Because the borings
 35 were made over water, peat was usually absent from the boring logs (California Department of Water
 36 Resources 2011). This may be because the peat had floated from the bottom of the waterways over
 37 time, or may be because the absence of peat indicates that the watercourse's present course has not
 38 deviated greatly since the late Pleistocene.

39 The silty and sandy soil deposits underlying the peaty and organic soil over parts of the Delta are late-
 40 Pleistocene age dune sand, which are liquefiable during major earthquakes. The tops of these materials
 41 are exposed in some areas, but generally lie beneath the peaty soil at depths of about 10–40 feet bgs
 42 along the pipeline/tunnel alignment (Real and Knudsen 2009). Liquefaction hazard mapping by Real
 43 and Knudsen (2009), which covers only the southwestern part of the Plan Area, including the part of
 44 the alignment from near Isleton to the Palm Tract, indicates that the lateral ground deformation
 45 potential would range from <0.1 to 6.0 feet. Liquefaction-induced ground settlement during the 1906

1 San Francisco earthquake was also reported near Alternative 1A facilities at a bridge crossing over
2 Middle River just north of Woodward Island (Youd and Hoose 1978). Local variations in thickness and
3 lateral extent of liquefiable soil may exist, and they may have important influence on liquefaction-
4 induced ground deformations.

5 **NEPA Effects:** Figure 9-6 shows that the Alternative 1A alignment has no substantial levee damage
6 potential from liquefaction in its extreme northern part and low to medium-high levee damage
7 potential throughout the remainder of the Plan Area.

8 Because the tunnel invert would be at depths of 100–160 feet bgs, the potential effects on these
9 facilities due to liquefaction is judged to be low. However, the surface and near-surface facilities that
10 would be constructed at the access road, intake, pumping plant, and forebay areas would likely be
11 founded on liquefiable soil.

12 The potential effect could be substantial because seismically induced ground shaking could cause
13 liquefaction, which could result in loss of property or personal injury, and damage pipelines, tunnels,
14 intake facilities, pumping plants, and other facilities. The damage could disrupt the water supply
15 through the conveyance system. In an extreme event, an uncontrolled release of water from the
16 damaged conveyance system could cause flooding and inundation of structures.

17 In the process of preparing final facility designs, site-specific geotechnical and groundwater
18 investigations would be conducted to identify and characterize the vertical (depth) and horizontal
19 (spatial) extents of liquefiable soil. Engineering soil parameters that could be used to further assess the
20 liquefaction potential, such as SPT blow counts, CPT penetration tip pressure/resistance, and gradation
21 of soil, would also be obtained. SPT blow counts and CPT tip pressure are used to estimate soil
22 resistance to cyclic loadings by using empirical relationships that were developed based on
23 occurrences of liquefaction (or lack of them) during past earthquakes. The resistance then can be
24 compared to cyclic shear stress induced by the design earthquake. If soil resistance is less than induced
25 stress, the potential of having liquefaction during the design earthquakes is high. It is also known that
26 soil with high “fines” (i.e., silt- and clay-sized particles) content are less susceptible to liquefaction.

27 During final design, site-specific potential for liquefaction would be investigated by a geotechnical
28 engineer. In areas determined to have a potential for liquefaction, a California-registered civil engineer
29 or California-certified engineering geologist would develop design measures and construction methods
30 to meet design criteria established by building codes and construction standards to ensure that the
31 design earthquake does not cause damage to or failure of the facility. Such measures and methods
32 include removing and replacing potentially liquefiable soil, strengthening foundations (for example,
33 using post-tensioned slab, reinforced mats, and piles) to resist excessive total and differential
34 settlements, and using *in situ* ground improvement techniques (such as deep dynamic compaction,
35 vibro-compaction, vibro-replacement, compaction grouting, and other similar methods). The results of
36 the site-specific evaluation and California-registered civil engineer or California-certified engineering
37 geologist’s recommendations would be documented in a detailed geotechnical report prepared in
38 accordance with state guidelines, in particular *Guidelines for Evaluating and Mitigating Seismic Hazards*
39 *in California* (California Geological Survey 2008). As described in Section 9.3.1, *Methods for Analysis*,
40 and in Appendix 3B, *Environmental Commitments*, such design codes, guidelines, and standards include
41 USACE’s *Engineering and Design—Stability Analysis of Concrete Structures and Soil Liquefaction during*
42 *Earthquakes*, by the Earthquake Engineering Research Institute. Conformance with these design
43 requirements is an environmental commitment by DWR to ensure that liquefaction risks are minimized
44 as the water conveyance features are operated.

1 DWR would ensure that the geotechnical design recommendations are included in the design of project
 2 facilities and construction specifications to minimize the potential effects from liquefaction and
 3 associated hazards. DWR would also ensure that the design specifications are properly executed during
 4 construction.

5 In particular, conformance with the following codes and standards would reduce the potential risk for
 6 increased likelihood of loss of property or personal injury from structural failure resulting from strong
 7 seismic shaking of water conveyance features during operations:

- 8 • DWR Division of Engineering State Water Project–Seismic Loading Criteria Report, Sept 2012.
- 9 • USACE Engineering and Design–Time-History Dynamic Analysis of Concrete Hydraulic Structure, EM
 10 1110-2-6051, 2003
- 11 • USACE Engineering and Design–Response Spectra and Seismic Analysis for Concrete Hydraulic
 12 Structures, EM 1110-2-6050, 1999.
- 13 • American Society of Civil Engineers Minimum Design Loads for Buildings and Other Structures,
 14 ASCE-7-05, 2005.
- 15 • USACE Engineering and Design–Design of Pile Foundations, EM 1110-2-2906, 1991
- 16 • California Code of Regulations, Title 8, Section 3203, California Code of Regulations.

17 Generally, the applicable codes require that facilities be built so that if soil in the foundation or
 18 surrounding area are subject to liquefaction, the removal or densification of the liquefiable material
 19 should be considered, along with alternative foundation designs. Additionally, any modification to a
 20 federal levee system would require USACE approval under 33 USC 408 (a 408 Permit) and would have
 21 to pass quality assurance review by the Major Subordinate Command prior to being forwarded to
 22 USACE headquarters for final approval by the Chief of Engineers.

23 The worker safety codes and standards specify protective measures that must be taken at construction
 24 sites to minimize the risk of injury or death from structural or earth failure (e.g., utilizing personal
 25 protective equipment). The relevant codes and standards represent performance standards that must
 26 be met by contractors and these measures are subject to monitoring by state and local agencies. Cal-
 27 OSHA requirements for an IIPP and the terms of the IIPP to protect worker safety are the principal
 28 measures that would be enforced at project sites during operations.

29 Conformance to these and other applicable design specifications and standards would ensure that the
 30 hazard of liquefaction and associated ground movements would not create an increased likelihood of
 31 loss of property, personal injury or death of individuals from structural failure resulting from seismic-
 32 related ground failure along the Alternative 1A conveyance alignment during operation of the water
 33 conveyance features. Therefore, the effect would not be adverse.

34 **CEQA Conclusion:** Seismically induced ground shaking could cause liquefaction. Liquefaction could
 35 damage pipelines, tunnels, intake facilities, pumping plants, and other facilities, and thereby disrupt the
 36 water supply through the conveyance system. In an extreme event, an uncontrolled release of water
 37 from the damaged conveyance system could cause flooding and inundation of structures. However,
 38 through the final design process, measures to address the liquefaction hazard would be required to
 39 conform to applicable design codes, guidelines, and standards. As described in Section 9.3.1, *Methods*
 40 *for Analysis*, and in Appendix 3B, *Environmental Commitments*, such design codes, guidelines, and
 41 standards include USACE's *Engineering and Design—Stability Analysis of Concrete Structures* and *Soil*
 42 *Liquefaction during Earthquakes*, by the Earthquake Engineering Research Institute. Conformance with

1 these design standards is an environmental commitment by DWR to ensure that liquefaction risks are
 2 minimized as the Alternative 1A water conveyance features are operated and there would be no
 3 increased likelihood of loss of property, personal injury or death of individuals. The hazard would be
 4 controlled to a safe level. The impact would be less than significant. No mitigation is required.

5 **Impact GEO-9: Loss of Property, Personal Injury, or Death from Landslides and Other Slope**
 6 **Instability during Operation of Water Conveyance Features**

7 Alternative 1A would involve excavation that creates new cut-and-fill slopes and construction of new
 8 embankments and levees. As a result of ground shaking and high soil-water content during heavy
 9 rainfall, existing and new slopes that are not properly engineered and natural stream banks could fail
 10 and cause damage to facilities. Levees can fail for several reasons: 1) high velocities of water flow can
 11 result in high rates of erosion and erode and overtop a levee; 2) the higher velocities of water flow can
 12 also lead to higher rates of erosion along the inner parts of levees and lead to undercutting and
 13 clumping of the levee into the river. Heavy rainfall or seepage into the levee from the river can increase
 14 fluid pressure in the levee and lead to slumping on the outer parts of the levee. If the slumps grow to
 15 the top of the levee, large sections of the levee may slump onto the floodplain and lower the elevation of
 16 the top of the levee, leading to overtopping; 3) increasing levels of water in the river will cause the
 17 water table in the levee to rise which will increase fluid pressure and may result in seepage and
 18 eventually lead to internal erosion called piping. Piping will erode the material under the levee,
 19 undermining it and causing its collapse and failure.

20 With the exception of levee slopes and natural stream banks, the topography along the Alternative 1A
 21 conveyance alignment is nearly level to very gently sloping. The areas that may be susceptible to slope
 22 failure are along existing levee slopes, and at intakes, pumping plants, forebay, and certain access road
 23 locations. Outside these areas, the land is nearly level and consequently has a negligible potential for
 24 slope failure. Based on review of topographic maps and a landslide map of Alameda County (Roberts et
 25 al. 1999), the conveyance facilities would not be constructed on, nor would it be adjacent to, slopes that
 26 are subject to mudflows/debris flows from natural slopes.

27 **NEPA Effects:** The potential effect could be substantial because levee slopes and stream banks may fail,
 28 either from high pore-water pressure caused by high rainfall and weak soil, or from seismic shaking.
 29 Structures built on these slopes could be damaged or fail entirely as a result of slope instability. As
 30 discussed in Impact SW-2 in Chapter 6, *Surface Water*, operation of the water conveyance features
 31 under Alternative 1A would not result in an increase in potential risk for flood management compared
 32 to existing conditions. Peak monthly flows under Alternative 1A in the locations considered were
 33 similar to or less than those that would occur under existing conditions. Since flows would not be
 34 substantially greater, the potential for increased rates of erosion or seepage are low. For additional
 35 discussion on the possible exposure of people or structures to impacts from flooding due to levee
 36 failure, please refer to Impact SW-6 in Chapter 6, *Surface Water*.

37 During project design, a geotechnical engineer would develop slope stability design criteria (such as
 38 minimum slope safety factors and allowable slope deformation and settlement) for the various
 39 anticipated loading conditions. The design criteria would be documented in a detailed geotechnical
 40 report prepared in accordance with state guidelines, in particular *Guidelines for Evaluating and*
 41 *Mitigating Seismic Hazards in California* (California Geological Survey 2008). As discussed in Chapter 3,
 42 *Description of the Alternatives*, the foundation soil beneath slopes, embankments, or levees could be
 43 improved to increase its strength and to reduce settlement and deformation. Foundation soil
 44 improvement could involve excavation and replacement with engineered fill; preloading; ground

1 modifications using jet-grouting, compaction grouting, chemical grouting, shallow soil mixing, deep soil
 2 mixing, vibro-compaction, or vibro-replacement; or other methods. Engineered fill also would be used
 3 to construct new slopes, embankments, and levees. Surface and internal drainage systems would be
 4 installed as necessary to reduce erosion and piping (internal erosion) potential.

5 Site-specific geotechnical and hydrological information would be used, and the design would conform
 6 with the current standards and construction practices, as described in Section 9.3.1, *Methods for*
 7 *Analysis*, such as USACE's *Design and Construction of Levees* and USACE's *EM 1110-2-1902, Slope*
 8 *Stability*. The design requirements would be presented in a detailed geotechnical report. Conformance
 9 with these design requirements is an environmental commitment by DWR to ensure that slope stability
 10 hazards would be avoided as the water conveyance features are operated. DWR would ensure that the
 11 geotechnical design recommendations are included in the design of cut and fill slopes, embankments,
 12 and levees to minimize the potential effects from slope failure. DWR would also ensure that the design
 13 specifications are properly executed during construction.

14 In particular, conformance with the following codes and standards would reduce the potential risk for
 15 increased likelihood of loss of property or personal injury from structural failure resulting from seismic
 16 shaking or from high-pore water pressure:

- 17 • DWR Division of Engineering State Water Project–Seismic Loading Criteria Report, Sept 2012.
- 18 • DWR Division of Flood Management FloodSAFE Urban Levee Design Criteria, May 2012.
- 19 • USACE Slope Stability, EM 1110-2-1902, 2003.
- 20 • California Code of Regulations, Title 8, Section 3203, California Code of Regulations.

21 Generally, the applicable codes require that facilities be built to certain factors of safety in order to
 22 ensure that facilities perform as designed for the life of the structure despite various soil parameters.

23 The worker safety codes and standards specify protective measures that must be taken at construction
 24 sites to minimize the risk of injury or death from structural or earth failure (e.g., utilizing personal
 25 protective equipment). The relevant codes and standards represent performance standards that must
 26 be met by contractors and these measures are subject to monitoring by state and local agencies. Cal-
 27 OSHA requirements for an IIPP and the terms of the IIPP to protect worker safety are the principal
 28 measures that would be enforced at project sites during operations.

29 Conformance to the above and other applicable design specifications and standards would ensure that
 30 the hazard of slope instability would not create an increased likelihood of loss of property, personal
 31 injury or death of individuals along the Alternative 1A conveyance alignment during operation of the
 32 water conveyance features. Therefore, the effect would not be adverse.

33 **CEQA Conclusion:** Unstable levee slopes and natural stream banks may fail, either from high pore-
 34 water pressure caused by high rainfall and weak soil, or from seismic shaking. Structures built on these
 35 slopes could be damaged or fail entirely as a result of slope instability. However, through the final
 36 design process, measures to address this hazard would be required to conform to applicable design
 37 codes, guidelines, and standards. The measures would be described in a detailed geotechnical report
 38 prepared in accordance with state guidelines, in particular *Guidelines for Evaluating and Mitigating*
 39 *Seismic Hazards in California* (California Geological Survey 2008). As described in Section 9.3.1, *Methods*
 40 *for Analysis*, and in Appendix 3B, *Environmental Commitments*, such design codes, guidelines, and
 41 standards include the California Building Code and resource agency and professional engineering
 42 specifications, such as USACE's *Engineering and Design—Earthquake Design and Evaluation for Civil*

1 *Works Projects.* Conformance with these codes and standards is an environmental commitment by DWR
2 to ensure cut and fill slopes and embankments will be stable as the Alternative 1A water conveyance
3 features are operated and there would be no increased likelihood of loss of property, personal injury or
4 death of individuals. The impact would be less than significant. No mitigation is required.

5 **Impact GEO-10: Loss of Property, Personal Injury, or Death from Seiche or Tsunami during**
6 **Operation of Water Conveyance Features**

7 Based on recorded tsunami wave heights at the Golden Gate (Contra Costa Transportation Agency
8 2009) and in the interior of the San Francisco Bay and on tsunami inundation maps prepared by the
9 California Department of Conservation (2009), the height of a tsunami wave reaching the Suisun Marsh
10 and the Delta would be small because of the distance from the ocean and attenuating effect of the San
11 Francisco Bay. Therefore, the potential hazard of loss of property or personal injury as a result of a
12 tsunami on the water conveyance facilities is low.

13 Similarly, with the exception of the Clifton Court Forebay and the Byron Tract Forebay, the potential for
14 a substantial seiche to take place in the Plan Area that would cause loss of property or personal injury
15 in the construction areas is considered low because seismic and water body geometry conditions for a
16 seiche to occur near conveyance facilities are not favorable. Fugro Consultants, Inc. (2011) identified
17 the potential for a seiche of an unspecified wave height to occur in the Clifton Court Forebay, caused by
18 strong ground motions along the underlying West Tracy fault, assuming that this fault is potentially
19 active. Since the fault also exists in the immediate vicinity of the Byron Tract Forebay, a seiche could
20 also occur in the Byron Tract Forebay.

21 **NEPA Effects:** The effect of a tsunami generated in the Pacific Ocean would not be adverse because the
22 distance from the ocean and attenuating effect of the San Francisco Bay would likely allow only a low
23 (i.e., less than 2 feet) tsunami wave height to reach the Delta (Contra Costa Transportation Agency
24 2009). With the assumption of an 18-inch sea level rise at mid-century, the tsunami effect would not be
25 adverse since the attenuating effect of the San Francisco Bay (a 100-year return period tsunami wave
26 run-up elevation at Golden Gate Bridge of 8.2 feet NGVD) would dissipate as it moves east toward the
27 East Bay and the Delta. By the time it reaches the East Bay it would be half as high (City and County of
28 San Francisco 2011). As it moves to the Delta, the wave run-up is likely low (3.5 feet or less) tsunami
29 wave height.

30 Because the majority of the region's faults are strike-slip faults, a tsunami is not expected to be a major
31 threat as a result of a regional earthquake. The primary tsunami threat along the central California
32 coast is from distant earthquakes along subduction zones elsewhere in the Pacific basin, including
33 Alaska. Since 1877, Alaska earthquakes have produced tsunami run-ups in the Bay Area nine times or
34 on average, every 28 years. Historically, the run-ups from these events have been less than 1 foot (City
35 and County of San Francisco 2011).

36 In most parts of the Plan Area, the effects of a seiche would not be adverse because the seismic hazard
37 and the geometry of the water bodies (i.e., wide and shallow) near conveyance facilities are not
38 favorable for a seiche to occur. However, assuming that the West Tracy fault is potentially active, a
39 potential exists for a seiche to occur in the Clifton Court Forebay and the Byron Tract Forebay. The
40 effect could be adverse because the waves generated by a seiche could overtop the Byron Tract
41 Forebay and Clifton Court Forebay embankments, causing erosion of the embankments and subsequent
42 flooding in the vicinity.

1 However, design-level geotechnical studies would be conducted by a licensed civil engineer who
 2 practices in geotechnical engineering. The studies would determine the peak ground acceleration
 3 caused by movement of the West Tracy fault and the maximum probable seiche wave that could be
 4 generated by the ground shaking. The California-registered civil engineer or California-certified
 5 engineering geologist's recommended measures to address this hazard, as well as the hazard of a
 6 seiche overtopping the Clifton Court Forebay embankment and subsequent adverse effect on the Byron
 7 Tract Forebay embankment, would conform to applicable design codes, guidelines, and standards. As
 8 described in Section 9.3.1, *Methods for Analysis*, and in Appendix 3B, *Environmental Commitments*, such
 9 design codes, guidelines, and standards include the Division of Safety of Dams *Guidelines for Use of the*
 10 *Consequence Hazard Matrix and Selection of Ground Motion Parameters*, DWR's Division of Flood
 11 Management *FloodSAFE Urban Levee Design Criteria*, and USACE's *Engineering and Design—Earthquake*
 12 *Design and Evaluation for Civil Works Projects*. Conformance with these codes and standards is an
 13 environmental commitment by DWR to ensure that the adverse effects of a seiche are controlled to an
 14 acceptable level while the forebay facility is operated.

15 DWR would ensure that the geotechnical design recommendations are included in the design of project
 16 facilities and construction specifications to minimize the potential effects from seismic events and
 17 consequent seiche waves. DWR would also ensure that the design specifications are properly executed
 18 during construction.

19 In particular, conformance with the following codes and standards would reduce the potential risk for
 20 increased likelihood of loss of property or personal injury from tsunami or seiche:

- 21 • U.S. Department of the Interior and USGS Climate Change and Water Resources Management: A
 22 Federal Perspective, Circular 1331.
- 23 • State of California Sea-Level Rise Task Force of CO-CAT, Sea-Level Rise Interim Guidance
 24 Document, 2010
- 25 • California Code of Regulations, Title 8, Section 3203, California Code of Regulations.

26 Generally, the applicable codes provide guidance on estimating the effects of climate change and sea
 27 level rise and associated effects when designing a project and ensuring that a project is able to respond
 28 to these effects.

29 The worker safety codes and standards specify protective measures that must be taken at construction
 30 sites to minimize the risk of injury or death from structural or earth failure (e.g., utilizing personal
 31 protective equipment). The relevant codes and standards represent performance standards that must
 32 be met by contractors and these measures are subject to monitoring by state and local agencies. Cal-
 33 OSHA requirements for an IIPP and the terms of the IIPP to protect worker safety are the principal
 34 measures that would be enforced at project sites during operations.

35 Conformance to these and other applicable design specifications and standards would ensure that the
 36 Byron Tract Forebay embankment would be designed and constructed to contain and withstand the
 37 anticipated maximum seiche wave height and would not create an increased likelihood of loss of
 38 property, personal injury or death of individuals along the Alternative 1A conveyance alignment during
 39 operation of the water conveyance features. Therefore, the effect would not be adverse.

40 **CEQA Conclusion:** Based on recorded tsunami wave heights at the Golden Gate (Contra Costa
 41 Transportation Agency 2009) and in the interior of the San Francisco Bay and on tsunami inundation
 42 maps prepared by the California Department of Conservation (2009), the height of a tsunami wave
 43 reaching the Suisun Marsh and the Delta would be small because of the distance from the ocean and

1 attenuating effect of the San Francisco Bay. The impact would be less than significant. No mitigation is
2 required.

3 Similarly, the potential for a significant seiche to occur in most parts of the Plan Area is considered low
4 because the seismic hazard and the geometry of the water bodies (i.e., wide and shallow) near
5 conveyance facilities are not favorable for a seiche to occur. However, assuming that the West Tracy
6 fault is potentially active, a potential exists for a seiche to occur in the Clifton Court Forebay and the
7 Byron Tract Forebay (Fugro Consultants 2011). The impact would not be significant because the Byron
8 Tract Forebay embankment would be designed and constructed according to applicable design codes,
9 guidelines, and standards to contain and withstand the anticipated maximum seiche wave height and
10 potential seiche wave overtopping of the Clifton Court Forebay and Byron Tract Forebay embankments
11 as the Alternative 1A water conveyance features are operated and there would be no increased
12 likelihood of loss of property, personal injury or death of individuals. The impact would be less than
13 significant. No mitigation is required.

14 **Impact GEO-11: Ground Failure Caused by Increased Groundwater Surface Elevations from**
15 **Unlined Canal Seepage as a Result of Operating the Water Conveyance Facilities**

16 *NEPA Effects:* Alternative 1A would not involve construction of unlined canals; therefore, there would
17 be no increase in groundwater surface elevations and consequently no effect to groundwater surface
18 elevations caused by canal seepage. Therefore, the effect would not be adverse.

19 *CEQA Conclusion:* Alternative 1A would not involve construction of unlined canals; therefore, there
20 would be no increase in groundwater surface elevations and consequently no impact caused by canal
21 seepage. There would be no impact. No mitigation is required.

22 **Impact GEO-12: Loss of Property, Personal Injury, or Death Resulting from Structural Failure**
23 **Caused by Rupture of a Known Earthquake Fault at Restoration Opportunity Areas**

24 According to the available AP Earthquake Fault Zone Maps, only the Suisun Marsh ROA could be
25 affected by rupture of an earthquake fault. The active Green Valley fault crosses the southwestern
26 corner of the ROA. The active Cordelia fault extends approximately 1 mile into the northwestern corner
27 of the ROA. Rupture of these faults could damage levees and berms constructed as part of the
28 restoration, which could result in failure of the levees and flooding of otherwise protected areas.

29 Within the Delta, active or potentially active blind thrust faults were identified in the seismic study
30 (California Department of Water Resources 2007a). The extreme southeastern corner of the Suisun
31 Marsh is underlain by the Montezuma blind thrust zone. Parts of the Cache Slough and Yolo Bypass
32 ROAs are underlain by part of the North Midland blind thrust zone. The Cosumnes/Mokelumne River
33 and East Delta ROAs are underlain by the Thornton Arch zone. Although these blind thrusts are not
34 expected to rupture to the ground surface during earthquake events, they may produce ground or
35 near-ground shear zones, bulging, or both. In the seismic study (California Department of Water
36 Resources 2007a), the Thornton Arch blind thrust was assigned a 20% probability of being active. The
37 depth to the Thornton Arch blind fault is unknown. Based on limited geologic and seismic survey
38 information, it appears that the potential of having any shear zones, bulging, or both at the sites of the
39 habitat levees is low because the depth to the blind thrust faults is generally deep.

40 *NEPA Effects:* The effect of implementing the conservation measures in the ROAs could be substantial
41 because rupture of the Cordelia and Green Valley faults could occur at the Suisun Marsh ROA and cause

1 damage or failure of ROA facilities, including levees and berms. Damage to these features could result in
2 their failure, causing flooding of otherwise protected areas.

3 Because there is limited information regarding the depths of the blind faults mentioned above, seismic
4 surveys would be performed in the vicinity of the faults as part of final design. These surveys would be
5 used to verify fault depths where levees and other features would be constructed. Collection of this
6 depth information would be part of broader, design-level geotechnical studies prepared by a
7 geotechnical engineer licensed in the state of California to support all aspects of site-specific project
8 design. The studies would assess site-specific conditions at and near all the project facility locations,
9 including the nature and engineering properties of all soil horizons and underlying geologic strata, and
10 groundwater conditions. The geotechnical engineers' information would be used to develop final
11 engineering solutions to any hazardous condition, consistent with the code and standards
12 requirements of federal, state and local oversight agencies. As described in Section 9.3.1, *Methods for*
13 *Analysis*, and in Appendix 3B, *Environmental Commitments*, such design codes, guidelines, and
14 standards include the California Building Code and resource agency and professional engineering
15 specifications, such as the Division of Safety of Dams Guidelines for Use of the Consequence Hazard
16 Matrix and Selection of Ground Motion Parameters, DWR's Division of Flood Management *FloodSAFE*
17 *Urban Levee Design Criteria*, and USACE's *Engineering and Design—Earthquake Design and Evaluation*
18 *for Civil Works Projects*. Conformance with these design standards is an environmental commitment by
19 the BDCP proponents to ensure that risks from a fault rupture are minimized as conservation levees
20 are constructed and maintained. The hazard would be controlled to a safe level by following the proper
21 design standards.

22 The BDCP proponents would ensure that the geotechnical design recommendations are included in the
23 design of project facilities and construction specifications to minimize the potential effects from seismic
24 events and the presence of adverse soil conditions. The BDCP proponents would also ensure that the
25 design specifications are properly executed during implementation.

26 In particular, conformance with the following codes and standards would reduce the potential risk for
27 increased likelihood of loss of property or personal injury from structural failure resulting from surface
28 rupture resulting from a seismic event during operation:

- 29 ● DWR Division of Engineering State Water Project – Seismic Loading Criteria Report, Sept 2012.
- 30 ● DWR DSOD Guidelines for Use of the Consequence-Hazard Matrix and Selection of Ground Motion
31 Parameters, 2002.
- 32 ● USACE Engineering and Design, Earthquake Design and Evaluation for Civil Works Projects, ER 1110-
33 2-1806, 1995.
- 34 ● USACE Design and Construction of Levees, EM 1110-2-1913, 2000.
- 35 ● USACE (Corps, CESP-K-ED-G), Geotechnical Levee Practice, SOP EDG-03, 2004.
- 36 ● DWR Division of Flood Management FloodSAFE Urban Levee Design Criteria, May 2012.
- 37 ● California Code of Regulations, Title 8, Sections 1509 and 3203, California Code of Regulations.

38 Generally, the applicable codes require that facilities be built so that they incur minimal damage in the
39 event of a foreseeable seismic event and that they remain functional following such an event and that
40 the facility is able to perform without catastrophic failure in the event of a maximum design earthquake
41 (the greatest earthquake reasonably expected to be generated by a specific source on the basis of
42 seismological and geological evidence).

1 The worker safety codes and standards specify protective measures that must be taken at construction
 2 sites to minimize the risk of injury or death from structural or earth failure (e.g., utilizing personal
 3 protective equipment, practicing crane and scaffold safety measures). The relevant codes and
 4 standards represent performance standards that must be met by contractors and these measures are
 5 subject to monitoring by state and local agencies. Cal-OSHA requirements for an IIPP and the terms of
 6 the IIPP to protect worker safety are the principal measures that would be enforced at construction
 7 sites.

8 Conformance to these and other applicable design specifications and standards would ensure that the
 9 hazard of ground movement in the vicinity of the blind thrusts underlying the ROAs would not
 10 jeopardize the integrity of the levees and other features constructed in the ROAs and would not create
 11 an increased likelihood of loss of property, personal injury or death of individuals in the ROAs. This
 12 effect would not be adverse.

13 **CEQA Conclusion:** Rupture of the Cordelia and Green Valley faults could occur at the Suisun Marsh ROA
 14 and damage ROA facilities, such as levees and berms. Damage to these features could result in their
 15 failure, causing flooding of otherwise protected areas. However, through the final design process for
 16 conservation measures in the ROAs, measures to address the fault rupture hazard would be required to
 17 conform to applicable design codes, guidelines, and standards. As described in Section 9.3.1, *Methods*
 18 *for Analysis*, and in Appendix 3B, *Environmental Commitments*, such design codes, guidelines, and
 19 standards include the Division of Safety of Dams Guidelines for Use of the Consequence Hazard Matrix
 20 and Selection of Ground Motion Parameters, DWR's Division of Flood Management *FloodSAFE Urban*
 21 *Levee Design Criteria*, and USACE's *Engineering and Design—Earthquake Design and Evaluation for Civil*
 22 *Works Projects*. Conformance with these design standards is an environmental commitment by the
 23 BDCP proponents to ensure that fault rupture risks are minimized as the conservation measures are
 24 implemented. The hazard would be controlled to a safe level and there would be no increased
 25 likelihood of loss of property, personal injury or death of individuals in the ROAs. The impact would be
 26 less than significant. No mitigation is required.

27 **Impact GEO-13: Loss of Property, Personal Injury, or Death from Structural Failure Resulting**
 28 **from Strong Seismic Shaking at Restoration Opportunity Areas**

29 Earthquake events may occur on the local and regional seismic sources at or near the ROAs. Because of
 30 its proximity to these faults, the Suisun Marsh ROA would be especially subject to ground shaking
 31 caused by the Concord-Green Valley fault. The Cache Slough ROA would be subject to shaking from the
 32 Northern Midland fault zone, which underlies the ROA. Although more distant from these sources, the
 33 other ROAs would be subject to shaking from the San Andreas, Hayward–Rodgers Creek, Calaveras,
 34 Concord–Green Valley, San Gregorio, Greenville, and Mt. Diablo Thrust faults and the more proximate
 35 blind thrusts in the Delta.

36 Among all the ROAs, the Suisun Marsh ROA would be most subject to ground shaking because of its
 37 proximity to active faults. The Suisun Marsh ROA is subject to a PGA of approximately 0.31–0.35 g for
 38 200-year return interval, while the PGA for the other ROAs ranges from approximately 0.11–0.26 g. The
 39 ground shaking could damage levees and other structures, and in an extreme event cause levees to fail
 40 such that protected areas flood.

41 **NEPA Effects:** All temporary facilities would be designed and built to meet the safety and
 42 collapse-prevention requirements for the above-anticipated seismic loads. Therefore, this effect is
 43 considered not adverse. No additional mitigation measures are required. All facilities would be
 44 designed and constructed in accordance with the requirements of the design measures described in

1 Chapter 3, *Description of the Alternatives*. Site-specific geotechnical information would be used to
 2 further assess the effects of local soil on the OBE and MDE ground shaking and to develop design
 3 criteria that minimize the potential of damage. Design-level geotechnical studies would be prepared by
 4 a geotechnical engineer licensed in the state of California during project design. The studies would
 5 assess site-specific conditions at and near all the project facility locations and provide the basis for
 6 designing the levees and other features to withstand the peak ground acceleration caused by fault
 7 movement in the region. The geotechnical engineer's recommended measures to address this hazard
 8 would conform to applicable design codes, guidelines, and standards. Potential design strategies or
 9 conditions could include avoidance (deliberately positioning structures and lifelines to avoid crossing
 10 identified shear rupture zones), geotechnical engineering (using the inherent capability of
 11 unconsolidated geomaterials to "locally absorb" and distribute distinct bedrock fault movements) and
 12 structural engineering (engineering the facility to undergo some limited amount of ground deformation
 13 without collapse or significant damage).

14 As described in Section 9.3.1, *Methods for Analysis*, and in Appendix 3B, *Environmental Commitments*,
 15 such design codes, guidelines, and standards include the California Building Code and resource agency
 16 and professional engineering specifications, such as the Division of Safety of Dams *Guidelines for Use of*
 17 *the Consequence Hazard Matrix and Selection of Ground Motion Parameters*, DWR's Division of Flood
 18 Management *FloodSAFE Urban Levee Design Criteria*, and USACE's *Engineering and Design—Earthquake*
 19 *Design and Evaluation for Civil Works Projects*. Conformance with these design standards is an
 20 environmental commitment by the BDCP proponents to ensure that strong seismic shaking risks are
 21 minimized as the conservation measures are implemented.

22 The BDCP proponents would ensure that the geotechnical design recommendations are included in the
 23 design of project features and construction specifications to minimize the potential effects from seismic
 24 events and the presence of adverse soil conditions. The BDCP proponents would also ensure that the
 25 design specifications are properly executed during implementation.

26 In particular, conformance with the following codes and standards would reduce the potential risk for
 27 increased likelihood of loss of property or personal injury from structural failure resulting from surface
 28 rupture resulting from a seismic event during operation:

- 29 ● DWR Division of Engineering State Water Project – Seismic Loading Criteria Report, Sept 2012.
- 30 ● DWR DSOD Guidelines for Use of the Consequence-Hazard Matrix and Selection of Ground Motion
 31 Parameters, 2002.
- 32 ● USACE Engineering and Design, Earthquake Design and Evaluation for Civil Works Projects, ER 1110-
 33 2-1806, 1995.
- 34 ● USACE Design and Construction of Levees, EM 1110-2-1913, 2000.
- 35 ● USACE (Corps, CESP-K-ED-G), Geotechnical Levee Practice, SOP EDG-03, 2004.
- 36 ● DWR Division of Flood Management FloodSAFE Urban Levee Design Criteria, May 2012.
- 37 ● California Code of Regulations, Title 8, Sections 1509 and 3203, California Code of Regulations.

38 Generally, the applicable codes require that facilities be built so that they incur minimal damage in the
 39 event of a foreseeable seismic event and that they remain functional following such an event and that
 40 the facility is able to perform without catastrophic failure in the event of a maximum design earthquake
 41 (the greatest earthquake reasonably expected to be generated by a specific source on the basis of
 42 seismological and geological evidence).

1 The worker safety codes and standards specify protective measures that must be taken at construction
 2 sites to minimize the risk of injury or death from structural or earth failure (e.g., utilizing personal
 3 protective equipment, practicing crane and scaffold safety measures). The relevant codes and
 4 standards represent performance standards that must be met by contractors and these measures are
 5 subject to monitoring by state and local agencies. Cal-OSHA requirements for an IIPP and the terms of
 6 the IIPP to protect worker safety are the principal measures that would be enforced at construction
 7 sites.

8 Conformance to these and other applicable design specifications and standards would ensure that the
 9 hazard of seismic shaking would not jeopardize the integrity of levees and other features at the ROAs
 10 and would not create an increased likelihood of loss of property, personal injury or death of individuals
 11 in the ROAs. This effect would not be adverse.

12 **CEQA Conclusion:** Ground shaking could damage levees, berms, and other structures. Amongst all the
 13 ROAs, the Suisun Marsh ROA would be the most subject to ground shaking because of its proximity to
 14 active faults. The Suisun Marsh ROA is subject to a PGA of approximately 0.31–0.35 g for 200-year
 15 return interval, while the PGA for the other ROAs ranges from approximately 0.11–0.26 g. Damage to
 16 these features could result in their failure, causing flooding of otherwise protected areas. However, as
 17 described in Section 9.3.1, *Methods for Analysis*, and in Appendix 3B, *Environmental Commitments*,
 18 design codes, guidelines, and standards, including the California Building Code and resource agency
 19 and professional engineering specifications, such as DWR's Division of Flood Management *FloodSAFE*
 20 *Urban Levee Design Criteria* and USACE's *Engineering and Design—Earthquake Design and Evaluation*
 21 *for Civil Works Projects* would be used for final design of conservation features. Conformance with these
 22 design standards is an environmental commitment by the BDCP proponents to ensure that strong
 23 seismic shaking risks are minimized as the conservation measures are operated and there would be no
 24 increased likelihood of loss of property, personal injury or death of individuals in the ROAs. The impact
 25 would be less than significant. No mitigation is required.

26 **Impact GEO-14: Loss of Property, Personal Injury, or Death from Structural Failure Resulting**
 27 **from Seismic-Related Ground Failure (Including Liquefaction) Beneath Restoration Opportunity**
 28 **Areas**

29 New structural features are proposed at the ROAs, such as levees as part of CM4, setback levees as part
 30 of CM5 and CM6, and experimental ramps and fish ladders at the Fremont Weir as part of CM2.
 31 Earthquake-induced ground shaking could cause liquefaction, resulting in damage to or failure of these
 32 levees and other features constructed at the restoration areas. The consequences of liquefaction are
 33 manifested in terms of compaction or settlement, loss of bearing capacity, lateral spreading (horizontal
 34 soil movement), and increased lateral soil pressure. Failure of levees and other structures could result
 35 in loss or injury, as well as flooding of otherwise protected areas in Suisun Marsh and behind new
 36 setback levees along the Sacramento and San Joaquin Rivers and in the South Delta ROA.

37 The ROAs vary with respect to their liquefaction hazard (Figure 9-6). The Suisun Marsh ROA generally
 38 has a moderate or high liquefaction hazard. The liquefaction damage potential among the other ROAs,
 39 as well as where setback levees would be constructed along the Old, Middle, and San Joaquin Rivers
 40 under CM5 and CM6, is generally low to medium.

41 **NEPA Effects:** The potential effect could be substantial because earthquake-induced liquefaction could
 42 damage ROA facilities, such as levees and berms. Damage to these features could result in their failure,
 43 causing flooding of otherwise protected areas.

1 During final design of conservation facilities, site-specific geotechnical and groundwater investigations
 2 would be conducted to identify and characterize the vertical (depth) and horizontal (spatial) extents of
 3 liquefiable soil. Engineering soil parameters that could be used to assess the liquefaction potential, such
 4 as SPT blow counts, CPT penetration tip pressure/resistance, and gradation of soil, would also be
 5 obtained. SPT blow counts and CPT tip pressure are used to estimate soil resistance to cyclic loadings
 6 by using empirical relationships that were developed based on occurrences of liquefaction (or lack of
 7 them) during past earthquakes. The resistance then can be compared to cyclic shear stress induced by
 8 the design earthquakes. If soil resistance is less than induced stress, the potential of having liquefaction
 9 during the design earthquakes is high. It is also known that soil with high “fines” (i.e., silt- and clay-
 10 sized particles) content is less susceptible to liquefaction.

11 During final design, the facility-specific potential for liquefaction would be investigated by a
 12 geotechnical engineer. In areas determined to have a potential for liquefaction, the engineer would
 13 develop design parameters and construction methods to meet the design criteria established to ensure
 14 that design earthquake does not cause damage to or failure of the facility. Such measures and methods
 15 include removing and replacing potentially liquefiable soil, strengthening foundations (for example,
 16 using post-tensioned slab, reinforced mats, and piles) to resist excessive total and differential
 17 settlements, using *in situ* ground improvement techniques (such as deep dynamic compaction, vibro-
 18 compaction, vibro-replacement, compaction grouting, and other similar methods), and conforming with
 19 current seismic design codes and requirements. As described in Section 9.3.1, *Methods for Analysis*, and
 20 in Appendix 3B, *Environmental Commitments*, such design codes, guidelines, and standards include
 21 USACE’s *Engineering and Design—Stability Analysis of Concrete Structures and Soil Liquefaction during*
 22 *Earthquakes*, by the Earthquake Engineering Research Institute. Conformance with these design
 23 standards is an environmental commitment by the BDCP proponents to ensure that liquefaction risks
 24 are minimized as the conservation measures are implemented. The hazard would be controlled to a
 25 safe level.

26 In particular, conformance with the following codes and standards would reduce the potential risk for
 27 increased likelihood of loss of property or personal injury from structural failure resulting from
 28 seismic-related ground failure:

- 29 • USACE Engineering and Design - Design of Pile Foundations, EM 1110-2-2906, 1991
- 30 • USACE Engineering and Design – Stability Analysis of Concrete Structures, EM 1110-2-2100, 2005
- 31 • USACE Engineering and Design, Earthquake Design and Evaluation for Civil Works Projects, ER 1110-
 32 2-1806, 1995
- 33 • California Code of Regulations, Title 8, Sections 1509 and 3203, California Code of Regulations.

34 Generally, the applicable codes require that facilities be built so that if soil in the foundation or
 35 surrounding area are subject to liquefaction, the removal or densification of the liquefiable material
 36 should be considered, along with alternative foundation designs.

37 The worker safety codes and standards specify protective measures that must be taken at construction
 38 sites to minimize the risk of injury or death from structural or earth failure (e.g., utilizing personal
 39 protective equipment, practicing crane and scaffold safety measures). The relevant codes and
 40 standards represent performance standards that must be met by contractors and these measures are
 41 subject to monitoring by state and local agencies. Cal-OSHA requirements for an IIPP and the terms of
 42 the IIPP to protect worker safety are the principal measures that would be enforced at construction
 43 sites.

1 The BDCP proponents would ensure that the geotechnical design recommendations are included in the
 2 design of levees and construction specifications to minimize the potential effects from liquefaction and
 3 associated hazard. The BDCP proponents would also ensure that the design specifications are properly
 4 executed during construction and would not create an increased likelihood of loss of property, personal
 5 injury or death of individuals in the ROAs. This effect would not be adverse.

6 **CEQA Conclusion:** Earthquake-induced ground shaking could cause liquefaction, resulting in damage to
 7 or failure of levees, berms, and other features constructed at the restoration areas. Failure of levees and
 8 other structures could result in loss or injury, as well as flooding of otherwise protected areas.
 9 However, through the final design process, measures to address the liquefaction hazard would be
 10 required to conform to applicable design codes, guidelines, and standards. As described in Section
 11 9.3.1, *Methods for Analysis*, and in Appendix 3B, *Environmental Commitments*, such design codes,
 12 guidelines, and standards include USACE's *Engineering and Design—Stability Analysis of Concrete*
 13 *Structures* and *Soil Liquefaction during Earthquakes*, by the Earthquake Engineering Research Institute.
 14 Conformance with these design standards is an environmental commitment by the BDCP proponents to
 15 ensure that liquefaction risks are minimized as the water conservation features are implemented. The
 16 hazard would be controlled to a safe level and there would be no increased likelihood of loss of
 17 property, personal injury or death of individuals in the ROAs. The impact would be less than significant.
 18 No mitigation is required.

19 **Impact GEO-15: Loss of Property, Personal Injury, or Death from Landslides and Other Slope**
 20 **Instability at Restoration Opportunity Areas**

21 Implementation of CM2–CM7, would involve breaching, modification or removal of existing levees and
 22 construction of new levees and embankments. CM4 which provides for the restoration of up to 65,000
 23 acres of tidal perennial aquatic, tidal mudflat, tidal freshwater emergent wetland, and tidal brackish
 24 emergent wetland natural communities within the ROAs involves the greatest amount of modifications
 25 to levees. Levee modifications, including levee breaching or lowering, may be performed to reintroduce
 26 tidal exchange, reconnect remnant sloughs, restore natural remnant meandering tidal channels,
 27 encourage development of dendritic channel networks, and improve floodwater conveyance.

28 Levee modifications could involve the removal of vegetation and excavation of levee materials. Excess
 29 earthen materials could be temporarily stockpiled, then re-spread on the surface of the new levee
 30 slopes where applicable or disposed of offsite. Any breaching or other modifications would be required
 31 to be designed and implemented to maintain the integrity of the levee system and to conform with
 32 flood management standards and permitting processes. This would be coordinated with the
 33 appropriate flood management agencies. Those agencies may include USACE, DWR, CVFPB, and other
 34 flood management agencies. For more detail on potential modifications to levees as a part of
 35 conservation measures, please refer to Chapter 3, *Description of Alternatives*.

36 New and existing levee slopes and stream/channel banks could fail and could damage facilities as a
 37 result of seismic shaking and as a result of high soil-water content during heavy rainfall.

38 With the exception of levee slopes, natural stream banks, and part of the Suisun Marsh ROA, the
 39 topography of ROAs is nearly level to gently sloping. The areas that may be susceptible to slope failure
 40 are along existing Sacramento and San Joaquin River and Delta island levees and stream/channel
 41 banks, particularly those levees that consist of non-engineered fill and those streambanks that are
 42 steep and consist of low strength soil.

1 The structures associated with conservation measures would not be constructed in, nor would they be
2 adjacent to, areas that are subject to mudflows/debris flows from natural slopes.

3 **NEPA Effects:** The potential effect could be substantial because levee slopes and embankments may fail,
4 either from high pore-water pressure caused by high rainfall and weak soil, or from seismic shaking.
5 Failure of these features could result in flooding of otherwise protected areas.

6 As outlined in Chapter 3, *Description of Alternatives*, erosion protection measures and protection
7 against related failure of adjacent levees would be taken where levee breaches were developed.
8 Erosion protection could include geotextile fabrics, rock revetments, riprap, or other material selected
9 during future evaluations for each location. Aggregate rock could be placed on the remaining levees to
10 provide an access road to the breach location. Erosion protection measures would also be taken where
11 levee lowering is done for the purposes of allowing seasonal or periodic inundation of lands during
12 high flows or high tides to improve habitat or to reduce velocities and elevations of floodwaters. To
13 reduce erosion potential on the new levee crest, a paved or gravel access road could be constructed
14 with short (approximately 1 foot) retaining walls on each edge of the crest to reduce undercutting of
15 the roadway by high tides. Levee modifications could also include excavation of watersides of the
16 slopes to allow placement of slope protection, such as riprap or geotextile fabric, and to modify slopes
17 to provide levee stability. Erosion and scour protection could be placed on the landside of the levee and
18 continued for several feet onto the land area away from the levee toe. Neighboring levees could require
19 modification to accommodate increased flows or to reduce effects of changes in water elevation or
20 velocities along channels following inundation of tidal marshes. Hydraulic modeling would be used
21 during subsequent analyses to determine the need for such measures.

22 New levees would be constructed to separate lands to be inundated for tidal marsh from non-
23 inundated lands, including lands with substantial subsidence. Levees could be constructed as described
24 for the new levees at intake locations. Any new levees would be required to be designed and
25 implemented to conform with applicable flood management standards and permitting processes. This
26 would be coordinated with the appropriate flood management agencies, which may include USACE,
27 DWR, CVFPB, and local flood management agencies.

28 Additionally, during project design, a geotechnical engineer would develop slope stability design
29 criteria (such as minimum slope safety factors and allowable slope deformation and settlement) for the
30 various anticipated loading conditions. As discussed in Chapter 3, *Description of the Alternatives*,
31 foundation soil beneath embankments and levees could be improved to increase its strength and to
32 reduce settlement and deformation. Foundation soil improvement could involve excavation and
33 replacement with engineered fill; preloading; ground modifications using jet-grouting, compaction
34 grouting, chemical grouting, shallow soil mixing, deep soil mixing, vibro-compaction, or
35 vibro-replacement; or other methods. Engineered fill could also be used to construct new
36 embankments and levees.

37 Site-specific geotechnical and hydrological information would be used, and the design would conform
38 with the current standards and construction practices, as described in Chapter 3, *Description of the*
39 *Alternatives*, such as USACE's *Design and Construction of Levees* and USACE's *EM 1110-2-1902, Slope*
40 *Stability*.

41 The BDCP proponents would ensure that the geotechnical design recommendations are included in the
42 design of embankments and levees to minimize the potential effects from slope failure. The BDCP
43 proponents would also ensure that the design specifications are properly executed during
44 implementation.

1 In particular, conformance with the following codes and standards would reduce the potential risk for
 2 increased likelihood of loss of property or personal injury from structural failure resulting from
 3 landslides or other slope instability:

- 4 • DWR Division of Engineering State Water Project – Seismic Loading Criteria Report, Sept 2012.
- 5 • DWR Division of Flood Management FloodSAFE Urban Levee Design Criteria, May 2012.
- 6 • USACE Slope Stability, EM 1110-2-1902, 2003.
- 7 • California Code of Regulations, Title 8, Section 3203, California Code of Regulations.

8 Generally, the applicable codes require that facilities be built to certain factors of safety in order to
 9 ensure that facilities perform as designed for the life of the structure despite various soil parameters.

10 The worker safety codes and standards specify protective measures that must be taken at construction
 11 sites to minimize the risk of injury or death from structural or earth failure (e.g., utilizing personal
 12 protective equipment). The relevant codes and standards represent performance standards that must
 13 be met by contractors and these measures are subject to monitoring by state and local agencies. Cal-
 14 OSHA requirements for an IIPP and the terms of the IIPP to protect worker safety are the principal
 15 measures that would be enforced at project sites during operations.

16 Conformance to the above and other applicable design specifications and standards would ensure that
 17 the hazard of slope instability would not jeopardize the integrity of levees and other features at the
 18 ROAs and would not create an increased likelihood of loss of property, personal injury or death of
 19 individuals in the ROAs. This effect would not be adverse.

20 **CEQA Conclusion:** Unstable new and existing levee and embankment slopes could fail as a result of
 21 seismic shaking and as a result of high soil-water content during heavy rainfall and cause flooding of
 22 otherwise protected areas. However, because the BDCP proponents would conform with applicable
 23 design guidelines and standards, such as USACE design measures, the hazard would be controlled to a
 24 safe level and there would be no increased likelihood of loss of property, personal injury or death of
 25 individuals in the ROAs. The impact would be less than significant. No mitigation is required.

26 **Impact GEO-16: Loss of Property, Personal Injury, or Death from Seiche or Tsunami at**
 27 **Restoration Opportunity Areas as a Result of Implementing the Conservation Actions**

28 **NEPA Effects:** The distance from the ocean and attenuating effect of the San Francisco Bay would likely
 29 allow only a low tsunami wave height to reach the Suisun Marsh and the Delta. Conditions for a seiche
 30 to occur at the ROAs are not favorable. Therefore, the effect would not be adverse.

31 **CEQA Conclusion:** Based on recorded tsunami heights at the Golden Gate, the height of a tsunami wave
 32 reaching the ROAs would be small because of the distance from the ocean and attenuating effect of the
 33 San Francisco Bay. Similarly, the potential for a significant seiche to occur in the Plan Area that would
 34 cause loss of property, personal injury, or death at the ROAs is considered low because conditions for a
 35 seiche to occur at the ROAs are not favorable. The impact would be less than significant. No mitigation
 36 is required.

9.3.3.3 Alternative 1B—Dual Conveyance with East Alignment and Intakes 1–5 (15,000 cfs; Operational Scenario A)

Impact GEO-1: Loss of Property, Personal Injury, or Death from Structural Failure Resulting from Strong Seismic Shaking of Water Conveyance Features during Construction

Earthquakes could be generated from local and regional seismic sources during construction of the Alternative 1B water conveyance facilities. Seismically induced ground shaking could cause injury of workers at the construction sites as a result of collapse of facilities.

The potential for experiencing earthquake ground shaking during construction in 2020 (during the project’s near-term implementation stage) was estimated using the results of the seismic study (California Department of Water Resources 2007a). The seismic study also computed seismic ground shaking hazards at six locations in the Delta for 2005, 2050, 2100, and 2200. The results of these analyses show that ground shaking in the Delta is not sensitive to the elapsed time since the last major earthquake (that is, the projected shaking hazard results for 2005, 2050, 2100, and 2200 are similar).

Table 9-18 lists the expected PGA and 1.0-S_a values in 2020 at selected facility locations along the Alternative 1B alignment. As with Alternative 1A, ground motions with a return period of 72 years and computed for 2005 are used to represent near-term (i.e., 2020) construction period motions for Alternative 1B.

Table 9-18. Expected Earthquake Ground Motions at Locations of Selected Major Facilities during Construction (2020)—Alternative 1B

Major Facilities	72-year Return Period Ground Motions			
	Peak Ground Acceleration (g)		1.0-sec S _a (g)	
	Stiff Soil ^a	Local Soil ^b	Stiff Soil ^a	Local Soil ^b
Intake and Fish Screen Area ^c	0.11	0.14	0.13	0.21
Siphon Location near Neugebaur Road in Stockton ^d	0.12	0.16	0.14	0.22
Clifton Court Forebay / Byron Tract Forebay	0.18	0.23	0.20	0.32

g = gravity

S_a = second spectral acceleration

^a Stiff soil site, with a V_{s100ft} value of 1,000 ft/s.

^b Site-adjusted factors of 1.3 and 1.6 were applied to PGA and 1.0-sec S_a values, respectively (adjustments from a stiff soil site to a soft soil site).

^c The results of California Department of Water Resources 2007a for the Sacramento site were used.

^d The results of California Department of Water Resources 2007a for the Stockton site were used.

NEPA Effects: The seismic study employed time-dependent seismic source models for several major faults in the region. These models were characterized based on the elapsed times since the last major seismic events on the faults. Therefore, the exposure risks predicted by the seismic study would increase if no major events occur on these faults through 2020. The effect would be adverse because seismically induced ground shaking could cause loss of property or personal injury at the Alternative 1B construction sites (including intake locations, pipelines between transition structures and canal transition structures, the canal, bridge crossings along the conveyance alignment, and the Byron Tract Forebay) as a result of collapse of facilities. The Byron Tract Forebay is located near an active blind

1 fault and the portion of the canal located east of Locke, as well as the portion of the canal which lies
 2 between Beaver Slough and Hog Slough, lie directly over an active blind fault and within the Thornton
 3 Arch Zone, resulting in an increased likelihood of loss of property or personal injury at these sites in the
 4 event of seismically-induced ground shaking. Although these blind thrusts are not expected to rupture
 5 to the ground surface under the forebays during earthquake events, they may produce ground or near-
 6 ground shear zones, bulging, or both (California Department of Water Resources 2007a). For a map of
 7 all permanent facilities and temporary work areas associated with this conveyance alignment, see
 8 Mapbook Figure M3-2.

9 However, during construction, all active construction sites would be designed and managed to meet the
 10 safety and collapse-prevention requirements of the relevant state codes and standards listed earlier in
 11 this chapter and expanded upon in Appendix 3B, *Environmental Commitments* for the above-anticipated
 12 seismic loads.

13 In particular, conformance with the following codes and standards would reduce the potential risk for
 14 increased likelihood of loss of property or personal injury from structural failure resulting from strong
 15 seismic shaking of water conveyance features during construction:

- 16 • DWR Division of Engineering State Water Project – Seismic Loading Criteria Report, Sept 2012.
- 17 • USACE Engineering and Design, Earthquake Design and Evaluation for Civil Works Projects, ER 1110-
 18 2-1806, 1995.
- 19 • USACE Engineering and Design – Earthquake Design and Evaluation of Concrete Hydraulic Structures,
 20 EM 1110-2-6053, 2007.
- 21 • USACE Engineering and Design – Response Spectra and Seismic Analysis for Concrete Hydraulic
 22 Structures, EM 1110-2-6050, 1999.
- 23 • USACE Engineering and Design – Stability Analysis of Concrete Structures, EM 1110-2-2100, 2005.
- 24 • California Code of Regulations, Title 8, Sections 1509 and 3203, California Code of Regulations.

25 Generally, the applicable codes require that facilities be built so that they incur minimal damage in the
 26 event of a foreseeable seismic event and that they remain functional following such an event and that
 27 the facility is able to perform without catastrophic failure in the event of a maximum design earthquake
 28 (the greatest earthquake reasonably expected to be generated by a specific source on the basis of
 29 seismological and geological evidence). The safety requirements could include shoring, specified slope
 30 angles, excavation depth restrictions for workers, lighting and other similar controls. Conformance
 31 with these standards and codes is an environmental commitment of the project (see Appendix 3B,
 32 *Environmental Commitments*).

33 The worker safety codes and standards specify protective measures that must be taken at construction
 34 sites to minimize the risk of injury from structural or earth failure. The relevant codes and standards
 35 represent performance standards that must be met by DWR and these measures are subject to
 36 monitoring by state and local agencies. Cal-OSHA requirements to protect worker safety are the
 37 principal measures that would be enforced at construction sites.

38 Conformance with these health and safety requirements and the application of accepted, proven
 39 construction engineering practices would reduce any potential risk such that construction of
 40 Alternative 1B would not create an increased likelihood of loss of property, personal injury or death of
 41 individuals. Therefore, there would be no adverse effect.

1 **CEQA Conclusion:** Seismically induced ground shaking that is estimated to occur and the resultant
 2 ground motion anticipated at Alternative 1B construction sites, including the canal, pipelines and the
 3 forebays, could cause collapse or other failure of project facilities while under construction. For
 4 example, facilities lying directly on or near active blind faults, such as the Byron Tract Forebay as well
 5 as along the canal near Locke and between Beaver Slough and Hog Slough, may have in an increased
 6 likelihood of loss of property or personal injury at these sites in the event of seismically-induced
 7 ground shaking. However, DWR would conform with Cal-OSHA and other state code requirements,
 8 such as shoring, bracing, lighting, excavation depth restrictions, required slope angles, and other
 9 measures, to protect worker safety. Conformance with these standards and codes is an environmental
 10 commitment of the project (see Appendix 3B, *Environmental Commitments*). Conformance with these
 11 health and safety requirements and the application of accepted, proven construction engineering
 12 practices would reduce any potential risk such that construction of Alternative 1B would not create an
 13 increased likelihood of loss of property, personal injury or death of individuals. This risk would be less
 14 than significant. No mitigation is required.

15 **Impact GEO-2: Loss of Property, Personal Injury, or Death from Settlement or Collapse Caused**
 16 **by Dewatering during Construction of Water Conveyance Features**

17 Settlement of excavations could occur as a result of construction dewatering if proven construction and
 18 dewatering methods and earthwork practices are not carried out. The settlement could cause the
 19 slopes of excavations to fail. This hazard is most likely to be present at the intake and pumping plant
 20 locations and the canal alignment. The preliminary dewatering analysis results indicate that the
 21 majority (more than 90%) of the dewatering needs for Alternative 1B construction would be associated
 22 with canal construction (i.e., for the excavation of the canal foundation). The proposed canal for
 23 Alternative 1B is located on alluvial floodbasin deposits, alluvial floodplain deposits, natural levee
 24 deposits, dredge soils, and the Modesto Formation. Similar dewatering may be necessary where intakes
 25 and conveyance pipelines cross waterways and major irrigation canals. The conveyance pipeline
 26 between Intake 3 and the canal crosses three canals or ditches. All are 0.3 miles southeast of the facility
 27 grounds for Intake 3 (or nearer). The conveyance pipeline between Intake 5 and the canal crosses three
 28 canals or ditches. These crossings occur approximately 0.25 miles, 0.5 miles, and 0.75 miles southeast
 29 and east southeast of the facility grounds for Intake 5. Conveyance pipelines construction for Intakes 1,
 30 2, and 4 would not be anticipated to intersect with waterways or major irrigation canals.

31 Dewatering can stimulate settlement in excavation and tunneling sites. The settlement could cause the
 32 slopes of excavations to fail.

33 **NEPA Effects:** This potential effect could be substantial because settlement or collapse during
 34 dewatering could cause injury of workers at the construction sites as a result of collapse of excavations.
 35 The hazard of settlement and subsequent collapse of excavations would be evaluated by assessing site-
 36 specific geotechnical and hydrological conditions along the canal, as well as where intakes and
 37 conveyance pipelines cross waterways and major irrigation canals. A California-registered civil
 38 engineer or California-certified engineering geologist would recommended measures in a geotechnical
 39 report to address these hazards, such as seepage cutoff walls and barriers, shoring, grouting of the
 40 bottom of the excavation, and strengthening of nearby structures, existing utilities, or buried
 41 structures. As described in Section 9.3.1, *Methods for Analysis*, the measures would conform to
 42 applicable design and building codes, guidelines, and standards, such as the California Building Code
 43 and USACE's *Engineering and Design—Structural Design and Evaluation of Outlet Works*. See Appendix
 44 3B, *Environmental Commitments*. In particular, conformance with the following codes and standards
 45 would reduce the potential risk for increased likelihood of loss of property or personal injury from

1 structural failure resulting from settlement or collapse at the construction site caused by dewatering
2 during construction:

- 3 • DWR Division of Flood Management FloodSAFE Urban Levee Design Criteria, May 2012.
- 4 • USACE Engineering and Design - Settlement Analysis, EM 1110-1-1904, 1990.
- 5 • California Code of Regulations, Title 8, Sections 1509 and 3203, California Code of Regulations.

6 Generally, the applicable codes require that facilities be built in such a way that settlement is
7 minimized. DWR would ensure that the geotechnical design recommendations are included in the
8 design of project facilities and construction specifications to minimize the potential effects from
9 settlement and failure of excavations.

10 DWR would ensure that the geotechnical design recommendations are included in the design of project
11 facilities and construction specifications to minimize the potential effects from settlement and failure of
12 excavations. DWR would also ensure that the design specifications are properly executed during
13 construction. DWR has made an environmental commitment to use the appropriate code and standard
14 requirements to minimize potential risks (Appendix 3B, *Environmental Commitments*).

15 The worker safety codes and standards specify protective measures that must be taken at construction
16 sites to minimize the risk of injury or death from structural or earth failure (e.g., utilizing personal
17 protective equipment, practicing crane and scaffold safety measures). The relevant codes and
18 standards represent performance standards that must be met by contractors and these measures are
19 subject to monitoring by state and local agencies. Cal-OSHA requirements for an IIPP and the terms of
20 the IIPP to protect worker safety are the principal measures that would be enforced at construction
21 sites.

22 Conformance to these and other applicable design specifications and standards would ensure that
23 construction of Alternative 1B would not create an increased likelihood of loss of property, personal
24 injury or death of individuals from settlement or collapse caused by dewatering. Therefore, there
25 would be no adverse effects.

26 **CEQA Conclusion:** Settlement or failure of excavations during construction could result in loss of
27 property or personal injury. However, DWR would conform with Cal-OSHA and other state code
28 requirements, such as using seepage cutoff walls, shoring, and other measures, to protect worker
29 safety. DWR would also ensure that the design specifications are properly executed during
30 construction. DWR has made an environmental commitment to use the appropriate code and standard
31 requirements to minimize potential risks (Appendix 3B, *Environmental Commitments*). Conformance
32 with these requirements and the application of accepted, proven construction engineering practices
33 would reduce any potential risk such that construction of Alternative 1B would not create an increased
34 likelihood of direct loss, injury or death of individuals from settlement or collapse caused by
35 dewatering. This risk would be less than significant. No mitigation is required.

36 **Impact GEO-3: Loss of Property, Personal Injury, or Death from Ground Settlement during** 37 **Construction of Water Conveyance Features**

38 Two types of ground settlement could be induced during construction of alternative 1B tunnel siphons:
39 large settlement and systematic settlement. Large settlement occurs primarily as a result of
40 over-excavation by the tunneling shield. The over-excavation is caused by failure of the tunnel boring
41 machine to control unexpected or adverse ground conditions (for example, running, raveling,
42 squeezing, and flowing ground) or operator error. Large settlement can lead to the creation of voids

1 and/or sinkholes above the tunnel siphon. In extreme circumstances, the settlement effects could
 2 translate to the ground surface, potentially causing loss of property or personal injury above the tunnel
 3 siphon construction.

4 Systematic settlement usually results from ground movements that occur before tunnel supports can
 5 exit the shield and the tunnel to make full contact with the ground. Soil with higher silt and clay content
 6 tend to experience less settlement than sandy soil. Additional ground movements can occur with the
 7 deflection of the tunnel siphon supports and over-excavation caused by steering/plowing of the tunnel
 8 boring machine at horizontal and vertical curves. A deeper tunnel siphon induces less ground surface
 9 settlement because a greater volume of soil material is available above the tunnel siphon to fill any
 10 systematic void space.

11 The geologic units in the area of the Alternative 1B alignment are shown on Figure 9-3 and summarized
 12 in Table 9-19. The characteristics of each unit would affect the potential for settlement during tunnel
 13 siphon construction. Segments 4, 5, 6, 7, 8 and 9, located south east of Locke and running down to
 14 Fourteenmile Slough, contain higher amounts of loose and fine sand than the other segments, so they
 15 pose a greater risk of settlement.

16 Given the likely design depth of the tunnel siphon, the potential for excessive systematic settlement
 17 expressed at the ground surface caused by tunnel siphon construction is thought to be relatively.
 18 Operator errors or highly unfavorable/unexpected ground conditions could result in larger settlement.
 19 Large ground settlements caused by tunnel siphon construction are almost always the result of using
 20 inappropriate tunneling equipment (incompatible with the ground conditions), improperly operating
 21 the machine, or encountering sudden or unexpected changes in ground conditions.

22 **NEPA Effects:** The potential effect could be substantial because ground settlement could occur during
 23 the tunnel siphon construction. During detailed project design, a site-specific subsurface geotechnical
 24 review would be conducted along the water conveyance facility alignment to verify or refine the
 25 findings of the preliminary geotechnical investigation. The tunneling equipment and drilling methods
 26 would be reevaluated and refined based on the results of the investigations, and field procedures for
 27 sudden changes in ground conditions would be implemented to minimize or avoid ground settlement.
 28 A California-registered civil engineer or California-certified engineering geologist would recommend
 29 measures to address these hazards, such as specifying the type of tunnel boring machine to be used in a
 30 given segment. The results of the site-specific evaluation and the engineer's recommendations would
 31 be documented in a detailed geotechnical report prepared in accordance with state guidelines, in
 32 particular, *Guidelines for Evaluating and Mitigating Seismic Hazards in California* (California Geological
 33 Survey 2008). As described in Section 9.3.1, *Methods for Analysis*, the measures would conform to
 34 applicable design and building codes, guidelines, and standards, such as USACE design measures. See
 35 Appendix 3B, *Environmental Commitments*.

36 In particular, conformance with the following codes and standards would reduce the potential risk for
 37 increased likelihood of loss of property or personal injury from ground settlement above the tunneling
 38 operation during construction:

- 39 • DWR Division of Engineering State Water Project – Seismic Loading Criteria Report, Sept 2012.
- 40 • DWR Division of Flood Management FloodSAFE Urban Levee Design Criteria, May 2012.
- 41 • California Code of Regulations, Title 8, Sections 1509 and 3203, California Code of Regulations.

1 **Table 9-19. Geology of Alternative 1B/East Alignment by Segments**

Segment ^a	Geologic Unit	Geologic Unit Description
Segment 1	Ql	Natural levee deposits: moderately to well-sorted sand, with some silt and clay
	Qb	Flood basin deposits: firm to stiff silty clay, clayey silt, and silt
	Qm2e	Eolian sand: well-sorted fine- to medium-grained sand
	Qr, Qry and Qro	Riverbank Formation: alluvial fans from glaciated basins that consist of moderately sorted to well-sorted sand, gravel, silt, and minor clay
Segment 2	Qb	Flood basin deposits: firm to stiff silty clay, clayey silt, and silt
	Qm2e	Eolian sand: well-sorted fine- to medium-grained sand
	Qry	Riverbank Formation: alluvial fans from glaciated basins that consist of moderately sorted to well-sorted sand, gravel, silt, and minor clay
Segment 3 (Tunnel Siphon Segment)	Ql	Natural levee deposits: moderately to well-sorted sand, with some silt and clay
	Qb	Flood basin deposits: firm to stiff silty clay, clayey silt, and silt
Segment 4	Qb	Flood basin deposits: firm to stiff silty clay, clayey silt, and silt
	Qr	Riverbank Formation: alluvial fans from glaciated basins consisting of moderately sorted to well sorted sand, gravel, silt and minor clay
	Qfp	Floodplain deposits: dense, sandy to silty clay
	Qm	Modesto Formation: loose sand and silt to compact silt and very fine sand
Segment 5, Segment 6, Segment 7, and Segment 8	Qm	Modesto Formation: loose sand and silt to compact silt and very fine sand
Segment 9	Qm	Modesto Formation: loose sand and silt to compact silt and very fine sand
	Qm2e	Eolian sand: well sorted fine- to medium-grained sand
	Qpm	Delta mud: mud and peat with minor silt or sand
Segment 10 (Tunnel Siphon Segment)	Qds	Dredge soils, post 1900
	Qpm	Delta mud: mud and peat with minor silt or sand
Segment 11	Qds	Dredge soils, post 1900
	Qpm	Delta mud: mud and peat with minor silt or sand
	Qfp	Floodplain deposits: dense, sandy to silty clay
Segment 12 and Segment 13	Qfp	Floodplain deposits: dense, sandy to silty clay
Segment 14 (Tunnel Siphon Segment)	Qfp	Floodplain deposits: dense sandy to silty clay

Source: Hansen et al. 2001 and Atwater 1982.

^a The segments are shown on Figure 9-3.

2

1 As described in detail in Impacts GEO-1 and GEO-2, DWR would ensure that the geotechnical design
 2 recommendations are included in the design of project facilities and construction specifications to
 3 minimize the potential effects from settlement. DWR would also ensure that the design specifications
 4 are properly executed during construction. DWR has made this conformance and monitoring process
 5 an environmental commitment of the BDCP (Appendix 3B, *Environmental Commitments*).

6 Generally, the applicable codes require that facilities be built so that they are designed for a landside
 7 slope stability and seepage/underseepage factors of safety greater than 1.0 (i.e., stable) and would
 8 therefore be less impacted in the event of ground settlement. The worker safety codes and standards
 9 specify protective measures that must be taken at construction sites to minimize the risk of injury or
 10 death from structural or earth failure (e.g., utilizing personal protective equipment, practicing crane
 11 and scaffold safety measures). The relevant codes and standards represent performance standards that
 12 must be met by contractors and these measures are subject to monitoring by state and local agencies.
 13 Cal-OSHA requirements for an IIPP and the terms of the IIPP to protect worker safety are the principal
 14 measures that would be enforced at construction sites.

15 Conformance to these and other applicable design specifications and standards would ensure that
 16 construction of Alternative 1B would not create an increased likelihood of loss of property, personal
 17 injury or death of individuals from ground settlement. Therefore, there would be no adverse effect.

18 **CEQA Conclusion:** Ground settlement above the tunnel siphon construction could result in loss of
 19 property or personal injury during construction. However, DWR would conform with Cal-OSHA, USACE
 20 and other design requirements to protect worker safety. DWR would also ensure that the design
 21 specifications are properly executed during construction. DWR has made an environmental
 22 commitment to use the appropriate code and standard requirements to minimize potential risks
 23 (Appendix 3B, *Environmental Commitments*). Conformance with these requirements and the
 24 application of accepted, proven construction engineering practices would reduce any potential risk
 25 such that construction of Alternative 1B would not create an increased likelihood of loss of property,
 26 personal injury or death of individuals from ground settlement. This risk would be less than significant.
 27 No mitigation is required.

28 **Impact GEO-4: Loss of Property, Personal Injury, or Death from Slope Failure during** 29 **Construction of Water Conveyance Features**

30 Excavation of borrow material could result in failure of cut slopes and application of temporary spoils
 31 and RTM at storage sites could cause excessive settlement in the spoils, potentially causing injury of
 32 workers at the construction sites. Soil and sediment, especially those consisting of loose alluvium and
 33 soft peat or mud, would particularly be prone to failure and movement. Additionally, groundwater is
 34 expected to be within a few feet of the ground surface in these areas, this may make excavations more
 35 prone to failure.

36 Borrow and spoils areas for construction of the canal foundation, intakes, sedimentation basins,
 37 pumping plants, forebays, and other supporting facilities would be sited near the locations of these
 38 structures (generally within 10 miles). Along the alignment, selected areas would also be used for
 39 disposing of the byproduct (RTM) of tunnel siphon construction. Table 9-20 describes the geology of
 40 these areas as mapped by Atwater (1982) (Figure 9-3).

1 **Table 9-20. Geology of Alternative 1B Borrow/Spoils and Resuable Tunnel Material Areas by Segments**

Segment ^a	Geologic Unit	Geologic Unit Description
Segment 1 Borrow/Spoils Area	Ql	Natural Levee deposits: moderately- to well-sorted sand, with some silt and clay.
	Qb	Flood basin deposits: firm to stiff silty clay, clayey silt, and silt
	Qm2e	Eolian sand: well-sorted fine- to medium-grained sand
	Qoe	Older eolian deposits
	Qr, Qry and Qro	Riverbank Formation: alluvial fans from glaciated basins which consist of moderately-sorted to well-sorted sand, gravel, silt and minor clay
Segment 2 Borrow/Spoils Area	Qm2e	Eolian sand: well-sorted fine- to medium-grained sand
	Qry	Riverbank Formation: alluvial fans from glaciated basins consisting of moderately-sorted to well-sorted sand, gravel, silt and minor clay
Segment 4 Borrow/Spoils Area	Qb	Flood basin deposits: firm to stiff silty clay, clayey silt, and silt
	Qfp	Floodplain deposits: dense, sandy to silty clay
	Qm	Modesto Formation: loose sand and silt to compact silt and very fine sand
Segment 5, Segment 7, and Segment 8 Borrow/Spoils Area	Qm	Modesto Formation: loose sand and silt to compact silt and very fine sand
Segment 9 Borrow/Spoils Area	Qm	Modesto Formation: loose sand and silt to compact silt and very fine sand
	Qm2e	Eolian sand: well-sorted fine- to medium-grained sand
	Qpm	Delta mud: mud and peat with minor silt or sand
Segment 11 Borrow/Spoils Area	Qds	Dredge soils, post 1900
	Qfp	Floodplain deposits: dense, sandy to silty clay
	Qpm	Delta mud: mud and peat with minor silt or sand
Segment 12 and Segment 13 Borrow/Spoils Area	Qfp	Floodplain deposits: dense, sandy to silty clay
	Qb	Flood basin deposits: firm to stiff silty clay, clayey silt, and silt
Segment 3 Resuable Tunnel Material Area	Ql	Natural Levee deposits: moderately to well-sorted sand, with some silt and clay.
	Qfp	Floodplain deposits: dense, sandy to silty clay
	Qr	Riverbank Formation: alluvial fans from glaciated basins consisting of moderately sorted to well sorted sand, gravel, silt and minor clay
Segment 10 Resuable Tunnel Material Area	Qm	Modesto Formation: loose sand and silt to compact silt and very fine sand
	Qm2e	Eolian sand: well-sorted fine- to medium-grained sand
Segment 14 Resuable Tunnel Material Area	Qfp	Floodplain deposits: dense, sandy to silty clay

Source: Hansen et al. 2001 and Atwater 1982.

^a The segments are shown on Figure 9-3.

2

1 **NEPA Effects:** The potential effect could be substantial because excavation of borrow material and the
2 resultant cutslopes and potential failure of spoils/RTM fill slopes could cause injury of workers at the
3 construction sites.

4 Excavations in borrow areas would be designed to avoid excessive ground movements on adjacent
5 areas and soil “boiling” (i.e., upwelling of groundwater) at the bottom of the excavation. Spoils would be
6 placed in 12-inch lifts with proper compaction and stored no higher than 12 feet above preconstruction
7 ground elevation with maximum side slopes of 5H:1V. During design, the potential for native ground
8 settlement below the spoils would be evaluated by a geotechnical engineer using site-specific
9 geotechnical and hydrological information. The use of shoring, seepage cutoff walls, and ground
10 modifications to prevent slope instability, soil boiling, or excessive settlement would be considered in
11 the design.

12 In addition to the risk of slope failure at borrow sites and spoils and RTM sites, there are also potential
13 impacts on levee stability resulting from construction of Alternative 1B water conveyance facilities. The
14 intakes would be sited along the existing Sacramento River levee system, requiring reconstruction of
15 levees to provide continued flood management. At each intake pumping plant site, a new setback levee
16 (ring levee) would be constructed. The space enclosed by the setback levee would be filled up to the
17 elevation of the top of the setback levee, creating a building pad for the adjacent pumping plant.

18 As discussed in Chapter 3, *Description of the Alternatives*, the new levees would be designed to provide
19 an adequate Sacramento River channel cross section and to provide the same level of flood protection
20 as the existing levee and would be constructed to geometries that meet or exceed PL 84-99 standards.
21 CALFED and DWR have adopted PL 84-99 as the preferred design standard for Delta levees. Transition
22 levees would be constructed to connect the existing levees to the new setback levees. A typical new
23 levee would have a broad-based, generally asymmetrical triangular cross section. The levee height
24 considered wind and wave erosion. As measured from the adjacent ground surface on the landside
25 vertically up to the elevation of the levee crest, would range from approximately 20 to 45 feet to
26 provide adequate freeboard above anticipated water surface elevations. The width of the levee (toe of
27 levee to toe of levee) would range from approximately 180 to 360 feet. The minimum crest width of the
28 levee would be 20 feet; however, in some places it would be larger to accommodate roadways and
29 other features. Cut-off walls would be constructed to avoid seepage, and the minimum slope of levee
30 walls would be three units horizontal to one unit vertical. All levee reconstruction will conform with
31 applicable state and federal flood management engineering and permitting requirements.

32 Depending on foundation material, foundation improvements would require excavation and
33 replacement of soil below the new levee footprint and potential ground improvement. The levees
34 would be armored with riprap—small to large angular boulders—on the waterside. Intakes would be
35 constructed using a sheetpile cofferdam in the river to create a dewatered construction area that would
36 encompass the intake site. The cofferdam would lie approximately 10–35 feet from the footprint of the
37 intake and would be built from upstream to downstream, with the downstream end closed last. The
38 distance between the face of the intake and the face of the cofferdam would be dependent on the
39 foundation design and overall dimensions. The length of each temporary cofferdam would vary by
40 intake location, but would range from 740 to 2,440 feet. Cofferdams would be supported by steel sheet
41 piles and/or king piles (heavy H-section steel piles). Installation of these piles may require both impact
42 and vibratory pile drivers. Some clearing and grubbing of levees would be required prior to installation
43 of the sheet pile cofferdam, depending on site conditions. Additionally, if stone bank protection, riprap,
44 or mature vegetation is present at intake construction site, it would be removed prior to sheet pile
45 installation.

1 As described in Section 9.3.1, *Methods for Analysis*, the measures would conform to applicable design
 2 and building codes, guidelines, and standards, such as the California Building Code and USACE's
 3 *Engineering and Design—Structural Design and Evaluation of Outlet Works*. DWR would ensure that the
 4 geotechnical design recommendations are included in the design of project facilities and construction
 5 specifications to minimize the potential effects from failure of excavations and settlement. DWR would
 6 also ensure that the design specifications are properly executed during construction.

7 In particular, conformance with the following codes and standards would reduce the potential risk for
 8 increased likelihood of loss of property or personal injury from settlement/failure of cutslopes of
 9 borrow sites and failure of soil or RTM fill slopes during construction:

- 10 ● DWR Division of Engineering State Water Project – Seismic Loading Criteria Report, Sept 2012.
- 11 ● DWR Division of Flood Management FloodSAFE Urban Levee Design Criteria, May 2012.
- 12 ● California Code of Regulations, Title 8, Sections 1509 and 3203, California Code of Regulations.

13 Generally, the applicable codes require that facilities be built to certain factors of safety in order to
 14 ensure that facilities perform as designed for the life of the structure despite various soil parameters.
 15 The worker safety codes and standards specify protective measures that must be taken at construction
 16 sites to minimize the risk of injury or death from structural or earth failure (e.g., utilizing personal
 17 protective equipment, practicing crane and scaffold safety measures). The relevant codes and
 18 standards represent performance standards that must be met by contractors and these measures are
 19 subject to monitoring by state and local agencies. Cal-OSHA requirements for an IIPP and the terms of
 20 the IIPP to protect worker safety are the principal measures that would be enforced at construction
 21 sites.

22 Conformance to these and other applicable design specifications and standards would ensure that
 23 construction of Alternative 1B would not create an increase likelihood of loss of property, personal
 24 injury or death of individuals from slope failure at borrow sites and spoils and RTM storage sites. The
 25 reconstruction of levees would improve levee stability over existing conditions due to improved side
 26 slopes, erosion countermeasures (geotextile fabrics, rock revetments, riprap, or other material),
 27 seepage reduction measures, and overall mass. Therefore, there would be no adverse effect.

28 **CEQA Conclusion:** Settlement/failure of cutslopes of borrow sites and failure of soil/RTM fill slopes
 29 could result in loss of property or personal injury during construction. However, DWR would conform
 30 with Cal-OSHA and other state code requirements and conform to applicable geotechnical design
 31 guidelines and standards, such as USACE design measures. Conformance with these requirements and
 32 the application of accepted, proven construction engineering practices would reduce any potential risk
 33 such that construction of Alternative 1B would not create an increased likelihood of loss of property,
 34 personal injury or death of individuals from slope failure at borrow sites and spoils and RTM storage
 35 sites. The reconstruction of levees would improve levee stability over existing conditions due to
 36 improved side slopes, erosion countermeasures, seepage reduction measures, and overall mass. The
 37 impact would be less than significant. No mitigation is required.

38 **Impact GEO-5: Loss of Property, Personal Injury, or Death from Structural Failure Resulting** 39 **from Construction-Related Ground Motions during Construction of Water Conveyance Features**

40 Pile driving and other heavy equipment operations would cause vibrations that could initiate
 41 liquefaction and associated ground movements in places where soil and groundwater conditions are
 42 present to allow liquefaction to occur. The consequences of liquefaction could be manifested in terms of

1 compaction or settlement, loss of bearing capacity, lateral spreading (horizontal soil movement),
 2 increased lateral soil pressure, and buoyancy within zones of liquefaction. These consequences could
 3 damage nearby structures and levees.

4 The lateral extent (or influenced distance) of damage potential caused by pile driving and heavy
 5 equipment operations depends on many factors, including soil conditions, the piling hammer used,
 6 frequency of piling, and the vibration tolerance of structures and levees.

7 Pile driving would be conducted at the intakes, where, based on boring logs, soil materials subject to
 8 liquefaction (e.g., saturated, poorly graded sand) are present. During project design, site-specific
 9 geotechnical and groundwater investigations would be conducted to build upon existing data (e.g.,
 10 California Department of Water Resources 2009a, 2010i) to identify and characterize the vertical
 11 (depth) and horizontal (spatial) variability in soil bearing capacity and extent of liquefiable soil.
 12 Engineering soil parameters that could be used to assess the liquefaction potential, such as SPT blow
 13 counts, CPT penetration tip pressure/resistance, and gradation of soil, would also be obtained. SPT
 14 blow counts and CPT tip pressure are used to estimate soil resistance to cyclic loadings by using
 15 empirical relationships that were developed based on occurrences of liquefaction (or lack of them)
 16 during past earthquakes. The resistance then can be compared to cyclic shear stress induced by the
 17 design earthquake (i.e., the earthquake that is expected to produce the strongest level of ground
 18 shaking at a site to which it is appropriate to design a structure to withstand). If soil resistance is less
 19 than induced stress, the potential of having liquefaction during the design earthquakes is high. It is also
 20 known that soil with high “fines” (i.e., silt- and clay-sized particles) content are less susceptible to
 21 liquefaction.

22 **NEPA Effects:** The potential effect could be substantial because construction-related ground motions
 23 could initiate liquefaction, which could cause failure of structures during construction, which could
 24 result in injury of workers at the construction sites.

25 During design, the facility-specific potential for liquefaction would be investigated by a geotechnical
 26 engineer. The potential effects of construction vibrations on nearby structures, levees, and utilities
 27 would be evaluated using specific piling information (such as pile type, length, spacing, and pile-driving
 28 hammer to be used). In areas determined to have a potential for liquefaction, the California-registered
 29 civil engineer or California-certified engineering geologist would develop design strategies and
 30 construction methods to ensure that pile driving and heavy equipment operations do not damage
 31 facilities under construction and surrounding structures and do not threaten the safety of workers at
 32 the site. As shown in Figure 9-6, the area from Disappointment Slough to Holt which Alternative 1B
 33 crosses through has medium to medium-high potential for levee liquefaction damage. Several siphons
 34 and a pumping plant north of Holt are located in this medium to medium-high potential for levee
 35 liquefaction damage area. Design measures may include predrilling or jetting, using open-ended pipe
 36 piles to reduce the energy needed for pile penetration, using CIDH piles/piers that do not require
 37 driving, using pile jacking to press piles into the ground by means of a hydraulic system, or driving piles
 38 during the drier summer months. Field data collected during design also would be evaluated to
 39 determine the need for and extent of strengthening levees, embankments, and structures to reduce the
 40 effect of vibrations. These construction methods would conform with current seismic design codes and
 41 requirements, as described in Chapter 3, *Description of the Alternatives*. Such design standards include
 42 USACE's *Engineering and Design—Stability Analysis of Concrete Structures and Soil Liquefaction during*
 43 *Earthquakes*, by the Earthquake Engineering Research Institute.

1 DWR has made the environmental commitment (see Appendix 3B, *Environmental Commitments*) that
 2 the construction methods recommended by the geotechnical engineer are included in the design of
 3 project facilities and construction specifications to minimize the potential for construction-induced
 4 liquefaction. DWR also has committed to ensure that these methods are followed during construction.

5 In particular, conformance with the following codes and standards would reduce the potential risk for
 6 increased likelihood of loss of property or personal injury from structural failure resulting from
 7 construction-related ground motions:

- 8 • USACE Engineering and Design - Design of Pile Foundations, EM 1110-2-2906, 1991
- 9 • USACE Engineering and Design, Earthquake Design and Evaluation for Civil Works Projects, ER 1110-
 10 2-1806, 1995
- 11 • California Code of Regulations, Title 8, Sections 1509 and 3203, California Code of Regulations.

12 Generally, the applicable codes require that facilities be built so that if soil in the foundation or
 13 surrounding area are subject to liquefaction, the removal or densification of the liquefiable material
 14 should be considered, along with alternative foundation designs. Additionally, any modification to a
 15 federal levee system would require USACE approval under 33 USC 408 (a 408 Permit) and would have
 16 to pass quality assurance review by the Major Subordinate Command prior to being forwarded to
 17 USACE headquarters for final approval by the Chief of Engineers.

18 The worker safety codes and standards specify protective measures that must be taken at construction
 19 sites to minimize the risk of injury or death from structural or earth failure (e.g., utilizing personal
 20 protective equipment, practicing crane and scaffold safety measures). The relevant codes and
 21 standards represent performance standards that must be met by contractors and these measures are
 22 subject to monitoring by state and local agencies. Cal-OSHA requirements for an IIPP and the terms of
 23 the IIPP to protect worker safety are the principal measures that would be enforced at construction
 24 sites.

25 Conformance to construction methods recommendations and other applicable specifications would
 26 ensure that construction of Alternative 1B would not create an increased likelihood of loss of property,
 27 personal injury or death of individuals due to construction-related ground motion and resulting
 28 potential liquefaction in the work area. The effect would not be adverse.

29 **CEQA Conclusion:** Construction-related ground motions could initiate liquefaction, which could cause
 30 failure of structures during construction, which could result in injury of workers at the construction
 31 sites. However, DWR has committed to conform with Cal-OSHA and other state code requirements and
 32 conform to applicable design guidelines and standards, such as USACE design measures. Conformance
 33 with these requirements and the application of accepted, proven construction engineering practices
 34 would reduce any potential risk such that construction of Alternative 1A would not create an increased
 35 likelihood of loss of property, personal injury or death of individuals from construction-related ground
 36 motion and resulting potential liquefaction in the work area, and the hazard would be controlled to a
 37 level that would protect worker safety (see Appendix 3B, *Environmental Commitments*). The impact
 38 would be less than significant. No mitigation is required.

39 **Impact GEO-6: Loss of Property, Personal Injury, or Death from Structural Failure Resulting** 40 **from Rupture of a Known Earthquake Fault during Operation of Water Conveyance Features**

41 According to the available AP Earthquake Fault Zone Maps, none of the Alternative 1B facilities would
 42 cross or be within any known active fault zones. However, numerous AP fault zones have been mapped

1 west of the conveyance alignment (Figure 9-5). The closest AP fault zone would be the Greenville fault,
2 located approximately 13 miles west of the Alternative 1B conveyance alignment. Because none of the
3 Alternative 1B constructed facilities would be within any of the fault zones (which include the area
4 approximately 200 to 500 feet on each side of the mapped surface trace to account for potential
5 branches of active faults), the potential that the facilities would be directly subject to fault offsets is
6 negligible.

7 In the Delta, active or potentially active blind thrust faults were identified in the seismic study.
8 Segments 2, 3, 4, and 5 of Alternative 1B conveyance alignment would cross the Thornton Arch fault
9 zone. The western part of the proposed Byron Tract Forebay adjacent to the Clifton Court Forebay is
10 underlain by the West Tracy fault. Although these blind thrusts are not expected to rupture to the
11 ground surface under the forebays during earthquake events, they may produce ground or
12 near-ground shear zones, bulging, or both (California Department of Water Resources 2007a).
13 Assuming that the West Tracy fault is potentially active, it could cause surface deformation in the
14 western part of the Clifton Court Forebay. Because the western part of the Byron Tract Forebay is also
15 underlain by the hanging wall of the fault, this part of the forebay may also experience uplift and
16 resultant surface deformation (Fugro Consultants 2011). In the seismic study (California Department of
17 Water Resources 2007a), the Thornton Arch and West Tracy blind thrusts have been assigned 20% and
18 90% probabilities of being active, respectively. The depth to the Thornton Arch blind fault is unknown.
19 The seismic study indicates that the West Tracy fault dies out as a discernible feature within
20 approximately 3,000 to 6,000 feet bgs (in the upper 1 to 2 second depth two-way time, estimated to be
21 approximately 3,000 to 6,000 feet using the general velocity function as published in the Association of
22 Petroleum Geologists Pacific Section newsletter [Tolmachoff 1993]).

23 It appears that the potential of having any shear zones, bulging, or both at the depths of the tunnel
24 siphons is low because the depth to the blind thrust faults is generally deep.

25 **NEPA Effects:** The effect would not be adverse because no active faults capable of surface rupture
26 extend into the Alternative 1B alignment. Additionally, although the Thornton Arch and West Tracy
27 blind thrusts occur beneath the Alternative 1B alignment, based on available information, they do not
28 present a hazard of surface rupture.

29 However, because of the limited information regarding the depths of the Thornton Arch and West
30 Tracy blind thrusts, seismic surveys would be performed on the faults during the design phase to
31 determine the depths to the top of the faults. More broadly, design-level geotechnical studies would be
32 prepared by a geotechnical engineer licensed in the state of California during project design. The
33 studies would further assess site-specific conditions at and near all the project facility locations,
34 including seismic activity, soil liquefaction, and other potential geologic and soil-related hazards. This
35 information would be used to verify assumptions and conclusions included in the EIR/EIS. The
36 geotechnical engineer's recommended measures to address adverse conditions would conform to
37 applicable design codes, guidelines, and standards. Potential design strategies or conditions could
38 include avoidance (deliberately positioning structures and lifelines to avoid crossing identified shear
39 rupture zones), geotechnical engineering (using the inherent capability of unconsolidated geomaterials
40 to "locally absorb" and distribute distinct bedrock fault movements) and structural engineering
41 (engineering the facility to undergo some limited amount of ground deformation without collapse or
42 significant damage).

43 As described in Section 9.3.1, *Methods for Analysis*, such design codes, guidelines, and standards are
44 considered environmental commitments by DWR (see also Appendix 3B, *Environmental Commitments*).

1 For construction of the water conveyance facilities, the codes and standards would include the
 2 California Building Code and resource agency and professional engineering specifications, such as the
 3 Division of Safety of Dams *Guidelines for Use of the Consequence Hazard Matrix and Selection of Ground*
 4 *Motion Parameters*, DWR's Division of Flood Management *FloodSAFE Urban Levee Design Criteria*, and
 5 USACE's *Engineering and Design—Earthquake Design and Evaluation for Civil Works Projects*. These
 6 codes and standards include minimum performance standards for structural design, given site-specific
 7 subsurface conditions.

8 DWR would ensure that the geotechnical design recommendations are included in the design of project
 9 facilities and construction specifications to minimize the potential effects from seismic events and the
 10 presence of adverse soil conditions. DWR would also ensure that the design specifications are properly
 11 executed during construction.

12 In particular, conformance with the following codes and standards would reduce the potential risk for
 13 increased likelihood of loss of property or personal injury from structural failure resulting from surface
 14 rupture resulting from a seismic event during operation:

- 15 • DWR Division of Engineering State Water Project – Seismic Loading Criteria Report, Sept 2012.
- 16 • USACE Engineering and Design – Time-History Dynamic Analysis of Concrete Hydraulic Structure, EM
 17 1110-2-6051, 2003.
- 18 • USACE Engineering and Design – Response Spectra and Seismic Analysis for Concrete Hydraulic
 19 Structures, EM 1110-2-6050, 1999.
- 20 • American Society of Civil Engineers Minimum Design Loads for Buildings and Other Structures,
 21 ASCE-7-05, 2005.
- 22 • California Code of Regulations, Title 8, Section 3203, California Code of Regulations.

23 Generally, the applicable codes require that facilities be built so that they incur minimal damage in the
 24 event of a foreseeable seismic event and that they remain functional following such an event and that
 25 the facility is able to perform without catastrophic failure in the event of a maximum design earthquake
 26 (the greatest earthquake reasonably expected to be generated by a specific source on the basis of
 27 seismological and geological evidence).

28 The worker safety codes and standards specify protective measures that must be taken at construction
 29 sites to minimize the risk of injury or death from structural or earth failure (e.g., utilizing personal
 30 protective equipment). The relevant codes and standards represent performance standards that must
 31 be met by contractors and these measures are subject to monitoring by state and local agencies. Cal-
 32 OSHA requirements for an IIPP and the terms of the IIPP to protect worker safety are the principal
 33 measures that would be enforced at construction sites.

34 Conformance to these and other applicable design specifications and standards would ensure that
 35 operation of Alternative 1B would not create an increased likelihood of loss of property, personal
 36 injury or death of individuals in the event of ground movement in the vicinity of the Thornton Arch
 37 fault zone would not jeopardize the integrity of the surface and subsurface facilities along the
 38 Alternative 1B conveyance alignment or the proposed forebay and associated facilities adjacent to the
 39 Clifton Court Forebay. Therefore, there would be no adverse effect.

40 **CEQA Conclusion:** There are no active fault capable of surface rupture that extend into the Alternative
 41 1B alignment. Although the Thornton Arch and West Tracy blind thrusts occur beneath the Alternative
 42 1B alignment, based on available information, they do not present a hazard of surface rupture.

1 Conformance to applicable design specifications and standards would ensure that operation of
 2 Alternative 1B would not create an increased likelihood of loss of property, injury or death of
 3 individuals in the event of ground movement in the vicinity of the Thornton Arch fault zone or West
 4 Tracy blind thrusts would not jeopardize the integrity of the surface and subsurface facilities along the
 5 Alternative 1B conveyance alignment or the proposed forebay and associated facilities adjacent to the
 6 Clifton Court Forebay. There would be no impact. No mitigation is required.

7 **Impact GEO-7: Loss of Property, Personal Injury, or Death from Structural Failure Resulting**
 8 **from Strong Seismic Shaking during Operation of Water Conveyance Features**

9 Earthquake events may occur on the local and regional seismic sources during operation of the
 10 Alternative 1B water conveyance facilities. The ground shaking could damage the canals, pipelines,
 11 tunnel and culvert siphons, intake facilities, pumping plants, and other facilities disrupting the water
 12 supply through the conveyance system. In an extreme event of strong seismic shaking, uncontrolled
 13 release of water from the damaged canal, pipelines, tunnel siphons, intake facilities, pumping plants,
 14 and other facilities could cause flooding, disruption of water supplies to the south, and inundation of
 15 structures. These effects are discussed more fully in Appendix 3E, *Potential Seismicity and Climate*
 16 *Change Risks to SWP/CVP Water Supplies*. The potential of earthquake ground shaking in the early long-
 17 term (2025) was estimated using the results of the seismic study (California Department of Water
 18 Resources 2007a). Table 9-21 lists the expected PGA and 1.0-S_a values for early long-term. Earthquake
 19 ground shakings for the OBE (144-year return period) and MDE (975-year return period) were
 20 estimated for the stiff soil site, as predicted in the seismic study (California Department of Water
 21 Resources 2007a), and for the anticipated soil conditions at the facility locations. No seismic study
 22 results exist for 2025, so the ground shakings estimated for 2050 were used for early long-term.

23 Table 9-21 shows that the proposed facilities would be subject to moderate-to-high earthquake ground
 24 shakings in the Early Long-term through 2025. All facilities would be designed and constructed in
 25 accordance with the requirements of the design measures described in Appendix 3B, *Environmental*
 26 *Commitments*. Site-specific geotechnical information would be used to further assess the effect of local
 27 soil on the OBE and MDE ground shakings and to develop design criteria to minimize the potential of
 28 damage.

29 **NEPA Effects:** The potential effect could be substantial because strong ground shaking could damage
 30 pipelines, tunnel and culvert siphons, intake facilities, pumping plants, and other facilities. The damage
 31 could disrupt the water supply through the conveyance system. In an extreme event, an uncontrolled
 32 release of water from the conveyance system could cause flooding and inundation of structures. Please
 33 refer to Chapter 6, *Surface Water* and Appendix 3E, *Potential Seismicity and Climate Change Risks to*
 34 *SWP/CVP Water Supplies*, for a detailed discussion of potential flood effects.

35 Design-level geotechnical studies would be conducted by a licensed civil engineer who practices in
 36 geotechnical engineering. The studies would assess site-specific conditions at and near all the project
 37 facility locations and provide the basis for designing the conveyance features to withstand the peak
 38 ground acceleration caused by fault movement in the region. The California-registered civil engineer or
 39 California-certified engineering geologist's recommended measures to address this hazard would
 40 conform to applicable design codes, guidelines, and standards.

Table 9-21. Expected Earthquake Ground Motions at Locations of Selected Major Facilities in the Early Long-Term (2025)—Alternative 1B

Major Facilities	144-year Return Period Ground Motions (OBE)			
	Peak Ground Acceleration (g)		1.0-sec S_a (g)	
	Stiff Soil ^a	Local Soil ^b	Stiff Soil ^a	Local Soil ^b
Intake Locations ^c	0.14	0.15	0.19	0.30
Tunnel Siphon Location near Venice Island ^d	0.30	0.33	0.31	0.50
Clifton Court Forebay / Byron Tract Forebay	0.28	0.31	0.30	0.48
Major Facilities	975-year Return Period Ground Motions (MDE)			
	Peak Ground Acceleration (g)		1.0-sec S_a (g)	
	Stiff Soil ^a	Local Soil ^e	Stiff Soil ^a	Local Soil ^e
Intake Locations ^c	0.24	0.24	0.33	0.53
Tunnel Siphon Location near Venice Island ^d	0.50	0.50	0.60	0.96
Clifton Court Forebay / Byron Tract Forebay	0.50	0.50	0.61	0.98

g = gravity

MDE = maximum design earthquake

OBE = operating basis earthquake

PGA = Peak Ground Acceleration

S_a = second spectral acceleration

^a Stiff soil site, with a V_{s100ft} value of 1,000 ft/s.

^b Site-adjusted factors of 1.1 and 1.60 were applied to PGA and 1.0-sec S_a values, respectively.

^c The results of California Department of Water Resources 2007a for the Sacramento site were used.

^d The results of California Department of Water Resources 2007a for the Sherman Island were used.

^e Site-adjusted factors of 1.0 and 1.60 were applied to PGA and 1.0-sec S_a values, respectively.

As described in Section 9.3.1, *Methods for Analysis*, and in Appendix 3B, *Environmental Commitments*, such design codes, guidelines, and standards include the California Building Code and resource agency and professional engineering specifications, such as the Division of Safety of Dams *Guidelines for Use of the Consequence Hazard Matrix and Selection of Ground Motion Parameters*, DWR's Division of Flood Management *FloodSAFE Urban Levee Design Criteria*, and USACE's *Engineering and Design—Earthquake Design and Evaluation for Civil Works Projects*. Conformance with these codes and standards is an environmental commitment by DWR to ensure that ground shaking risks are minimized as the water conveyance features are operated.

DWR would ensure that the geotechnical design recommendations are included in the design of project facilities and construction specifications to minimize the potential effects from seismic events and the presence of adverse soil conditions. DWR would also ensure that the design specifications are properly executed during construction. See Appendix 3B, *Environmental Commitments*.

In particular, conformance with the following codes and standards would reduce the potential risk for increased likelihood of loss of property or personal injury from structural failure resulting from strong seismic shaking of water conveyance features during operations:

- DWR Division of Engineering State Water Project – Seismic Loading Criteria Report, Sept 2012.
- USACE Engineering and Design – Time-History Dynamic Analysis of Concrete Hydraulic Structure, EM 1110-2-6051, 2003

- 1 • USACE Engineering and Design – Response Spectra and Seismic Analysis for Concrete Hydraulic
2 Structures, EM 1110-2-6050, 1999.
- 3 • American Society of Civil Engineers Minimum Design Loads for Buildings and Other Structures,
4 ASCE-7-05, 2005.
- 5 • California Code of Regulations, Title 8, Section 3203, California Code of Regulations.

6 Generally, the applicable codes require that facilities be built so that they incur minimal damage in the
7 event of a foreseeable seismic event and that they remain functional following such an event and that
8 the facility is able to perform without catastrophic failure in the event of a maximum design earthquake
9 (the greatest earthquake reasonably expected to be generated by a specific source on the basis of
10 seismological and geological evidence).

11 Conformance with these standards and codes are an environmental commitment of the project (see
12 Appendix 3B, *Environmental Commitments*). The worker safety codes and standards specify protective
13 measures that must be taken at construction sites to minimize the risk of injury or death from
14 structural or earth failure (e.g., utilizing personal protective equipment). The relevant codes and
15 standards represent performance standards that must be met by contractors and these measures are
16 subject to monitoring by state and local agencies. Cal-OSHA requirements for an IIPP and the terms of
17 the IIPP to protect worker safety are the principal measures that would be enforced at project sites
18 during operations.

19 Conformance to these and other applicable design specifications and standards would ensure that
20 operation of Alternative 1B would not create an increased likelihood of loss of property, personal
21 injury or death of individuals from strong seismic shaking of surface and subsurface facilities along the
22 Alternative 1B conveyance alignment. Therefore, there would be no adverse effect.

23 **CEQA Conclusion:** Seismically induced strong ground shaking could damage the canals, pipelines,
24 tunnel and culvert siphons, intake facilities, pumping plants, and other facilities. The damage could
25 disrupt SWP and CVP water supply deliveries through the conveyance system. In an extreme event, an
26 uncontrolled release of water from the damaged conveyance system could cause flooding and
27 inundation of structures. (Please refer to Appendix 3E, *Potential Seismicity and Climate Change Risks to*
28 *SWP/CVP Water Supplies*, for a detailed discussion of potential flood impacts.) However, through the
29 final design process, measures to address this hazard would be required to conform to applicable
30 design codes, guidelines, and standards. As described in Section 9.3.1, *Methods for Analysis*, and in
31 Appendix 3B, *Environmental Commitments*, such design codes, guidelines, and standards include the
32 California Building Code and resource agency and professional engineering specifications, such as the
33 Division of Safety of Dams *Guidelines for Use of the Consequence Hazard Matrix and Selection of Ground*
34 *Motion Parameters*, DWR's Division of Flood Management *FloodSAFE Urban Levee Design Criteria*, and
35 USACE's *Engineering and Design—Earthquake Design and Evaluation for Civil Works Projects*.

36 Conformance with these codes and standards is an environmental commitment by DWR to ensure that
37 ground shaking risks are minimized as the Alternative 1B water conveyance features are operated and
38 there would be no increased likelihood of loss of property, personal injury or death of individuals. The
39 hazard would be controlled to a safe level. The impact would be less than significant. No mitigation is
40 required.

1 **Impact GEO-8: Loss of Property, Personal Injury, or Death from Structural Failure Resulting**
 2 **from Seismic-Related Ground Failure (Including Liquefaction) during Operation of Water**
 3 **Conveyance Features**

4 Earthquake-induced ground shaking could cause liquefaction, resulting soil slumping or lateral
 5 spreading and subsequent damage to or breaching of water conveyance structures and facilities. The
 6 consequences of liquefaction are manifested in terms of compaction or settlement, loss of bearing
 7 capacity, lateral spreading (soil movement), increased lateral soil pressure, and buoyancy within zones
 8 of liquefaction. Failure of the canal, tunnel and culvert siphons, pipelines, levees, bridges, and other
 9 structures and facilities could result in loss or injury and disrupt SWP and CVP water supply deliveries.
 10 The potential for impacts from flooding as a result of levee or dam failure is also discussed in Chapter 6,
 11 *Surface Water*.

12 The native soils underlying Alternative 1B facilities consist of floodplain, natural levee, eolian sand, and
 13 flood basin deposits, along with more consolidated Modesto Formation materials locally. The more
 14 recently-deposited, sandy materials would be more prone to liquefaction. Figure 9-6 shows that the
 15 Alternative 1B alignment has no substantial liquefaction damage potential in its northern part and low
 16 to medium-high damage potential in its central and southern parts from Disappointment Slough down
 17 to the proposed Byron Tract Forebay.

18 **NEPA Effects:** The potential effect could be substantial because seismically induced ground shaking
 19 could cause liquefaction, which could result in damage to the canals, pipelines, tunnel and culvert
 20 siphons, intake facilities, pumping plants, and other facilities. The damage could disrupt the water
 21 supply through the conveyance system. In an extreme event, an uncontrolled release of water from the
 22 damaged conveyance system could cause flooding and inundation of structures. Please refer to
 23 Appendix 3E, *Potential Seismicity and Climate Change Risks to SWP/CVP Water Supplies*, for a detailed
 24 discussion of potential flood effects.

25 In the process of preparing final facility designs, site-specific geotechnical and groundwater
 26 investigations would be conducted to identify and characterize the vertical (depth) and horizontal
 27 (spatial) extents of liquefiable soil. Engineering soil parameters that could be used to further assess the
 28 liquefaction potential, such as SPT blow counts, CPT penetration tip pressure/resistance, and gradation
 29 of soil, would also be obtained. SPT blow counts and CPT tip pressure are used to estimate soil
 30 resistance to cyclic loadings by using empirical relationships that were developed based on
 31 occurrences of liquefaction (or lack of them) during past earthquakes. The resistance then can be
 32 compared to cyclic shear stress induced by the design earthquakes. If soil resistance is less than
 33 induced stress, the potential of having liquefaction during the design earthquakes is high. It is also
 34 known that soil with high “fines” (i.e., silt- and clay-sized particles) content are less susceptible to
 35 liquefaction.

36 During final design, site-specific potential for liquefaction would be investigated by a geotechnical
 37 engineer. In areas determined to have a potential for liquefaction, a California-registered civil engineer
 38 or California-certified engineering geologist would develop design measures and construction methods
 39 to meet design criteria established by building codes and construction standards to ensure that the
 40 design earthquake does not cause damage to or failure of the facility. Such measures and methods
 41 include removing and replacing potentially liquefiable soil, strengthening foundations (for example,
 42 and using post-tensioned slab, reinforced mats, and piles) to resist excessive total and differential
 43 settlements, using *in situ* ground improvement techniques (such as deep dynamic compaction, vibro-
 44 compaction, vibro-replacement, compaction grouting, and other similar methods). The results of the

1 site-specific evaluation and California-registered civil engineer or California-certified engineering
 2 geologist's recommendations would be documented in a detailed geotechnical report prepared in
 3 accordance with state guidelines, in particular *Guidelines for Evaluating and Mitigating Seismic Hazards*
 4 *in California* (California Geological Survey 2008). As described in Section 9.3.1, *Methods for Analysis*,
 5 and in Appendix 3B, *Environmental Commitments*, such design codes, guidelines, and standards include
 6 USACE's *Engineering and Design—Earthquake Design and Evaluation for Civil Works Projects and Soil*
 7 *Liquefaction during Earthquakes*, by the Earthquake Engineering Research Institute. Conformance with
 8 these design requirements is an environmental commitment by DWR to ensure that liquefaction risks
 9 are minimized as the water conveyance features are operated.

10 DWR would ensure that the geotechnical design recommendations are included in the design of project
 11 facilities and construction specifications to minimize the potential effects from liquefaction and
 12 associated hazard. DWR would also ensure that the design specifications are properly executed during
 13 construction.

14 In particular, conformance with the following codes and standards would reduce the potential risk for
 15 increased likelihood of loss of property or personal injury from structural failure resulting from strong
 16 seismic shaking of water conveyance features during operations:

- 17 • DWR Division of Engineering State Water Project – Seismic Loading Criteria Report, Sept 2012.
- 18 • USACE Engineering and Design – Time-History Dynamic Analysis of Concrete Hydraulic Structure, EM
 19 1110-2-6051, 2003
- 20 • USACE Engineering and Design – Response Spectra and Seismic Analysis for Concrete Hydraulic
 21 Structures, EM 1110-2-6050, 1999.
- 22 • American Society of Civil Engineers Minimum Design Loads for Buildings and Other Structures,
 23 ASCE-7-05, 2005.
- 24 • USACE Engineering and Design - Design of Pile Foundations, EM 1110-2-2906, 1991
- 25 • California Code of Regulations, Title 8, Section 3203, California Code of Regulations.

26 Generally, the applicable codes require that facilities be built so that if soil in the foundation or
 27 surrounding area are subject to liquefaction, the removal or densification of the liquefiable material
 28 should be considered, along with alternative foundation designs. Additionally, any modification to a
 29 federal levee system would require USACE approval under 33 USC 408 (a 408 Permit) and would have
 30 to pass quality assurance review by the Major Subordinate Command prior to being forwarded to
 31 USACE headquarters for final approval by the Chief of Engineers.

32 The worker safety codes and standards specify protective measures that must be taken at construction
 33 sites to minimize the risk of injury or death from structural or earth failure (e.g., utilizing personal
 34 protective equipment). The relevant codes and standards represent performance standards that must
 35 be met by contractors and these measures are subject to monitoring by state and local agencies. Cal-
 36 OSHA requirements for an IIPP and the terms of the IIPP to protect worker safety are the principal
 37 measures that would be enforced at project sites during operations.

38 Conformance to these and other applicable design specifications and standards would ensure that the
 39 hazard of liquefaction and associated ground movements would not create an increased likelihood of
 40 loss of property, personal injury or death of individuals from structural failure resulting from seismic-
 41 related ground failure along the Alternative 1B conveyance alignment during operation of the water
 42 conveyance features. Therefore, the effect would not be adverse.

1 **CEQA Conclusion:** Seismically induced ground shaking could cause liquefaction. Liquefaction could
 2 damage the canals, pipelines, tunnel and culvert siphons, intake facilities, pumping plants, and other
 3 facilities, and thereby disrupt the water supply through the conveyance system. In an extreme event,
 4 flooding and inundation of structures could result from an uncontrolled release of water from the
 5 damaged conveyance system. (Please refer to Chapter 6, *Surface Water*, for a detailed discussion of
 6 potential flood effects.) However, through the final design process, measures to address the
 7 liquefaction hazard would be required to conform to applicable design codes, guidelines, and
 8 standards. As described in Section 9.3.1, *Methods for Analysis*, and in Appendix 3B, *Environmental*
 9 *Commitments*, such design codes, guidelines, and standards include USACE's *Engineering and Design—*
 10 *Stability Analysis of Concrete Structures and Soil Liquefaction during Earthquakes*, by the Earthquake
 11 Engineering Research Institute. Conformance with these design standards is an environmental
 12 commitment by DWR to ensure that liquefaction risks are minimized as the Alternative 1B water
 13 conveyance features are operated and there would be no increased likelihood of loss of property,
 14 personal injury or death of individuals. The hazard would be controlled to a safe level. The impact
 15 would be less than significant. No mitigation is required.

16 **Impact GEO-9: Loss of Property, Personal Injury, or Death from Landslides and Other Slope**
 17 **Instability during Operation of Water Conveyance Features**

18 Alternative 1B would involve excavation that creates new cut-and-fill slopes and construction of new
 19 embankments and levees. As a result of ground shaking and high soil-water content during heavy
 20 rainfall, existing and new slopes that are not properly engineered and natural stream banks could fail.
 21 Levees can fail for several reasons: 1) high velocities of water flow can result in high rates of erosion
 22 and erode and overtop a levee; 2) the higher velocities of water flow can also lead to higher rates of
 23 erosion along the inner parts of levees and lead to undercutting and clumping of the levee into the
 24 river. Heavy rainfall or seepage into the levee from the river can increase fluid pressure in the levee and
 25 lead to slumping on the outer parts of the levee. If the slumps grow to the top of the levee, large
 26 sections of the levee may slump onto the floodplain and lower the elevation of the top of the levee,
 27 leading to overtopping; 3) increasing levels of water in the river will cause the water table in the levee
 28 to rise which will increase fluid pressure and may result in seepage and eventually lead to internal
 29 erosion called piping. Piping will erode the material under the levee, undermining it and causing its
 30 collapse and failure.

31 With the exception of levee slopes and natural stream banks, the topography along the Alternative 1B
 32 conveyance alignment is nearly level to very gently sloping. The areas susceptible to slope failure are
 33 along existing levee slopes and at intake, pumping plant, forebay, and certain access road locations.
 34 Outside these areas, the land is nearly level and consequently has a negligible potential for slope failure.

35 Based on review of topographic maps, the conveyance facilities would not be constructed on, nor would
 36 it be adjacent to, slopes that are subject to mudflows/debris flows from natural slopes.

37 **NEPA Effects:** The potential effect could be substantial because levee slopes and stream banks may fail,
 38 either from high pore-water pressure caused by high rainfall and weak soil, or from seismic shaking.
 39 Structures constructed on these slopes could be damaged or fail entirely as a result of slope instability.
 40 As discussed in Impact SW-2 in Chapter 6, *Surface Water*, operation of the water conveyance features
 41 under Alternative 1B would not result in an increase in potential risk for flood management compared
 42 to existing conditions. Peak monthly flows under Alternative 1B in the locations considered were
 43 similar to or less than those that would occur under existing conditions. Since flows would not be
 44 substantially greater, the potential for increased rates of erosion or seepage are low. For additional

1 discussion on the possible exposure of people or structures to a significant risk of loss or injury from
 2 flooding due to levee failure, please refer to Impact SW-6 in Chapter 6, *Surface Water*.

3 During project design, a geotechnical engineer would develop slope stability design criteria (such as
 4 minimum slope safety factors and allowable slope deformation and settlement) for the various
 5 anticipated loading conditions. The design criteria would be documented in a detailed geotechnical
 6 report prepared in accordance with state guidelines, in particular *Guidelines for Evaluating and*
 7 *Mitigating Seismic Hazards in California* (California Geological Survey 2008). As discussed in Chapter 3,
 8 *Description of the Alternatives*, the foundation soil beneath slopes, embankments, or levees could be
 9 improved to increase its strength and to reduce settlement and deformation. Foundation soil
 10 improvement could involve excavation and replacement with engineered fill; preloading; ground
 11 modifications using jet-grouting, compaction grouting, chemical grouting, shallow soil mixing, deep soil
 12 mixing, vibro-compaction, or vibro-replacement; or other methods. Engineered fill also would be used
 13 to construct new slopes, embankments, and levees. Surface and internal drainage systems would be
 14 installed as necessary to reduce erosion and piping (internal erosion) potential.

15 Site-specific geotechnical and hydrological information would be used, and the design would conform
 16 with the current standards and construction practices, as described in Section 9.3.1, *Methods for*
 17 *Analysis*, such as USACE's *Design and Construction of Levees* and USACE's *EM 1110-2-1902, Slope*
 18 *Stability*. The design requirements would be presented in a detailed geotechnical report. Conformance
 19 with these design requirements is an environmental commitment by DWR to ensure that slope stability
 20 hazards would be avoided as the water conveyance features are operated.

21 DWR would ensure that the geotechnical design recommendations are included in the design of cut and
 22 fill slopes, embankments, and levees to minimize the potential effects from slope failure. DWR would
 23 also ensure that the design specifications are properly executed during construction.

24 In particular, conformance with the following codes and standards would reduce the potential risk for
 25 increased likelihood of loss of property or personal injury from structural failure resulting from seismic
 26 shaking or from high-pore water pressure:

- 27 • DWR Division of Engineering State Water Project – Seismic Loading Criteria Report, Sept 2012.
- 28 • DWR Division of Flood Management FloodSAFE Urban Levee Design Criteria, May 2012.
- 29 • USACE Slope Stability, EM 1110-2-1902, 2003.
- 30 • California Code of Regulations, Title 8, Section 3203, California Code of Regulations.

31 Generally, the applicable codes require that facilities be built to certain factors of safety in order to
 32 ensure that facilities perform as designed for the life of the structure despite various soil parameters.

33 The worker safety codes and standards specify protective measures that must be taken at construction
 34 sites to minimize the risk of injury or death from structural or earth failure (e.g., utilizing personal
 35 protective equipment). The relevant codes and standards represent performance standards that must
 36 be met by contractors and these measures are subject to monitoring by state and local agencies. Cal-
 37 OSHA requirements for an IIPP and the terms of the IIPP to protect worker safety are the principal
 38 measures that would be enforced at project sites during operations.

39 Conformance to the above and other applicable design specifications and standards would ensure that
 40 the hazard of slope instability would not create an increased likelihood of loss of property or injury of
 41 individuals along the Alternative 1B conveyance alignment during operation of the water conveyance
 42 features. Therefore, the effect would not be adverse.

1 **CEQA Conclusion:** Unstable levee slopes and natural stream banks may fail, either from high pore-
 2 water pressure caused by high rainfall and weak soil, or from seismic shaking. Structures constructed
 3 on these slopes could be damaged or fail entirely as a result of slope instability. However, through the
 4 final design process, measures to address this hazard would be required to conform to applicable
 5 design codes, guidelines, and standards. The measures would be described in a detailed geotechnical
 6 report prepared in accordance with state guidelines, in particular *Guidelines for Evaluating and*
 7 *Mitigating Seismic Hazards in California* (California Geological Survey 2008). As described in Section
 8 9.3.1, *Methods for Analysis*, and in Appendix 3B, *Environmental Commitments*, such design codes,
 9 guidelines, and standards include the California Building Code and resource agency and professional
 10 engineering specifications, such as USACE's *Engineering and Design—Earthquake Design and Evaluation*
 11 *for Civil Works Projects*. Conformance with these codes and standards is an environmental commitment
 12 by DWR to ensure cut and fill slopes and embankments will be stable as the Alternative 1B water
 13 conveyance features are operated and there would be no increased likelihood of loss of property,
 14 personal injury or death of individuals. The impact would be less than significant. No mitigation is
 15 required.

16 **Impact GEO-10: Loss of Property, Personal Injury, or Death from Seiche or Tsunami during**
 17 **Operation of Water Conveyance Features**

18 Based on recorded tsunami wave heights at the Golden Gate (Contra Costa Transportation Agency
 19 2009) and in the interior of the San Francisco Bay and on tsunami inundation maps prepared by the
 20 California Department of Conservation (2009), the height of a tsunami wave reaching the Suisun Marsh
 21 and the Delta would be small because of the distance from the ocean and attenuating effect of the San
 22 Francisco Bay. Therefore, the potential hazard of loss of property or personal injury as a result of a
 23 tsunami on the water conveyance facilities is low.

24 Similarly, with the exception of the Clifton Court Forebay and the Byron Tract Forebay, the potential for
 25 a substantial seiche to take place in the Plan Area is considered low because seismic and water body
 26 geometry conditions for a seiche to occur near conveyance facilities are not favorable. Fugro
 27 Consultants, Inc. (2011) identified the potential for a seiche of an unspecified wave height to occur in
 28 the Clifton Court Forebay, caused by strong ground motions along the underlying West Tracy fault,
 29 assuming that this fault is potentially active. Since the fault also exists in the immediate vicinity of the
 30 Byron Tract Forebay, a seiche could also occur in the Byron Tract Forebay.

31 **NEPA Effects:** The effect of a tsunami generated in the Pacific Ocean would not be adverse because the
 32 distance from the ocean and attenuating effect of the San Francisco Bay would likely allow only a low
 33 (i.e., less than 2 feet) tsunami wave height to reach the Delta (Contra Costa Transportation Agency
 34 2009).

35 In most parts of the Plan Area, the effects of a seiche would not be adverse because the seismic hazard
 36 and the geometry of the water bodies (i.e., wide and shallow) near conveyance facilities are not
 37 favorable for a seiche to occur. However, assuming that the West Tracy fault is potentially active, a
 38 potential exists for a seiche to occur in the Clifton Court Forebay and the Byron Tract Forebay. The
 39 effect could be adverse because the waves generated by a seiche could overtop the Byron Tract
 40 Forebay and Clifton Court Forebay embankments, causing erosion of the embankments and subsequent
 41 flooding in the vicinity.

42 However, design-level geotechnical studies would be conducted by a licensed civil engineer who
 43 practices in geotechnical engineering. The studies would determine the peak ground acceleration
 44 caused by movement of the West Tracy fault and the maximum probable seiche wave that could be

1 generated by the ground shaking. The engineer's recommended measures to address this hazard, as
 2 well as the hazard of a seiche overtopping the Clifton Court Forebay embankment and subsequent
 3 adverse effect on the Byron Tract Forebay embankment, would conform to applicable design codes,
 4 guidelines, and standards. As described in Section 9.3.1, *Methods for Analysis*, and in Appendix 3B,
 5 *Environmental Commitments*, such design codes, guidelines, and standards include the Division of
 6 Safety of Dams *Guidelines for Use of the Consequence Hazard Matrix and Selection of Ground Motion*
 7 *Parameters*, DWR's Division of Flood Management *FloodSAFE Urban Levee Design Criteria*, and USACE's
 8 *Engineering and Design—Earthquake Design and Evaluation for Civil Works Projects*. Conformance with
 9 these codes and standards is an environmental commitment by DWR to ensure that the adverse effects
 10 of a seiche are controlled to an acceptable level while the forebay facility is operated.

11 DWR would ensure that the geotechnical design recommendations are included in the design of project
 12 facilities and in construction specifications to minimize the potential effects from seismic events and
 13 consequent seiche waves. DWR would also ensure that the design specifications are properly executed
 14 during construction.

15 In particular, conformance with the following codes and standards would reduce the potential risk for
 16 increased likelihood of loss of property or personal injury from tsunami or seiche:

- 17 • U.S. Department of the Interior and USGS Climate Change and Water Resources Management: A
 18 Federal Perspective, Circular 1331.
- 19 • State of California Sea-Level Rise Task Force of the CO-CAT, Sea-Level Rise Interim Guidance
 20 Document, 2010.
- 21 • California Code of Regulations, Title 8, Section 3203, California Code of Regulations.

22 Generally, the applicable codes provide guidance on estimating the effects of climate change and sea
 23 level rise and associated effects when designing a project and ensuring that a project is able to respond
 24 to these effects.

25 The worker safety codes and standards specify protective measures that must be taken at construction
 26 sites to minimize the risk of injury or death from structural or earth failure (e.g., utilizing personal
 27 protective equipment). The relevant codes and standards represent performance standards that must
 28 be met by contractors and these measures are subject to monitoring by state and local agencies. Cal-
 29 OSHA requirements for an IIPP and the terms of the IIPP to protect worker safety are the principal
 30 measures that would be enforced at project sites during operations.

31 Conformance to these and other applicable design specifications and standards would ensure that the
 32 Byron Tract Forebay embankment would be designed and constructed to contain and withstand the
 33 anticipated maximum seiche wave height and would not create an increased likelihood of loss of
 34 property, personal injury or death of individuals along the Alternative 1B conveyance alignment during
 35 operation of the water conveyance features. Therefore, the effect would not be adverse.

36 **CEQA Conclusion:** Based on recorded tsunami wave heights at the Golden Gate (Contra Costa
 37 Transportation Agency 2009) and in the interior of the San Francisco Bay and on tsunami inundation
 38 maps prepared by the California Department of Conservation (2009), the height of a tsunami wave
 39 reaching the Suisun Marsh and the Delta would be small because of the distance from the ocean and
 40 attenuating effect of the San Francisco Bay. The impact would be less than significant. No mitigation is
 41 required.

1 Similarly, the potential for a significant seiche to occur in most parts of the Plan Area is considered low
 2 because the seismic hazard and the geometry of the water bodies (i.e., wide and shallow) near
 3 conveyance facilities are not favorable for a seiche to occur. However, assuming that the West Tracy
 4 fault is potentially active, a potential exists for a seiche to occur in the Clifton Court Forebay and the
 5 Byron Tract Forebay (Fugro Consultants 2011). The impact would not be significant because the Byron
 6 Tract Forebay embankment would be designed and constructed according to applicable design codes,
 7 guidelines, and standards to contain and withstand the anticipated maximum seiche wave height and
 8 potential seiche wave overtopping of the Clifton Court Forebay and Byron Tract Forebay embankments
 9 as the Alternative 1B water conveyance features are operated and there would be no increased
 10 likelihood of loss of property, personal injury or death of individuals. The impact would be less than
 11 significant. No mitigation is required.

12 **Impact GEO-11: Ground Failure Caused by Increased Groundwater Surface Elevations from**
 13 **Unlined Canal Seepage as a Result of Operating the Water Conveyance Facilities**

14 If unlined canals (as opposed to lined canals) would be constructed, seepage from the sideslopes and
 15 bottom of the unlined canals could occur where the normal water level in the canal is higher than the
 16 water surface elevation of the adjacent areas. The seepage could raise the water table on the landside of
 17 the embankments through more permeable lenses of sand and/or gravel in the foundation soil.
 18 Increased water table levels may increase the likelihood of ground settlement and earthquake-induced
 19 liquefaction.

20 **NEPA Effects:** The effect would be adverse because seepage from an unlined canal could raise the water
 21 table in the area adjacent to the canal and increase the hazard of liquefaction in the vicinity.

22 However, the amount of seepage from the canal is not expected to be substantial because the canal
 23 foundation and surface materials, derived from local borrow areas, would be selected based on site-
 24 specific geotechnical evaluations. An engineer would design the canal to prevent excessive loss of water
 25 from seepage. Additionally, control of excessive seepage may be accomplished through the installation
 26 of a slurry cutoff wall in the canal. A cutoff wall would be most effective in areas where the canal is
 27 constructed in relatively permeable materials, such as layers of permeable sand and gravels. Additional
 28 measures that could be implemented to offset the effects of seepage water include the following:

- 29 ● Use of a drainage ditch parallel to the canal to control seepage. Water in the drainage ditch would
 30 then be pumped into the sloughs or back into the canal.
- 31 ● Installation of pressure-relief wells to collect subsurface water and direct it into the parallel
 32 drainage ditch.

33 As indicated above and in Chapter 3, *Description of the Alternatives*, engineers would use site-specific
 34 geotechnical and hydrological information to design the canal, and the design would conform with the
 35 current standards and construction practices specified by USACE and DWR design standards. As
 36 described in Section 9.3.1, *Methods for Analysis*, such design codes, guidelines, and standards are
 37 considered environmental commitments by DWR (see also Appendix 3B, *Environmental Commitments*).
 38 For construction of the canal and any required seepage control measures, the codes and standards
 39 would include the California Building Code and resource agency and professional engineering
 40 specifications, such as USACE's *Engineering and Design—Earthquake Design and Evaluation for Civil*
 41 *Works Projects*. These codes and standards include minimum performance standards for structural
 42 design, given site-specific subsurface conditions.

1 DWR would ensure that the geotechnical design recommendations are included in the canal design to
 2 minimize the potential excessive seepage. DWR would also ensure that the design specifications are
 3 properly executed during construction.

4 In particular, conformance with the following codes and standards would reduce the potential risk for
 5 increased likelihood of loss of property or personal injury as a result of ground failure resulting from
 6 unlined canal seepage:

- 7 • USACE Engineering and Design, Earthquake Design and Evaluation for Civil Works Projects, ER 1110-
 8 2-1806, 1995.
- 9 • USACE Engineering and Design - Settlement Analysis, EM 1110-1-1904, 1990.
- 10 • USACE Slope Stability, EM 1110-2-1902, 2003.
- 11 • DWR Division of Flood Management FloodSAFE Urban Levee Design Criteria, May 2012.
- 12 • California Code of Regulations, Title 8, Section 3203, California Code of Regulations.

13 Generally, the applicable codes require that facilities be built so that they are designed for a landside
 14 slope stability and seepage/underseepage factors of safety greater than 1.0 (i.e., stable) and would
 15 therefore be less impacted in the event of potential excessive seepage and resulting soil instability.

16 The worker safety codes and standards specify protective measures that must be taken at construction
 17 sites to minimize the risk of injury or death from structural or earth failure (e.g., utilizing personal
 18 protective equipment). The relevant codes and standards represent performance standards that must
 19 be met by contractors and these measures are subject to monitoring by state and local agencies. Cal-
 20 OSHA requirements for an IIPP and the terms of the IIPP to protect worker safety are the principal
 21 measures that would be enforced at project sites during operations.

22 Conformance to the applicable design specifications and standards would ensure that the hazard of
 23 seepage from the canal would not cause an excessive increase in the water surface elevation in areas
 24 adjoining the canal resulting in ground failure. Therefore, the effect would not be adverse.

25 **CEQA Conclusion:** Seepage from an unlined canal could raise the water table level along the canal,
 26 thereby increasing the hazard of liquefaction where the water table is not already close to the surface.
 27 The increased hazard of liquefaction could threaten the integrity of the canal in the event that
 28 liquefaction occurs. However, because DWR would conform with applicable design guidelines and
 29 standards, such as USACE design measures, there would be no increased likelihood of loss of property,
 30 personal injury or death of individuals from ground failure caused by increased groundwater surface
 31 elevations. The impact would be less than significant. No mitigation is required.

32 **Impact GEO-12: Loss of Property, Personal Injury, or Death Resulting from Structural Failure** 33 **Caused by Rupture of a Known Earthquake Fault at Restoration Opportunity Areas**

34 According to the available AP Earthquake Fault Zone Maps, only the Suisun Marsh ROA could be
 35 affected by rupture of an earthquake fault. The active Green Valley fault crosses the southwestern
 36 corner of the ROA. The active Cordelia fault extends approximately one mile into the northwestern
 37 corner of the ROA. Rupture of these faults could damage levees and berms constructed as part of the
 38 restoration, which could result in failure of the levees and flooding of otherwise protected areas.

39 Within the Delta, active or potentially active blind thrust faults were identified in the seismic study
 40 (California Department of Water Resources 2007a). The extreme southeastern corner of the Suisun

1 Marsh ROA is underlain by the Montezuma blind thrust zone. Parts of the Cache Slough and Yolo
 2 Bypass ROAs are underlain by part of the North Midland blind thrust zone. The Cosumnes/Mokelumne
 3 River and East Delta ROAs are underlain by the Thornton Arch zone. Although these blind thrusts are
 4 not expected to rupture to the ground surface during earthquake events, they may produce ground or
 5 near-ground shear zones, bulging, or both. In the seismic study (California Department of Water
 6 Resources 2007a), the Thornton Arch blind thrust was assigned a 20% probability of being active. The
 7 depth to the Thornton Arch blind fault is unknown. Based on limited geologic and seismic survey
 8 information, it appears that the potential of having any shear zones, bulging, or both at the depths of
 9 the habitat levees is low because the depth to the blind thrust faults is generally deep.

10 **NEPA Effects:** The effect of implementing the conservation measures in the ROAs could be substantial
 11 because rupture of the Cordelia and Green Valley faults could occur at the Suisun Marsh ROA and cause
 12 damage or failure of ROA facilities, including levees and berms. Damage to these features could result in
 13 their failure, causing flooding of otherwise protected areas.

14 Because there is limited information regarding the depths of the blind faults mentioned above, seismic
 15 surveys would be performed in the vicinity of the faults as part of final design. These surveys would be
 16 used to verify fault depths where levees and other features would be constructed. Collection of this
 17 depth information would be part of broader, design-level geotechnical studies prepared by a licensed
 18 engineer to support all aspects of site-specific project design. The studies would assess site-specific
 19 conditions at and near all the project facility locations, including the nature and engineering properties
 20 of all soil horizons and underlying geologic strata, and groundwater conditions. The engineer's
 21 information would be used to develop final engineering solutions to any hazardous condition,
 22 consistent with the code and standards requirements of federal, state and local oversight agencies. As
 23 described in Section 9.3.1, *Methods for Analysis*, and in Appendix 3B, *Environmental Commitments*, such
 24 design codes, guidelines, and standards include the California Building Code and resource agency and
 25 professional engineering specifications, such as the Division of Safety of Dams Guidelines for Use of the
 26 Consequence Hazard Matrix and Selection of Ground Motion Parameters, DWR's Division of Flood
 27 Management *FloodSAFE Urban Levee Design Criteria*, and USACE's *Engineering and Design—Earthquake
 28 Design and Evaluation for Civil Works Projects*. Conformance with these design standards is an
 29 environmental commitment by the BDCP proponents to ensure that risks from a fault rupture are
 30 minimized as conservation levees are constructed and maintained. The hazard would be controlled to a
 31 safe level by following the proper design standards.

32 The BDCP proponents would ensure that the geotechnical design recommendations are included in the
 33 design of project facilities and construction specifications to minimize the potential effects from seismic
 34 events and the presence of adverse soil conditions. The BDCP proponents would also ensure that the
 35 design specifications are properly executed during implementation.

36 In particular, conformance with the following codes and standards would reduce the potential risk for
 37 increased likelihood of loss of property or personal injury from structural failure resulting from surface
 38 rupture resulting from a seismic event during operation:

- 39 ● DWR Division of Engineering State Water Project – Seismic Loading Criteria Report, Sept 2012.
- 40 ● DWR DSOD Guidelines for Use of the Consequence-Hazard Matrix and Selection of Ground Motion
 41 Parameters, 2002.
- 42 ● USACE Engineering and Design, *Earthquake Design and Evaluation for Civil Works Projects*, ER 1110-
 43 2-1806, 1995.

- 1 • USACE Design and Construction of Levees, EM 1110-2-1913, 2000.
- 2 • USACE (Corps, CESPCK-ED-G), Geotechnical Levee Practice, SOP EDG-03, 2004.
- 3 • DWR Division of Flood Management FloodSAFE Urban Levee Design Criteria, May 2012.
- 4 • California Code of Regulations, Title 8, Sections 1509 and 3203, California Code of Regulations.

5 Generally, the applicable codes require that facilities be built so that they incur minimal damage in the
 6 event of a foreseeable seismic event and that they remain functional following such an event and that
 7 the facility is able to perform without catastrophic failure in the event of a maximum design earthquake
 8 (the greatest earthquake reasonably expected to be generated by a specific source on the basis of
 9 seismological and geological evidence).

10 The worker safety codes and standards specify protective measures that must be taken at construction
 11 sites to minimize the risk of injury or death from structural or earth failure (e.g., utilizing personal
 12 protective equipment, practicing crane and scaffold safety measures). The relevant codes and
 13 standards represent performance standards that must be met by contractors and these measures are
 14 subject to monitoring by state and local agencies. Cal-OSHA requirements for an IIPP and the terms of
 15 the IIPP to protect worker safety are the principal measures that would be enforced at construction
 16 sites.

17 Conformance to these and other applicable design specifications and standards would ensure that the
 18 hazard of ground movement in the vicinity of the blind thrusts underlying the ROAs would not
 19 jeopardize the integrity of the levees and other features constructed in the ROAs and would not create
 20 an increased likelihood of loss of property, personal injury or death of individuals in the ROAs. This
 21 effect would not be adverse.

22 **CEQA Conclusion:** Rupture of the Cordelia and Green Valley faults could occur at the Suisun Marsh ROA
 23 and damage ROA facilities, such as levees and berms. Damage to these features could result in their
 24 failure, causing flooding of otherwise protected areas. However, through the final design process for
 25 conservation measures in the ROAs, measures to address the fault rupture hazard would be required to
 26 conform to applicable design codes, guidelines, and standards. As described in Section 9.3.1, *Methods*
 27 *for Analysis*, and in Appendix 3B, *Environmental Commitments*, such design codes, guidelines, and
 28 standards include the Division of Safety of Dams Guidelines for Use of the Consequence Hazard Matrix
 29 and Selection of Ground Motion Parameters, DWR's Division of Flood Management *FloodSAFE Urban*
 30 *Levee Design Criteria*, and USACE's *Engineering and Design—Earthquake Design and Evaluation for Civil*
 31 *Works Projects*. Conformance with these design standards is an environmental commitment by the
 32 BDCP proponents to ensure that fault rupture risks are minimized as the conservation measures are
 33 implemented. The hazard would be controlled to a safe level and there would be no increased
 34 likelihood of loss of property, personal injury or death of individuals in the ROAs. The impact would be
 35 less than significant. No mitigation is required.

36 **Impact GEO-13: Loss of Property, Personal Injury, or Death from Structural Failure Resulting** 37 **from Strong Seismic Shaking at Restoration Opportunity Areas**

38 Earthquake events may occur on the local and regional seismic sources at the ROAs. Because of its
 39 proximity to these faults, the Suisun Marsh ROA would be especially subject to ground shaking caused
 40 by the Concord-Green Valley fault. The Cache Slough ROA would be subject to shaking from the
 41 Northern Midland fault zone, which underlies the ROA. Although more distant from these sources, the
 42 other ROAs would be subject to shaking from the San Andreas, Hayward–Rodgers Creek, Calaveras,

1 Concord–Green Valley, San Gregorio, Greenville, and Mt. Diablo Thrust faults and the more proximate
2 blind thrusts in the Delta.

3 Among all the ROAs, the Suisun Marsh ROA would be most subject to ground shaking because of its
4 proximity to active faults. The Suisun Marsh ROA is subject to a PGA of approximately 0.31 to 0.35 g for
5 200-year return interval, while the PGA for the other ROAs ranges from approximately 0.11 to 0.26 g.
6 The ground shaking could damage levees and other structures, and in an extreme event cause levees to
7 fail such that protected areas flood.

8 **NEPA Effects:** All temporary facilities would be designed and built to meet the safety and
9 collapse-prevention requirements for the above-anticipated seismic loads. Therefore, this effect is
10 considered not adverse. No additional mitigation measures are required. All facilities would be
11 designed and constructed in accordance with the requirements of the design measures described in
12 Chapter 3, *Description of the Alternatives*. Site-specific geotechnical information would be used to
13 further assess the effects of local soil on the OBE and MDE ground shaking and to develop design
14 criteria that minimize the potential of damage.

15 Design-level geotechnical studies would be prepared by a geotechnical engineer licensed in the state of
16 California during project design. The studies would assess site-specific conditions at and near all the
17 project facility locations and provide the basis for designing the levees and other features to withstand
18 the peak ground acceleration caused by fault movement in the region. The geotechnical engineer's
19 recommended measures to address this hazard would conform to applicable design codes, guidelines,
20 and standards. Potential design strategies or conditions could include avoidance (deliberately
21 positioning structures and lifelines to avoid crossing identified shear rupture zones), geotechnical
22 engineering (using the inherent capability of unconsolidated geomaterials to "locally absorb" and
23 distribute distinct bedrock fault movements) and structural engineering (engineering the facility to
24 undergo some limited amount of ground deformation without collapse or significant damage).

25 As described in Section 9.3.1, *Methods for Analysis*, and in Appendix 3B, *Environmental Commitments*,
26 such design codes, guidelines, and standards include the California Building Code and resource agency
27 and professional engineering specifications, such as the Division of Safety of Dams *Guidelines for Use of*
28 *the Consequence Hazard Matrix and Selection of Ground Motion Parameters*, DWR's Division of Flood
29 Management *FloodSAFE Urban Levee Design Criteria*, and USACE's *Engineering and Design—Earthquake*
30 *Design and Evaluation for Civil Works Projects*. Conformance with these design standards is an
31 environmental commitment by the BDCP proponents to ensure that strong seismic shaking risks are
32 minimized as the conservation measures are implemented.

33 The BDCP proponents would ensure that the geotechnical design recommendations are included in the
34 design of project features and construction specifications to minimize the potential effects from seismic
35 events and the presence of adverse soil conditions. The BDCP proponents would also ensure that the
36 design specifications are properly executed during implementation.

37 In particular, conformance with the following codes and standards would reduce the potential risk for
38 increased likelihood of loss of property or personal injury from structural failure resulting from surface
39 rupture resulting from a seismic event during operation:

- 40 ● DWR Division of Engineering State Water Project – Seismic Loading Criteria Report, Sept 2012.
- 41 ● DWR DSOD Guidelines for Use of the Consequence-Hazard Matrix and Selection of Ground Motion
42 Parameters, 2002.

- 1 • USACE Engineering and Design, Earthquake Design and Evaluation for Civil Works Projects, ER 1110-
2 2-1806, 1995.
- 3 • USACE Design and Construction of Levees, EM 1110-2-1913, 2000.
- 4 • USACE (Corps, CESP-K-ED-G), Geotechnical Levee Practice, SOP EDG-03, 2004.
- 5 • DWR Division of Flood Management FloodSAFE Urban Levee Design Criteria, May 2012.
- 6 • California Code of Regulations, Title 8, Sections 1509 and 3203, California Code of Regulations.

7 Generally, the applicable codes require that facilities be built so that they incur minimal damage in the
8 event of a foreseeable seismic event and that they remain functional following such an event and that
9 the facility is able to perform without catastrophic failure in the event of a maximum design earthquake
10 (the greatest earthquake reasonably expected to be generated by a specific source on the basis of
11 seismological and geological evidence).

12 The worker safety codes and standards specify protective measures that must be taken at construction
13 sites to minimize the risk of injury or death from structural or earth failure (e.g., utilizing personal
14 protective equipment, practicing crane and scaffold safety measures). The relevant codes and
15 standards represent performance standards that must be met by contractors and these measures are
16 subject to monitoring by state and local agencies. Cal-OSHA requirements for an IIPP and the terms of
17 the IIPP to protect worker safety are the principal measures that would be enforced at construction
18 sites.

19 Conformance to these and other applicable design specifications and standards would ensure that the
20 hazard of seismic shaking would not jeopardize the integrity of levees and other features at the ROAs
21 and would not create an increased likelihood of loss of property, personal injury or death of individuals
22 in the ROAs. This effect would not be adverse.

23 **CEQA Conclusion:** Ground shaking could damage levees, berms, and other structures. Among all the
24 ROAs, the Suisun Marsh ROA would be the most subject to ground shaking because of its proximity to
25 active faults. The Suisun Marsh ROA is subject to a PGA of approximately 0.31 to 0.35 g for 200-year
26 return interval, while the PGA for the other ROAs ranges from approximately 0.11 to 0.26 g. Damage to
27 these features could result in their failure, causing flooding of otherwise protected areas. However, as
28 described in Section 9.3.1, *Methods for Analysis*, and in Appendix 3B, *Environmental Commitments*,
29 design codes, guidelines, and standards, including the California Building Code and resource agency
30 and professional engineering specifications, such as DWR's Division of Flood Management *FloodSAFE*
31 *Urban Levee Design Criteria* and USACE's *Engineering and Design—Earthquake Design and Evaluation*
32 *for Civil Works Projects* would be used for final design of conservation features. Conformance with these
33 design standards is an environmental commitment by the BDCP proponents to ensure that strong
34 seismic shaking risks are minimized as the conservation measures are operated and there would be no
35 increased likelihood of loss of property, personal injury or death of individuals in the ROAs. The impact
36 would be less than significant. No mitigation is required.

37 **Impact GEO-14: Loss of Property, Personal Injury, or Death from Structural Failure Resulting**
38 **from Seismic-Related Ground Failure (Including Liquefaction) Beneath Restoration Opportunity**
39 **Areas**

40 New structural features are proposed at the ROAs, such as levees as part of CM4, setback levees as part
41 of CM5 and CM6, and experimental ramps and fish ladders at the Fremont Weir as part of CM2.
42 Earthquake-induced ground shaking could cause liquefaction, resulting in damage to or failure of

1 levees and other features constructed at the restoration areas. The consequences of liquefaction are
 2 manifested in terms of compaction or settlement, loss of bearing capacity, lateral spreading (soil
 3 movement), and increased lateral soil pressure. Failure of levees and other features could result in
 4 flooding of otherwise protected areas in Suisun Marsh and behind new setback levees along the
 5 Sacramento and San Joaquin Rivers and in the South Delta ROA.

6 The ROAs vary with respect to their liquefaction hazard (Figure 9-6). The Suisun Marsh ROA generally
 7 has a moderate liquefaction hazard. The liquefaction damage potential among the other ROAs is
 8 generally low to medium.

9 **NEPA Effects:** The potential effect could be substantial because earthquake-induced liquefaction could
 10 damage ROA facilities, such as levees and berms. Damage to these features could result in their failure,
 11 causing flooding of otherwise protected areas.

12 During final design of conservation facilities, site-specific geotechnical and groundwater investigations
 13 would be conducted to identify and characterize the vertical (depth) and horizontal (spatial) extents of
 14 liquefiable soil. Engineering soil parameters that could be used to assess the liquefaction potential, such
 15 as SPT blow counts, CPT penetration tip pressure/resistance, and gradation of soil, would also be
 16 obtained. SPT blow counts and CPT tip pressure are used to estimate soil resistance to cyclic loadings
 17 by using empirical relationships that were developed based on occurrences of liquefaction (or lack of
 18 them) during past earthquakes. The resistance then can be compared to cyclic shear stress induced by
 19 the design earthquakes. If soil resistance is less than induced stress, the potential of having liquefaction
 20 during the design earthquakes is high. It is also known that soil with high “fines” (i.e., silt- and clay-
 21 sized particles) content are less susceptible to liquefaction.

22 During final design, the facility-specific potential for liquefaction would be investigated by a
 23 geotechnical engineer. In areas determined to have a potential for liquefaction, the engineer would
 24 develop design parameters and construction methods to meet the design criteria established to ensure
 25 that design earthquake does not cause damage to or failure of the facility. Such measures and methods
 26 include removing and replacing potentially liquefiable soil, strengthening foundations (for example,
 27 using post-tensioned slab, reinforced mats, and piles) to resist excessive total and differential
 28 settlements, using *in situ* ground improvement techniques (such as deep dynamic compaction, vibro-
 29 compaction, vibro-replacement, compaction grouting, and other similar methods), and conforming with
 30 current seismic design codes and requirements, as described in Section 9.3.1, *Methods for Analysis*, and
 31 in Appendix 3B, *Environmental Commitments*, such design codes, guidelines, and standards include
 32 USACE’s *Engineering and Design—Stability Analysis of Concrete Structures and Soil Liquefaction during*
 33 *Earthquakes*, by the Earthquake Engineering Research Institute. Conformance with these design
 34 standards is an environmental commitment by the BDCP proponents to ensure that liquefaction risks
 35 are minimized as the conservation measures are implemented. The hazard would be controlled to a
 36 safe level.

37 In particular, conformance with the following codes and standards would reduce the potential risk for
 38 increased likelihood of loss of property or personal injury from structural failure resulting from
 39 seismic-related ground failure:

- 40 • USACE Engineering and Design - Design of Pile Foundations, EM 1110-2-2906, 1991
- 41 • USACE Engineering and Design – Stability Analysis of Concrete Structures, EM 1110-2-2100, 2005
- 42 • USACE Engineering and Design, Earthquake Design and Evaluation for Civil Works Projects, ER 1110-
 43 2-1806, 1995

- California Code of Regulations, Title 8, Sections 1509 and 3203, California Code of Regulations.

Generally, the applicable codes require that facilities be built so that if soil in the foundation or surrounding area are subject to liquefaction, the removal or densification of the liquefiable material should be considered, along with alternative foundation designs.

The worker safety codes and standards specify protective measures that must be taken at construction sites to minimize the risk of injury or death from structural or earth failure (e.g., utilizing personal protective equipment, practicing crane and scaffold safety measures). The relevant codes and standards represent performance standards that must be met by contractors and these measures are subject to monitoring by state and local agencies. Cal-OSHA requirements for an IIPP and the terms of the IIPP to protect worker safety are the principal measures that would be enforced at construction sites.

The BDCP proponents would ensure that the geotechnical design recommendations are included in the design of levees and construction specifications to minimize the potential effects from liquefaction and associated hazard. The BDCP proponents would also ensure that the design specifications are properly executed during implementation and would not create an increased likelihood of loss of property, personal injury or death of individuals in the ROAs. This effect would not be adverse.

CEQA Conclusion: Earthquake-induced ground shaking could cause liquefaction, resulting in damage to or failure of levees, berms, and other features constructed at the restoration areas. Failure of levees and other structures could result in flooding of otherwise protected areas. However, through the final design process, measures to address the liquefaction hazard would be required to conform to applicable design codes, guidelines, and standards. As described in Section 9.3.1, *Methods for Analysis*, and in Appendix 3B, *Environmental Commitments*, such design codes, guidelines, and standards include USACE's *Engineering and Design—Stability Analysis of Concrete Structures and Soil Liquefaction during Earthquakes*, by the Earthquake Engineering Research Institute. Conformance with these design standards is an environmental commitment by the BDCP proponents to ensure that liquefaction risks are minimized as the water conservation features are implemented. The hazard would be controlled to a safe level and there would be no increased likelihood of loss of property, personal injury or death of individuals in the ROAs. The impact would be less than significant. No mitigation is required.

Impact GEO-15: Loss of Property, Personal Injury, or Death from Landslides and Other Slope Instability at Restoration Opportunity Areas

Implementation of CM2–CM7, would involve breaching, modification or removal of existing levees and construction of new levees and embankments. CM4 which provides for the restoration of up to 65,000 acres of tidal perennial aquatic, tidal mudflat, tidal freshwater emergent wetland, and tidal brackish emergent wetland natural communities within the ROAs involves the greatest amount of modifications to levees. Levee modifications, including levee breaching or lowering, may be performed to reintroduce tidal exchange, reconnect remnant sloughs, restore natural remnant meandering tidal channels, encourage development of dendritic channel networks, and improve floodwater conveyance.

Levee modifications could involve the removal of vegetation and excavation of levee materials. Excess earthen materials could be temporarily stockpiled, then re-spread on the surface of the new levee slopes where applicable or disposed of offsite. Any breaching or other modifications would be required to be designed and implemented to maintain the integrity of the levee system and to conform with flood management standards and permitting processes. This would be coordinated with the appropriate flood management agencies. Those agencies may include USACE, DWR, CVFPB, and other

1 flood management agencies. For more detail on potential modifications to levees as a part of
2 conservation measures, please refer to Chapter 3, *Description of Alternatives*.

3 New and existing levee slopes and stream/channel banks could fail and could damage facilities as a
4 result of seismic shaking and as a result of high soil-water content during heavy rainfall. With the
5 exception of levee slopes, natural stream banks, and part of the Suisun Marsh ROA, the topography of
6 ROAs is nearly level to gently sloping. The areas that may be susceptible to slope failure are along
7 existing Sacramento and San Joaquin River and Delta island levees and stream/channel banks
8 particularly those levees that consist of non-engineered fill and those streambanks that are steep and
9 consist of low strength soil.

10 The structures associated with conservation measures would not be constructed in, nor would they be
11 adjacent to, areas that are subject to mudflows/debris flows from natural slopes.

12 **NEPA Effects:** The potential effect could be substantial because levee slopes and embankments may fail,
13 either from high pore-water pressure caused by high rainfall and weak soil, or from seismic shaking.
14 Failure of these features could result in flooding of otherwise protected areas.

15 As outlined in Chapter 3, *Description of Alternatives*, erosion protection measures and protection
16 against related failure of adjacent levees would be taken where levee breaches were developed.
17 Erosion protection could include geotextile fabrics, rock revetments, riprap, or other material selected
18 during future evaluations for each location. Aggregate rock could be placed on the remaining levees to
19 provide an access road to the breach location. Erosion protection measures would also be taken where
20 levee lowering is done for the purposes of allowing seasonal or periodic inundation of lands during
21 high flows or high tides to improve habitat or to reduce velocities and elevations of floodwaters. To
22 reduce erosion potential on the new levee crest, a paved or gravel access road could be constructed
23 with short (approximately 1 foot) retaining walls on each edge of the crest to reduce undercutting of
24 the roadway by high tides. Levee modifications could also include excavation of watersides of the
25 slopes to allow placement of slope protection, such as riprap or geotextile fabric, and to modify slopes
26 to provide levee stability. Erosion and scour protection could be placed on the landside of the levee and
27 continued for several feet onto the land area away from the levee toe. Neighboring levees could require
28 modification to accommodate increased flows or to reduce effects of changes in water elevation or
29 velocities along channels following inundation of tidal marshes. Hydraulic modeling would be used
30 during subsequent analyses to determine the need for such measures.

31 New levees would be constructed to separate lands to be inundated for tidal marsh from non-
32 inundated lands, including lands with substantial subsidence. Levees could be constructed as described
33 for the new levees at intake locations. Any new levees would be required to be designed and
34 implemented to conform with applicable flood management standards and permitting processes. This
35 would be coordinated with the appropriate flood management agencies, which may include USACE,
36 DWR, CVFPB, and local flood management agencies.

37 Additionally, during project design, a geotechnical engineer would develop slope stability design
38 criteria (such as minimum slope safety factors and allowable slope deformation and settlement) for the
39 various anticipated loading conditions. As required by design standards and building codes (see
40 Appendix 3B, *Environmental Commitments*), foundation soil beneath embankments and levees could be
41 improved to increase its strength and to reduce settlement and deformation. Foundation soil
42 improvement could involve excavation and replacement with engineered fill; preloading; ground
43 modifications using jet-grouting, compaction grouting, chemical grouting, shallow soil mixing, deep soil

1 mixing, vibro-compaction, or vibro-replacement; or other methods. Engineered fill could also be used
2 to construct new embankments and levees.

3 Site-specific geotechnical and hydrological information would be used, and the design would conform
4 with the current standards and construction practices, as described in Chapter 3, such as USACE's
5 *Design and Construction of Levees* and USACE's *EM 1110-2-1902, Slope Stability*.

6 The BDCP proponents would ensure that the geotechnical design recommendations are included in the
7 design of embankments and levees to minimize the potential effects from slope failure. The BDCP
8 proponents would also ensure that the design specifications are properly executed during
9 implementation.

10 In particular, conformance with the following codes and standards would reduce the potential risk for
11 increased likelihood of loss of property or personal injury from structural failure resulting from
12 landslides or other slope instability:

- 13 • DWR Division of Engineering State Water Project – Seismic Loading Criteria Report, Sept 2012.
- 14 • DWR Division of Flood Management FloodSAFE Urban Levee Design Criteria, May 2012.
- 15 • USACE Slope Stability, EM 1110-2-1902, 2003.
- 16 • California Code of Regulations, Title 8, Section 3203, California Code of Regulations.

17 Generally, the applicable codes require that facilities be built to certain factors of safety in order to
18 ensure that facilities perform as designed for the life of the structure despite various soil parameters.µ

19 The worker safety codes and standards specify protective measures that must be taken at construction
20 sites to minimize the risk of injury or death from structural or earth failure (e.g., utilizing personal
21 protective equipment). The relevant codes and standards represent performance standards that must
22 be met by contractors and these measures are subject to monitoring by state and local agencies. Cal-
23 OSHA requirements for an IIPP and the terms of the IIPP to protect worker safety are the principal
24 measures that would be enforced at project sites during operations.

25 Conformance to the above and other applicable design specifications and standards would ensure that
26 the hazard of slope instability would not jeopardize the integrity of levee and other features at the
27 ROAs and would not create an increased likelihood of loss of property, personal injury or death of
28 individuals in the ROAs. This effect would not be adverse.

29 **CEQA Conclusion:** Unstable new and existing levee and embankment slopes could fail as a result of
30 seismic shaking and as a result of high soil-water content during heavy rainfall and cause flooding of
31 otherwise protected areas. However, because the BDCP proponents would conform with applicable
32 design guidelines and standards, such as USACE design measures, the hazard would be controlled to a
33 safe level and there would be no increased likelihood of loss of property, personal injury or death of
34 individuals in the ROAs. The impact would be less than significant. No mitigation is required.

35 **Impact GEO-16: Loss of Property, Personal Injury, or Death from Seiche or Tsunami at** 36 **Restoration Opportunity Areas as a Result of Implementing the Conservation Actions**

37 The distance from the ocean and attenuating effect of the San Francisco Bay would likely allow only a
38 low tsunami wave height to reach the Suisun Marsh and the Delta. Conditions for a seiche to occur at
39 the ROAs are not favorable. Therefore, the effect would not be adverse.

CEQA Conclusion: Based on recorded tsunami wave heights at the Golden Gate, the height of a tsunami wave reaching the ROAs would be small because of the distance from the ocean and attenuating effect of the San Francisco Bay. Similarly, the potential for a significant seiche to occur in the Plan Area that would cause loss of property, personal injury, or death at the ROAs is considered low because conditions for a seiche to occur at the ROAs are not favorable. The impact would be less than significant. No mitigation is required.

9.3.3.4 Alternative 1C—Dual Conveyance with West Alignment and Intakes W1–W5 (15,000 cfs; Operational Scenario A)

Impact GEO-1: Loss of Property, Personal Injury, or Death from Structural Failure Resulting from Strong Seismic Shaking of Water Conveyance Features during Construction

Earthquakes could be generated from on local and regional seismic sources during construction of the Alternative 1C water conveyance facilities. Seismically induced ground shaking could cause injury of workers at the construction sites as a result of collapse of facilities.

The potential for experiencing earthquake ground shaking during construction in 2020 (during the project's near-term implementation stage) was estimated using the results of the seismic study (California Department of Water Resources 2007a). The study also computed seismic ground shaking hazards at six locations in the Delta for 2005, 2050, 2100, and 2200. The results of these analyses show that the ground shakings in the Delta are not sensitive to the elapsed time since the last major earthquake (that is, the projected shaking hazard results for 2005, 2050, 2100, and 2200) are similar.

Table 9-22 lists the expected PGA and 1.0- S_a values in 2020 at selected facility locations along the Alternative 1C alignment. As with Alternative 1B, ground motions with a return period of 72 years and computed for 2005 were used to represent near-term (i.e., 2020) construction period motions for Alternative 1C.

Table 9-22. Expected Earthquake Ground Motions at Locations of Selected Major Facilities during Construction (2020)—Alternative 1C

Major Facilities	72-year Return Period Ground Motions			
	Peak Ground Acceleration (g)		1.0-sec S_a (g)	
	Stiff Soil ^a	Local Soil ^b	Stiff Soil ^a	Local Soil ^b
Intake and Fish Screen Area ^c	0.11	0.14	0.13	0.21
Tunnel Location between Bradford Island and Webb Tract ^d	0.20	0.26	0.22	0.35
Clifton Court Forebay/Byron Tract Forebay	0.18	0.23	0.20	0.32

g = gravity

S_a = second spectral acceleration

^a Stiff soil site, with a V_{s100ft} value of 1,000 ft/s.

^b Site-adjusted factors of 1.3 and 1.6 were applied to PGA and 1.0-sec S_a values, respectively (adjustments from a stiff soil site to a soft soil site).

^c The results of California Department of Water Resources 2007a for the Sacramento site were used.

^d The results of California Department of Water Resources 2007a for the Sherman Island were used.

1 **NEPA Effects:** The seismic study employed time-dependent seismic source models for several major
 2 faults in the region. These models were characterized based on the elapsed times since the last major
 3 seismic events on the faults. Therefore, the exposure risks predicted by the study would increase if no
 4 major events occur on these faults through 2020. The effect would be adverse because seismically
 5 induced ground shaking could cause collapse of facilities. For example, the concrete batch plant and
 6 fuel station on Bradford Island, several siphons, a fuel station and concrete batch plant west of Clifton
 7 Court Forebay, the entire length of the water conveyance from the middle of Ryer Island down to the
 8 Byron Tract Forebay for Alternative 1C all lie on or near the Southern Midland fault, a single,
 9 potentially seismogenic fault; or the West Tracy fault. Both are active blind faults, resulting in an
 10 increased likelihood of loss of property or personal injury at these sites in the event of seismically-
 11 induced ground shaking. Although these blind thrusts are not expected to rupture to the ground surface
 12 under the forebays during earthquake events, they may produce ground or near-ground shear zones,
 13 bulging, or both (California Department of Water Resources 2007a). For a map of all permanent
 14 facilities and temporary work areas associated with this conveyance alignment, see Mapbook Figure
 15 M3-3.

16 However, during construction, all active construction sites would be designed and managed to meet the
 17 safety and collapse-prevention requirements of the relevant state codes and standards listed earlier in
 18 this chapter and expanded upon in Appendix 3B, *Environmental Commitments* for the above-anticipated
 19 seismic loads. In particular, conformance with the following codes and standards would reduce the
 20 potential risk for increased likelihood of loss of property or personal injury from structural failure
 21 resulting from strong seismic shaking of water conveyance features during construction:

- 22 • DWR Division of Engineering State Water Project – Seismic Loading Criteria Report, Sept 2012.
- 23 • USACE Engineering and Design, Earthquake Design and Evaluation for Civil Works Projects, ER 1110-
 24 2-1806, 1995.
- 25 • USACE Engineering and Design – Earthquake Design and Evaluation of Concrete Hydraulic Structures,
 26 EM 1110-2-6053, 2007.
- 27 • USACE Engineering and Design – Response Spectra and Seismic Analysis for Concrete Hydraulic
 28 Structures, EM 1110-2-6050, 1999.
- 29 • USACE Engineering and Design – Stability Analysis of Concrete Structures, EM 1110-2-2100, 2005.
- 30 • California Code of Regulations, Title 8, Sections 1509 and 3203, California Code of Regulations.

31 Generally, the applicable codes require that facilities be built so that they incur minimal damage in the
 32 event of a foreseeable seismic event and that they remain functional following such an event and that
 33 the facility is able to perform without catastrophic failure in the event of a maximum design earthquake
 34 (the greatest earthquake reasonably expected to be generated by a specific source on the basis of
 35 seismological and geological evidence). The safety requirements could include shoring, specified slope
 36 angles, excavation depth restrictions for workers, lighting and other similar controls. Conformance
 37 with these standards and codes are an environmental commitment of the project (see Appendix 3B,
 38 *Environmental Commitments*).

39 The worker safety codes and standards specify protective measures that must be taken at construction
 40 sites to minimize the risk of injury or death from structural or earth failure (e.g., utilizing personal
 41 protective equipment, practicing crane and scaffold safety measures). The relevant codes and
 42 standards represent performance standards that must be met by DWR and these measures are subject
 43 to monitoring by state and local agencies. Cal-OSHA requirements to protect worker safety are the

1 principal measures that would be enforced at construction sites. Cal-OSHA requirements for an IIPP
 2 and the terms of the IIPP to protect worker safety are the principal measures that would be enforced at
 3 construction sites.

4 Conformance with these health and safety requirements and the application of accepted, proven
 5 construction engineering practices would reduce any potential risk such that construction of
 6 Alternative 1C would not create an increased likelihood of loss of property, personal injury or death of
 7 individuals. Therefore, there would be no adverse effect.

8 **CEQA Conclusion:** Seismically induced ground shaking that is estimated to occur and the resultant
 9 ground motion anticipated at Alternative 1C construction sites, including the canal, pipelines and the
 10 forebays, could cause collapse or other failure of project facilities while under construction. For
 11 example, the concrete batch plant and fuel station on Bradford Island, several siphons, a fuel station
 12 and concrete batch plant west of Clifton Court Forebay, the entire length of the water conveyance from
 13 the middle of Ryer Island down to the Byron Tract Forebay for Alternative 1C all lie on or near the
 14 Southern Midland fault, a single, potentially seismogenic fault; or the West Tracy fault. Both are active
 15 blind faults, resulting in an increased likelihood of direct loss or injury at these sites in the event of
 16 seismically-induced ground shaking. However, DWR would conform with Cal-OSHA and other state
 17 code requirements, such as shoring, bracing, lighting, excavation depth restrictions, required slope
 18 angles, and other measures, to protect worker safety. Conformance with these standards and codes is
 19 an environmental commitment of the project (see Appendix 3B, *Environmental Commitments*).
 20 Conformance with these health and safety requirements and the application of accepted, proven
 21 construction engineering practices would reduce any potential risk such that construction of
 22 Alternative 1C would not create an increased likelihood of loss of property, personal injury or death of
 23 individuals. This risk would be less than significant. No mitigation is required.

24 **Impact GEO-2: Loss of Property, Personal Injury, or Death from Settlement or Collapse Caused**
 25 **by Dewatering during Construction of Water Conveyance Features**

26 Settlement of excavations could occur as a result of construction dewatering if proven construction and
 27 dewatering methods and earthwork practices are not carried out. The settlement could cause the
 28 slopes of excavations to fail. This hazard is most likely to be present at the intake and pumping plant
 29 locations and the canal alignment. The preliminary dewatering analysis results indicate that the
 30 majority (more than 90%) of the dewatering needs for Alternative 1C construction would be associated
 31 with canal construction (i.e., for the excavation of the canal foundation). The proposed canal for
 32 Alternative 1C is located on alluvial floodbasin deposits, alluvial floodplain deposits, natural levee
 33 deposits, peat and muck, and the Modesto Formation. Similar dewatering may be necessary where
 34 conveyance pipelines cross waterways and major irrigation canals. The conveyance pipeline between
 35 Intake 1 and the canal crosses 5 canals or ditches, Winchester Lake, and Elk Slough. The intersections
 36 with Winchester Lake and one of the canals or ditches occur about 0.4 miles west of the Sacramento
 37 River. The crossing of Elk Slough occurs approximately 0.8 miles southwest of the slough's confluence
 38 with the Sacramento River. The pipeline crosses 3 canals or ditches north of S. River Road, east and
 39 west of Rose Road. The final intersection with a canal or ditch is about 0.3 miles north of Clarksburg
 40 Road, west of the community of Clarksburg. The intake pipeline and conveyance pipeline associated
 41 with Intake 2 would each intersect one canal or ditch. Both of these intersection points would be less
 42 than 0.1 mile south of County Road 141 on Merritt Island. The intake pipeline and conveyance pipeline
 43 associated with Intake 3 would each intersect one canal or ditch. Both of these intersection points
 44 would be less than 0.1 mile south of County Road 142 on Merritt Island.

1 The conveyance pipeline between Intake 4 and the canal would intersect with one canal or ditch, about
 2 0.3 miles northwest of the facility grounds for Intake 4. The conveyance pipeline between Intake 5 and
 3 the canal would cross two canals or ditches. These lies east and southeast of Elk Slough, approximately
 4 0.25 miles and 0.5 miles (respectively) north of the facility grounds for Intake 5.

5 Dewatering can stimulate settlement in excavation and tunneling sites. The settlement could cause the
 6 slopes of excavations to fail.

7 **NEPA Effects:** The potential effect could be substantial because settlement or collapse during
 8 dewatering could cause collapse of excavations.

9 The hazard of settlement and subsequent collapse of excavations would be evaluated by assessing site-
 10 specific geotechnical and hydrological conditions along the canal, as well as where intake and forebay
 11 pipelines cross waterways and major irrigation canals. A California-registered civil engineer or
 12 California-certified engineering geologist would recommended measures in a geotechnical report to
 13 address these hazards, such as seepage cutoff walls and barriers, shoring, grouting of the bottom of the
 14 excavation, and strengthening of nearby structures, existing utilities, or buried structures. As described
 15 in Section 9.3.1, *Methods for Analysis*, the measures would conform to applicable design and building
 16 codes, guidelines, and standards, such as the California Building Code and USACE's *Engineering and*
 17 *Design—Structural Design and Evaluation of Outlet Works*. See Appendix 3B, *Environmental*
 18 *Commitments*.

19 In particular, conformance with the following codes and standards would reduce the potential risk for
 20 increased likelihood of loss of property or personal injury from structural failure resulting from
 21 settlement or collapse at the construction site caused by dewatering during construction:

- 22 • DWR Division of Flood Management FloodSAFE Urban Levee Design Criteria, May 2012.
- 23 • USACE Engineering and Design - Settlement Analysis, EM 1110-1-1904, 1990.
- 24 • California Code of Regulations, Title 8, Sections 1509 and 3203, California Code of Regulations.

25 Generally, the applicable codes require that facilities be built in such a way that settlement is
 26 minimized. DWR would ensure that the geotechnical design recommendations are included in the
 27 design of project facilities and construction specifications to minimize the potential effects from
 28 settlement and failure of excavations.

29 DWR would ensure that the geotechnical design recommendations are included in the design of project
 30 facilities and construction specifications to minimize the potential effects from settlement and failure of
 31 excavations. DWR would also ensure that the design specifications are properly executed during
 32 construction. DWR has made an environmental commitment to use the appropriate code and standard
 33 requirements to minimize potential risks (Appendix 3B, *Environmental Commitments*).

34 The worker safety codes and standards specify protective measures that must be taken at construction
 35 sites to minimize the risk of injury or death from structural or earth failure (e.g., utilizing personal
 36 protective equipment, practicing crane and scaffold safety measures). The relevant codes and
 37 standards represent performance standards that must be met by contractors and these measures are
 38 subject to monitoring by state and local agencies. Cal-OSHA requirements for an IIPP and the terms of
 39 the IIPP to protect worker safety are the principal measures that would be enforced at construction
 40 sites.

1 Conformance to these and other applicable design specifications and standards would ensure that
2 construction of Alternative 1C would not create an increased likelihood of loss of property, personal
3 injury or death of individuals from settlement or collapse caused by dewatering. Therefore, there
4 would be no adverse effect.

5 **CEQA Conclusion:** Settlement or failure of excavations during construction could result in loss of
6 property or personal injury. However, DWR would conform with Cal-OSHA and other state code
7 requirements, such as using seepage cutoff walls, shoring, and other measures, to protect worker
8 safety. DWR would also ensure that the design specifications are properly executed during
9 construction. DWR has made an environmental commitment to use the appropriate code and standard
10 requirements to minimize potential risks (Appendix 3B, *Environmental Commitments*). Conformance
11 with these requirements and the application of accepted, proven construction engineering practices
12 would reduce any potential risk such that construction of Alternative 1C would not create an increased
13 likelihood of loss of property, personal injury or death of individuals from settlement or collapse
14 caused by dewatering. The impact would be less than significant. No mitigation is required.

15 **Impact GEO-3: Loss of Property, Personal Injury, or Death from Ground Settlement during** 16 **Construction of Water Conveyance Features**

17 Two types of ground settlement could be induced during Alternative 1C tunnel construction: large
18 settlement and systematic settlement. Large settlement occurs primarily as a result of over-excavation
19 by the tunneling shield. The over-excavation is caused by failure of the tunnel boring machine to
20 control unexpected or adverse ground conditions (for example, running, raveling, squeezing, and
21 flowing ground) or operator error. Large settlement can lead to the creation of voids and/or sinkholes
22 above the tunnel and the culvert siphons. In extreme circumstances, the settlement effects could
23 translate to the ground surface, potentially causing loss of property or personal injury above the
24 tunneling operation.

25 Systematic settlement usually results from ground movements that occur before tunnel supports can
26 exit the shield and the tunnel to make full contact with the ground. Soil with higher silt and clay content
27 tend to experience less settlement than sandy soil. Additional ground movements can occur with the
28 deflection of the tunnel supports and over-excavation caused by steering/plowing of the tunnel boring
29 machine at horizontal and vertical curves. A deeper tunnel induces less ground surface settlement
30 because a greater volume of soil material is available above the tunnel to fill any systematic void space.

31 The geologic units in the area of the Alternative 1C alignment are shown on Figure 9-3 and summarized
32 in Table 9-23. The characteristics of each unit would affect the potential for settlement during tunnel
33 construction. Segment 4, located from the middle of Ryer Island running south to just west of Summer
34 Lake, is primarily where the tunnel portion of Alternative 1C lies.

1 **Table 9-23. Geology of Alternative 1C/West Alignment by Segments**

Segment ^a	Geologic Unit	Geologic Unit Description
Segment 1 and Segment 2	Ql	Natural levee deposits: moderately to well-sorted sand, with some silt and clay.
	Qb	Flood basin deposits: firm to stiff silty clay, clayey silt, and silt
Segment 3	Ql	Natural levee deposits: moderately- to well-sorted sand, with some silt and clay.
	Qb	Flood basin deposits: firm to stiff silty clay, clayey silt, and silt
	Qpm	Delta mud: mud and peat with minor silt or sand
Segment 4 (Tunnel Portion)	Ql	Natural levee deposits: moderately- to well-sorted sand, with some silt and clay.
	Qpm	Delta mud: mud and peat with minor silt or sand
	Qds	Dredge soils, post 1900
	Qm2e	Eolian sand: well-sorted fine- to medium-grained sand
Segment 5, Segment 6, and Segment 7	Qymc	Alluvial fans and terraces from non-glaciated drainage basins: sand, silt and gravel
	Qm2e	Eolian sand: well-sorted fine- to medium-grained sand
Segment 8, Segment 9 and Segment 10	Qymc	Alluvial fans and terraces from non-glaciated drainage basins: sand, silt and gravel
Segment 11	Qch	Alluvial fans and terraces from non-glaciated drainage basins: clay, silt, sand, and gravel.
	Qfp	Floodplain deposits: dense, sandy to silty clay
Segment 12	Qch	Alluvial fans and terraces from non-glaciated drainage basins: clay, silt, sand, and gravel.
Byron Tract Forebay (Northwest of Clifton Court Forebay Location)	Qfp	Floodplain deposits: dense, sandy to silty clay
	Qch	Alluvial fans and terraces from non-glaciated drainage basins: clay, silt, sand, and gravel.
	Qymc	Alluvial fans and terraces from non-glaciated drainage basins: sand, silt and gravel

Source: Hansen et al. 2001 and Atwater 1982.
^a The segments are shown on Figure 9-3.

2

3 Given the likely design depth of the tunnel and the culvert siphons, the potential for excessive
4 systematic settlement expressed at the ground surface caused by tunnel installation is thought to be
5 relatively low. Operator errors or highly unfavorable/unexpected ground conditions could result in
6 larger settlement. Large ground settlements caused by tunnel construction are almost always the result
7 of using inappropriate tunneling equipment (incompatible with the ground conditions), improperly
8 operating the machine, or encountering sudden or unexpected changes in ground conditions.

9 **NEPA Effects:** The potential effect could be substantial because ground settlement could occur during
10 the tunneling operation. During detailed project design, a site-specific subsurface geotechnical
11 evaluation would be conducted along the water conveyance facility alignment to verify or refine the
12 findings of the preliminary geotechnical investigation. The tunneling equipment and drilling methods
13 would be reevaluated and refined based on the results of the investigations, and field procedures for
14 sudden changes in ground conditions would be implemented to minimize or avoid ground settlement.
15 A California-registered civil engineer or California-certified engineering geologist would recommend
16 measures to address these hazards, such as specifying the type of tunnel boring machine to be used in a

1 given segment. The results of the site-specific evaluation and the engineer's recommendations would
 2 be documented in a detailed geotechnical report prepared in accordance with state guidelines, in
 3 particular *Guidelines for Evaluating and Mitigating Seismic Hazards in California* (California Geological
 4 Survey 2008).

5 In particular, conformance with the following codes and standards would reduce the potential risk for
 6 increased likelihood of loss of property or personal injury from ground settlement above the tunneling
 7 operation during construction:

- 8 • DWR Division of Engineering State Water Project – Seismic Loading Criteria Report, Sept 2012.
- 9 • DWR Division of Flood Management FloodSAFE Urban Levee Design Criteria, May 2012.
- 10 • California Code of Regulations, Title 8, Sections 1509 and 3203, California Code of Regulations.

11 As described in detail in Impacts GEO-1 and GEO-2, DWR would ensure that the geotechnical design
 12 recommendations are included in the design of project facilities and construction specifications to
 13 minimize the potential effects from settlement. DWR would also ensure that the design specifications
 14 are properly executed during construction. DWR has made this conformance and monitoring process
 15 an environmental commitment of the BDCP (Appendix 3B, *Environmental Commitments*).

16 Generally, the applicable codes require that facilities be built so that they are designed for a landside
 17 slope stability and seepage/underseepage factors of safety greater than 1.0 (i.e., stable) and would
 18 therefore be less impacted in the event of ground settlement. The worker safety codes and standards
 19 specify protective measures that must be taken at construction sites to minimize the risk of injury or
 20 death from structural or earth failure (e.g., utilizing personal protective equipment, practicing crane
 21 and scaffold safety measures). The relevant codes and standards represent performance standards that
 22 must be met by contractors and these measures are subject to monitoring by state and local agencies.
 23 Cal-OSHA requirements for an IIPP and the terms of the IIPP to protect worker safety are the principal
 24 measures that would be enforced at construction sites.

25 Conformance to these and other applicable design specifications and standards would ensure that
 26 construction of Alternative 1C would not create an increased likelihood of loss of property, personal
 27 injury or death of individuals from ground settlement. Therefore, there would be no adverse effect.

28 **CEQA Conclusion:** Ground settlement above the tunneling operation could result in loss of property or
 29 personal injury during construction. However, DWR would conform with Cal-OSHA, USACE and other
 30 design requirements to protect worker safety. DWR would also ensure that the design specifications
 31 are properly executed during construction. DWR has made an environmental commitment to use the
 32 appropriate code and standard requirements to minimize potential risks (Appendix 3B, *Environmental*
 33 *Commitments*). Conformance with these requirements and the application of accepted, proven
 34 construction engineering practices would reduce any potential risk such that construction of
 35 Alternative 1C would not create an increased likelihood of loss of property, personal injury or death of
 36 individuals from ground settlement. This risk would be less than significant. No mitigation is required.

37 **Impact GEO-4: Loss of Property, Personal Injury, or Death from Slope Failure during** 38 **Construction of Water Conveyance Features**

39 Excavation of borrow material could result in failure of cut slopes and application of temporary spoils
 40 and RTM at storage sites could cause excessive settlement in the spoils, potentially causing injury of
 41 workers at the construction sites. Soil and sediment, especially those consisting of loose alluvium and
 42 soft peat or mud, would particularly be prone to failure and movement. Additionally, groundwater is

1 expected to be within a few feet of the ground surface in these areas, this may make excavations more
2 prone to failure.

3 Borrow and spoils areas for construction of the canal foundation, intakes, sedimentation basins,
4 pumping plants, forebays, and other supporting facilities would be sited near the locations of these
5 structures (generally within 10 miles). Along the alignment, selected areas would also be used for
6 disposing of the byproduct (RTM) of tunnel construction. Table 9-24 describes the geology of these
7 areas as mapped by Atwater (1982) (Figure 9-3).

8 **Table 9-24. Geology of Alternative 1C Borrow/Spoils and Reusable Tunnel Material Areas by Segments**

Segment ^a	Geologic Unit	Geologic Unit Description
Segment 1 and Segment 2 Borrow/Spoils	Ql	Natural levee deposits: moderately- to well-sorted sand, with some silt and clay.
	Qb	Flood basin deposits: firm to stiff silty clay, clayey silt, and silt
Segment 3 Borrow/Spoils	Ql	Natural levee deposits: moderately- to well-sorted sand, with some silt and clay.
	Qb	Flood basin deposits: firm to stiff silty clay, clayey silt, and silt
	Qpm	Delta mud: mud and peat with minor silt or sand
Segment 6, Segment 7, Segment 8 and Segment 9 Borrow/Spoils	Qymc	Alluvial fans and terraces from non-glaciated drainage basins: sand, silt and gravel
	Qymc	Alluvial fans and terraces from non-glaciated drainage basins: sand, silt and gravel
Segment 10 Borrow/Spoils	Qfp	Floodplain deposits: dense, sandy to silty clay
	Qch	Alluvial fans and terraces from non-glaciated drainage basins: clay, silt, sand, and gravel.
Segment 11 and Segment 12 Borrow/Spoils	Qch	Alluvial fans and terraces from non-glaciated drainage basins: clay, silt, sand, and gravel.
	Qpm	Delta mud: mud and peat with minor silt or sand
Segment 4 Reusable Tunnel Material Area	Qm2e	Eolian sand: well-sorted fine- to medium-grained sand
	Qymc	Alluvial fans and terraces from non-glaciated drainage basins: sand, silt and gravel

Source: Hansen et al. 2001 and Atwater 1982.

^a The segments are shown on Figure 9-3.

9

10 **NEPA Effects:** The potential effect could be substantial because excavation of borrow material and the
11 resultant cutslopes and potential failure of spoils/RTM fill slopes could cause injury of workers at the
12 construction sites.

13 Excavations in borrow areas would be designed to avoid excessive ground movements on adjacent
14 areas and soil “boiling” (i.e., upwelling of groundwater) at the bottom of the excavation. Spoils would be
15 placed in 12-inch lifts with proper compaction and stored no higher than 12 feet above preconstruction
16 ground elevation with maximum side slopes of 5H:1V. During design, the potential for native ground
17 settlement below the spoils would be evaluated by a geotechnical engineer using site-specific
18 geotechnical and hydrological information. The use of shoring, seepage cutoff walls, and ground

1 modifications to prevent slope instability, soil boiling, or excessive settlement would be considered in
2 the design. As described in Section 9.3.1, *Methods for Analysis*, the measures would conform to
3 applicable design and building codes, guidelines, and standards, such as the California Building Code
4 and USACE's *Engineering and Design—Structural Design and Evaluation of Outlet Works*.

5 In addition to the risk of slope failure at borrow sites and spoils and RTM sites, there are also potential
6 impacts on levee stability resulting from construction of Alternative 1C water conveyance facilities. The
7 intakes would be sited along the existing Sacramento River levee system, requiring reconstruction of
8 levees to provide continued flood management. At each intake pumping plant site, a new setback levee
9 (ring levee) would be constructed. The space enclosed by the setback levee would be filled up to the
10 elevation of the top of the setback levee, creating a building pad for the adjacent pumping plant.

11 As discussed in Chapter 3, *Description of the Alternatives*, the new levees would be designed to provide
12 an adequate Sacramento River channel cross section and to provide the same level of flood protection
13 as the existing levee and would be constructed to geometries that meet or exceed PL 84-99 standards.
14 CALFED and DWR have adopted PL 84-99 as the preferred design standard for Delta levees. Transition
15 levees would be constructed to connect the existing levees to the new setback levees. A typical new
16 levee would have a broad-based, generally asymmetrical triangular cross section. The levee height
17 considered wind and wave erosion. As measured from the adjacent ground surface on the landside
18 vertically up to the elevation of the levee crest, would range from approximately 20 to 45 feet to
19 provide adequate freeboard above anticipated water surface elevations. The width of the levee (toe of
20 levee to toe of levee) would range from approximately 180 to 360 feet. The minimum crest width of the
21 levee would be 20 feet; however, in some places it would be larger to accommodate roadways and
22 other features. Cut-off walls would be constructed to avoid seepage, and the minimum slope of levee
23 walls would be three units horizontal to one unit vertical. All levee reconstruction will conform with
24 applicable state and federal flood management engineering and permitting requirements.

25 Depending on foundation material, foundation improvements would require excavation and
26 replacement of soil below the new levee footprint and potential ground improvement. The levees
27 would be armored with riprap—small to large angular boulders—on the waterside. Intakes would be
28 constructed using a sheetpile cofferdam in the river to create a dewatered construction area that would
29 encompass the intake site. The cofferdam would lie approximately 10–35 feet from the footprint of the
30 intake and would be built from upstream to downstream, with the downstream end closed last. The
31 distance between the face of the intake and the face of the cofferdam would be dependent on the
32 foundation design and overall dimensions. The length of each temporary cofferdam would vary by
33 intake location, but would range from 740 to 2,440 feet. Cofferdams would be supported by steel sheet
34 piles and/or king piles (heavy H-section steel piles). Installation of these piles may require both impact
35 and vibratory pile drivers. Some clearing and grubbing of levees would be required prior to installation
36 of the sheet pile cofferdam, depending on site conditions. Additionally, if stone bank protection, riprap,
37 or mature vegetation is present at intake construction site, it would be removed prior to sheet pile
38 installation.

39 As described in Section 9.3.1, *Methods for Analysis*, the measures would conform to applicable design
40 and building codes, guidelines, and standards, such as the California Building Code and USACE's
41 *Engineering and Design—Structural Design and Evaluation of Outlet Works*. DWR has made the
42 environmental commitment (see Appendix 3B, *Environmental Commitments*) that the geotechnical
43 design recommendations are included in the design of project facilities and construction specifications
44 to minimize the potential effects from failure of excavations and settlement. DWR also has committed
45 to ensure that the design specifications are properly executed during construction. In particular,

1 conformance with the following codes and standards would reduce the potential risk for increased
 2 likelihood of loss of property or personal injury from settlement/failure of cutslopes of borrow sites
 3 and failure of soil or RTM fill slopes during construction:

- 4 • DWR Division of Engineering State Water Project – Seismic Loading Criteria Report, Sept 2012.
- 5 • DWR Division of Flood Management FloodSAFE Urban Levee Design Criteria, May 2012.
- 6 • California Code of Regulations, Title 8, Sections 1509 and 3203, California Code of Regulations.

7 Generally, the applicable codes require that facilities be built to certain factors of safety in order to
 8 ensure that facilities perform as designed for the life of the structure despite various soil parameters.
 9 The worker safety codes and standards specify protective measures that must be taken at construction
 10 sites to minimize the risk of injury or death from structural or earth failure (e.g., utilizing personal
 11 protective equipment, practicing crane and scaffold safety measures). The relevant codes and
 12 standards represent performance standards that must be met by contractors and these measures are
 13 subject to monitoring by state and local agencies. Cal-OSHA requirements for an IIPP and the terms of
 14 the IIPP to protect worker safety are the principal measures that would be enforced at construction
 15 sites.

16 Conformance to these and other applicable design specifications and standards would ensure that
 17 construction of Alternative 1C would not create an increased likelihood of loss of property, personal
 18 injury or death of individuals from slope failure at borrow sites and spoils and RTM storage sites. The
 19 reconstruction of levees would improve levee stability over existing conditions due to improved side
 20 slopes, erosion countermeasures (geotextile fabrics, rock revetments, riprap, or other material),
 21 seepage reduction measures, and overall mass. Therefore, there would be no adverse effect.

22 **CEQA Conclusion:** Settlement/failure of cutslopes of borrow sites and failure of soil/RTM fill slopes
 23 could result in loss of property or personal injury during construction. However, because DWR would
 24 conform with Cal-OSHA and other state code requirements and conform to applicable geotechnical
 25 design guidelines and standards, such as USACE design measures. Conformance with these
 26 requirements and the application of accepted, proven construction engineering practices would reduce
 27 any potential risk such that construction of Alternative 1C would not create an increased likelihood of
 28 loss of property, personal injury or death of individuals from slope failure at borrow sites and spoils
 29 and RTM storage sites. The reconstruction of levees would improve levee stability over existing
 30 conditions due to improved side slopes, erosion countermeasures, seepage reduction measures, and
 31 overall mass. The impact would be less than significant. No mitigation is required.

32 **Impact GEO-5: Loss of Property, Personal Injury, or Death from Structural Failure Resulting** 33 **from Construction-Related Ground Motions during Construction of Water Conveyance Features**

34 Pile driving and other heavy equipment operations would cause vibrations that could initiate
 35 liquefaction and associated ground movements in places where soil and groundwater conditions are
 36 present to allow liquefaction to occur. The consequences of liquefaction could be manifested in terms of
 37 compaction or settlement, loss of bearing capacity, lateral spreading (horizontal soil movement),
 38 increased lateral soil pressure, and buoyancy within zones of liquefaction. These consequences could
 39 cause loss of property or personal injury and could damage nearby structures and levees.

40 The lateral extent (or influenced distance) of damage potential caused by pile driving and heavy
 41 equipment operations depends on many factors, including soil conditions, the piling hammer used,
 42 frequency of piling, and the vibration tolerance of structures and levees.

1 Pile driving would be conducted at the intakes, where, based on boring logs, soil materials subject to
 2 liquefaction (e.g., saturated, poorly graded sand) are present. During project design, site-specific
 3 geotechnical and groundwater investigations would be conducted to build upon existing data (e.g.,
 4 California Department of Water Resources 2009b, 2010d, 2010i) to identify and characterize the
 5 vertical (depth) and horizontal (spatial) variability in soil bearing capacity and extent of liquefiable soil.
 6 Engineering soil parameters that could be used to assess the liquefaction potential, such as SPT blow
 7 counts, CPT penetration tip pressure/resistance, and gradation of soil, would also be obtained. SPT
 8 blow counts and CPT tip pressure are used to estimate soil resistance to cyclic loadings by using
 9 empirical relationships that were developed based on occurrences of liquefaction (or lack of them)
 10 during past earthquakes (i.e., the earthquake that is expected to produce the strongest level of ground
 11 shaking at a site to which it is appropriate to design a structure to withstand). The resistance then can
 12 be compared to cyclic shear stress induced by the design earthquakes. If soil resistance is less than
 13 induced stress, the potential of having liquefaction during the design earthquakes is high. It is also
 14 known that soil with high “fines” (i.e., silt- and clay-sized particles) content are less susceptible to
 15 liquefaction.

16 **NEPA Effects:** The potential effect could be substantial because construction-related ground motions
 17 could initiate liquefaction, which could cause failure of structures during construction. During design,
 18 the facility-specific potential for liquefaction would be investigated by a geotechnical engineer. The
 19 potential effects of construction vibrations on nearby structures, levees, and utilities would
 20 be evaluated using specific piling information (such as pile type, length, spacing, and pile-driving
 21 hammer to be used). In areas determined to have a potential for liquefaction, the engineer would
 22 develop design measures and construction methods to ensure that pile driving and heavy equipment
 23 operations do not damage facilities under construction and surrounding structures and do not threaten
 24 the safety of workers at the site. As shown in Figure 9-6, a majority of Alternative 1C crosses through an
 25 area classified as medium to low liquefaction hazard. Alternative 1C also runs through Brannan Island
 26 and Twitchell Island, which have medium to medium-high levee liquefaction damage potential. A barge
 27 unloading facility is located at the northern end of Brannan Island in this medium to medium-high
 28 levee liquefaction damage potential area. Design strategies may include predrilling or jetting, using
 29 open-ended pipe piles to reduce the energy needed for pile penetration, using CIDH piles/piers that do
 30 not require driving, using pile jacking to press piles into the ground by means of a hydraulic system, or
 31 driving piles during the drier summer months. Field data collected during design also would be
 32 evaluated to determine the need for and extent of strengthening levees, embankments, and structures
 33 to reduce the effect of vibrations. These construction methods would conform with current seismic
 34 design codes and requirements, as described in Chapter 3, *Description of the Alternatives*. Such design
 35 standards include USACE’s *Engineering and Design—Stability Analysis of Concrete Structures and Soil*
 36 *Liquefaction during Earthquakes*, by the Earthquake Engineering Research Institute.

37 DWR has made the environmental commitment (see Appendix 3B, *Environmental Commitments*)
 38 recommended by the geotechnical engineer are included in the design of project facilities and
 39 construction specifications to minimize the potential for construction-induced liquefaction. DWR also
 40 has committed to ensure that these methods are followed during construction.

41 In particular, conformance with the following codes and standards would reduce the potential risk for
 42 increased likelihood of loss of property or personal injury from structural failure resulting from
 43 construction-related ground motions:

- 44 • USACE Engineering and Design - Design of Pile Foundations, EM 1110-2-2906, 1991

- 1 • USACE Engineering and Design, Earthquake Design and Evaluation for Civil Works Projects, ER 1110-
2 2-1806, 1995
- 3 • California Code of Regulations, Title 8, Sections 1509 and 3203, California Code of Regulations.

4 Generally, the applicable codes require that facilities be built so that if soil in the foundation or
5 surrounding area are subject to liquefaction, the removal or densification of the liquefiable material
6 should be considered, along with alternative foundation designs. Additionally, any modification to a
7 federal levee system would require USACE approval under 33 USC 408 (a 408 Permit) and would have
8 to pass quality assurance review by the Major Subordinate Command prior to being forwarded to
9 USACE headquarters for final approval by the Chief of Engineers.

10 The worker safety codes and standards specify protective measures that must be taken at construction
11 sites to minimize the risk of injury or death from structural or earth failure (e.g., utilizing personal
12 protective equipment, practicing crane and scaffold safety measures). The relevant codes and
13 standards represent performance standards that must be met by contractors and these measures are
14 subject to monitoring by state and local agencies. Cal-OSHA requirements for an IIPP and the terms of
15 the IIPP to protect worker safety are the principal measures that would be enforced at construction
16 sites.

17 Conformance to construction methods recommendations and other applicable specifications would
18 ensure that construction of Alternative 1C would not create an increased likelihood of loss of property,
19 personal injury or death of individuals due to construction-related ground motion and resulting
20 potential liquefaction in the work area. Therefore, the effect would not be adverse.

21 **CEQA Conclusion:** Construction-related ground motions could initiate liquefaction, which could cause
22 failure of structures during construction, which could result in injury of workers at the construction
23 sites. However, DWR has committed to conform with Cal-OSHA and other state code requirements and
24 conform to applicable design guidelines and standards, such as USACE design measures. Conformance
25 with these requirements and the application of accepted, proven construction engineering practices
26 would reduce any potential risk such that construction of Alternative 1C would not create an increased
27 likelihood of loss of property, personal injury or death of individuals from construction-related ground
28 motion and resulting potential liquefaction in the work area and the hazard would be controlled to a
29 level that would protect worker safety (see Appendix 3B, *Environmental Commitments*). The impact
30 would be less than significant. No mitigation is required.

31 **Impact GEO-6: Loss of Property, Personal Injury, or Death from Structural Failure Resulting** 32 **from Rupture of a Known Earthquake Fault during Operation of Water Conveyance Features**

33 According to the available AP Earthquake Fault Zone Maps, none of the Alternative 1C facilities would
34 cross or be within any known active fault zones. However, numerous AP fault zones have been mapped
35 west of the conveyance alignment (Figure 9-5). The closest AP fault zone would be the Greenville fault,
36 located approximately 8.1 miles west of the Alternative 1C conveyance facilities. The Midway fault is
37 also mapped approximately 3.4 miles west of the Alternative 1C conveyance facilities, near the cities of
38 Tracy and Livermore. Because none of the Alternative 1C constructed facilities would be within any of
39 the fault zones (which include the area approximately 200 to 500 feet on each side of the mapped
40 surface trace to account for potential branches of active faults) the potential that the facilities would be
41 directly subject to fault offsets is negligible.

42 In the Delta, active or potentially active blind thrust faults were identified in the seismic study. Segment
43 4 of the Alternative 1C conveyance alignment would cross the Southern Midland fault and continue

1 through the Montezuma Hills fault zone. Segment 5 and part of Segment 6 would also cross the
2 Montezuma Hills fault zone. The western part of the proposed Byron Tract Forebay adjacent to the
3 Clifton Court Forebay is underlain by the West Tracy fault and the southernmost segment of the
4 Southern Midland fault. Although these blind thrusts are not expected to rupture to the ground surface
5 under the forebays during earthquake events, they may produce ground or near-ground shear zones,
6 bulging, or both (California Department of Water Resources 2007a). Assuming that the West Tracy fault
7 is potentially active, it could cause surface deformation in the western part of the Clifton Court Forebay.
8 Because the western part of the Byron Tract Forebay is also underlain by the hanging wall of the fault,
9 this part of the forebay may also experience uplift and resultant surface deformation (Fugro
10 Consultants 2011). In the seismic study, the South Midland, Montezuma Hills, and West Tracy blind
11 thrusts were assigned 80%, 50%, and 90% probabilities of being active, respectively (California
12 Department of Water Resources 2007a).

13 The depth to the Montezuma Hills faults is unknown. The seismic study (California Department of
14 Water Resources 2007a) indicates that the West Tracy fault dies out as a discernible feature within
15 approximately 3,000 to 6,000 feet bgs (in the upper 1 to 2 second depth two-way time, estimated to be
16 approximately 3,000 to 6,000 feet using the general velocity function as published in the Association of
17 Petroleum Geologists Pacific Section newsletter [Tolmachoff 1993]). This same study indicates that the
18 tip of the Southern Midway fault is said to extend above the base of the Tertiary Markley Formation to
19 depths of about 1.5 km or 4,900 feet, and possibly shallower. The minimum fault depth has not been
20 determined.

21 It appears that the potential of having any shear zones, bulging, or both at the depths of the canal and
22 the proposed forebay at Clifton Court is low because the depth to the blind thrust faults is generally
23 deep.

24 **NEPA Effects:** The effect would not be adverse, because no active faults capable of surface rupture
25 extend into the Alternative 1C alignment. Additionally, although the West Tracy blind thrust occurs
26 beneath the Alternative 1C alignment, based on available information, it do not present a hazard of
27 surface rupture.

28 However, because there is limited information regarding the depths of these faults, seismic surveys
29 would be performed on the South Midland, Montezuma Hills, and West Tracy blind thrusts during the
30 design phase to determine the depths to the top of the faults. More broadly, design-level geotechnical
31 studies would be prepared by a geotechnical engineer licensed in the state of California during project
32 design. The studies would further assess site-specific conditions at and near all the project facility
33 locations, including seismic activity, soil liquefaction, and other potential geologic and soil-related
34 hazards. This information would be used to verify assumptions and conclusions included in the
35 EIR/EIS. The geotechnical engineer's recommended measures to address adverse conditions would
36 conform to applicable design codes, guidelines, and standards. Potential design strategies or conditions
37 could include avoidance (deliberately positioning structures and lifelines to avoid crossing identified
38 shear rupture zones), geotechnical engineering (using the inherent capability of unconsolidated
39 geomaterials to "locally absorb" and distribute distinct bedrock fault movements) and structural
40 engineering (engineering the facility to undergo some limited amount of ground deformation without
41 collapse or significant damage).

42 As described in Section 9.3.1, *Methods for Analysis*, such design codes, guidelines, and standards are
43 considered environmental commitments by DWR (see also Appendix 3B, *Environmental Commitments*).
44 For construction of the water conveyance facilities, the codes and standards would include the

1 California Building Code and resource agency and professional engineering specifications, such as the
 2 Division of Safety of Dams *Guidelines for Use of the Consequence Hazard Matrix and Selection of Ground*
 3 *Motion Parameters*, DWR's Division of Flood Management *FloodSAFE Urban Levee Design Criteria*, and
 4 USACE's *Engineering and Design—Earthquake Design and Evaluation for Civil Works Projects*. These
 5 codes and standards include minimum performance standards for structural design, given site-specific
 6 subsurface conditions.

7 DWR would ensure that the geotechnical design recommendations are included in the design of project
 8 facilities and construction specifications to minimize the potential effects from seismic events and the
 9 presence of adverse soil conditions. DWR would also ensure that the design specifications are properly
 10 executed during construction.

11 In particular, conformance with the following codes and standards would reduce the potential risk for
 12 increased likelihood of loss of property or personal injury from structural failure resulting from surface
 13 rupture resulting from a seismic event during operation:

- 14 • DWR Division of Engineering State Water Project – Seismic Loading Criteria Report, Sept 2012.
- 15 • USACE Engineering and Design – Time-History Dynamic Analysis of Concrete Hydraulic Structure, EM
 16 1110-2-6051, 2003.
- 17 • USACE Engineering and Design – Response Spectra and Seismic Analysis for Concrete Hydraulic
 18 Structures, EM 1110-2-6050, 1999.
- 19 • American Society of Civil Engineers Minimum Design Loads for Buildings and Other Structures,
 20 ASCE-7-05, 2005.
- 21 • California Code of Regulations, Title 8, Section 3203, California Code of Regulations.

22 Generally, the applicable codes require that facilities be built so that they incur minimal damage in the
 23 event of a foreseeable seismic event and that they remain functional following such an event and that
 24 the facility is able to perform without catastrophic failure in the event of a maximum design earthquake
 25 (the greatest earthquake reasonably expected to be generated by a specific source on the basis of
 26 seismological and geological evidence).

27 The worker safety codes and standards specify protective measures that must be taken at construction
 28 sites to minimize the risk of injury or death from structural or earth failure (e.g., utilizing personal
 29 protective equipment). The relevant codes and standards represent performance standards that must
 30 be met by contractors and these measures are subject to monitoring by state and local agencies. Cal-
 31 OSHA requirements for an IIPP and the terms of the IIPP to protect worker safety are the principal
 32 measures that would be enforced at construction sites.

33 Conformance to these and other applicable design specifications and standards would ensure that
 34 operation of Alternative 1C would not create an increased likelihood of loss of property, injury or death
 35 of individuals in the event of ground movement in the vicinity of the South Midland, Montezuma Hills,
 36 and West Tracy, blind thrusts would not jeopardize the integrity of the surface and subsurface facilities
 37 along the Alternative 1C conveyance alignment or the proposed forebay and associated facilities
 38 adjacent to the Clifton Court Forebay. Therefore, there would be no adverse effect.

39 **CEQA Conclusion:** There are no active faults capable of surface rupture that extend into the Alternative
 40 1C alignment. Although the Montezuma Hills, West Tracy and South Midland blind thrusts occur
 41 beneath the Alternative 1C alignment, based on available information, they do not present a hazard of
 42 surface rupture. Conformance to applicable design specifications and standards would ensure that

1 operation of Alternative 1C would not create an increased likelihood of loss of property, personal injury
2 or death of individuals in the event of ground movement in these areas and would not jeopardize the
3 integrity of the surface and subsurface facilities along the Alternative 1C conveyance alignment or the
4 proposed forebay and associated facilities adjacent to the Clifton Court Forebay. There would be no
5 impact. No mitigation is required.

6 **Impact GEO-7: Loss of Property, Personal Injury, or Death from Structural Failure Resulting**
7 **from Strong Seismic Shaking during Operation of Water Conveyance Features**

8 Earthquake events may occur on the local and regional seismic sources during operation of the
9 Alternative 1C water conveyance facilities. The ground shaking could damage the canals, pipelines,
10 tunnel, culvert siphons, intake facilities, pumping plants, and other facilities disrupting the water
11 supply through the conveyance system. In an extreme event of strong seismic shaking, uncontrolled
12 release of water from the damaged canal, pipelines, tunnel, culvert siphons, intake facilities, pumping
13 plants, and other facilities could cause flooding, disruption of water supplies to the south, and
14 inundation of structures. These effects are discussed more fully in Appendix 3E, *Potential Seismicity and*
15 *Climate Change Risks to SWP/CVP Water Supplies*.

16 The potential of earthquake ground shaking in the early long-term (2025) was estimated using the
17 results of the seismic study (California Department of Water Resources 2007a). Table 9-25 lists the
18 expected PGA and 1.0-S_a values in 2025 at selected facility locations for the early long-term. Earthquake
19 ground shaking for the OBE (144-year return period) and MDE (975-year return period) was estimated
20 for the stiff soil site, as predicted in the seismic study (California Department of Water Resources
21 2007a), and for the anticipated soil conditions at the facility locations. No seismic study results exist for
22 2025, so the ground shaking estimated for 2050 was used for the early long-term (2025).

23 Table 9-25 shows that the proposed facilities would be subject to moderate-to-high earthquake ground
24 shaking in the early long-term (2025). All facilities would be designed and constructed in accordance
25 with the requirements of the design measures described earlier in this chapter. Site-specific
26 geotechnical information would be used to further assess the effect of local soil on the OBE and MDE
27 ground shaking and to develop design criteria to minimize the potential of damage.

28 **NEPA Effects:** This potential effect could be substantial because strong ground shaking could damage
29 pipelines, tunnel, culvert siphons, intake facilities, pumping plants, and other facilities. The damage
30 could disrupt the water supply through the conveyance system. In an extreme event, an uncontrolled
31 release of water from the conveyance system could cause flooding and inundation of structures. Please
32 refer to Chapter 6, *Surface Water* and Appendix 3E, *Potential Seismicity and Climate Change Risks to*
33 *SWP/CVP Water Supplies*, for a detailed discussion of potential flood effects.

1 **Table 9-25. Expected Earthquake Ground Motions at Locations of Selected Major Facilities in the Early Long-Term**
 2 **(2025)—Alternative 1C**

Major Facilities	144-year Return Period Ground Motions (OBE)			
	PGA (g)		1.0-sec S_a (g)	
	Stiff Soil ^a	Local Soil ^b	Stiff Soil ^a	Local Soil ^b
Intake and Fish Screen Area ^c	0.14	0.15	0.19	0.30
Tunnel Location between Bradford Island and Webb Tract ^d	0.30	0.33	0.31	0.50
Clifton Court Forebay / Byron Tract Forebay	0.28	0.31	0.30	0.48
Major Facilities	975-year Return Period Ground Motions (MDE)			
	PGA (g)		1.0-sec S_a (g)	
	Stiff Soil ^a	Local Soil ^e	Stiff Soil ^a	Local Soil ^e
Intake and Fish Screen Area ^c	0.24	0.24	0.33	0.53
Tunnel Location between Bradford Island and Webb Tract ^d	0.50	0.50	0.60	0.96
Clifton Court Forebay / Byron Tract Forebay	0.50	0.50	0.61	0.98

g = gravity
 MDE = maximum design earthquake
 OBE = operating basis earthquake
 PGA = Peak Ground Acceleration
 S_a = second spectral acceleration
^a Stiff soil site, with a V_{s100ft} value of 1,000 ft/s.
^b Site-adjusted factors of 1.1 and 1.60 were applied to PGA and 1.0-sec S_a values, respectively.
^c The results of California Department of Water Resources 2007a for the Sacramento site were used.
^d The results of California Department of Water Resources 2007a for the Sherman Island were used.
^e Site-adjusted factors of 1.0 and 1.60 were applied to PGA and 1.0-sec S_a values, respectively.

3

4 Design-level geotechnical studies would be conducted by a licensed civil engineer who practices in
 5 geotechnical engineering. The studies would assess site-specific conditions at and near all the project
 6 facility locations and provide the basis for designing the conveyance features to withstand the peak
 7 ground acceleration caused by fault movement in the region. The California-registered civil engineer or
 8 California-certified engineering geologist's recommended measures to address this hazard would
 9 conform to applicable design codes, guidelines, and standards. As described in in the methodology
 10 section in this chapter and in Appendix 3B, *Environmental Commitments*, such design codes, guidelines,
 11 and standards include the California Building Code and resource agency and professional engineering
 12 specifications, such as the Division of Safety of Dams *Guidelines for Use of the Consequence Hazard*
 13 *Matrix and Selection of Ground Motion Parameters*, DWR's Division of Flood Management *FloodSAFE*
 14 *Urban Levee Design Criteria*, and USACE's *Engineering and Design—Earthquake Design and Evaluation*
 15 *for Civil Works Projects*. Conformance with these codes and standards are an environmental
 16 commitment by DWR to ensure that ground shaking risks are minimized as the water conveyance
 17 features are operated.

18 DWR would ensure that the geotechnical design recommendations are included in the design of project
 19 facilities and construction specifications to minimize the potential effects from seismic events and the
 20 presence of adverse soil conditions. DWR would also ensure that the design specifications are properly
 21 executed during construction. See Appendix 3B, *Environmental Commitments*.

1 In particular, conformance with the following codes and standards would reduce the potential risk for
 2 increased likelihood of loss of property or personal injury from structural failure resulting from strong
 3 seismic shaking of water conveyance features during operations:

- 4 • DWR Division of Engineering State Water Project – Seismic Loading Criteria Report, Sept 2012.
- 5 • USACE Engineering and Design – Time-History Dynamic Analysis of Concrete Hydraulic Structure, EM
 6 1110-2-6051, 2003
- 7 • USACE Engineering and Design – Response Spectra and Seismic Analysis for Concrete Hydraulic
 8 Structures, EM 1110-2-6050, 1999.
- 9 • American Society of Civil Engineers Minimum Design Loads for Buildings and Other Structures,
 10 ASCE-7-05, 2005.
- 11 • California Code of Regulations, Title 8, Section 3203, California Code of Regulations.

12 Generally, the applicable codes require that facilities be built so that they incur minimal damage in the
 13 event of a foreseeable seismic event and that they remain functional following such an event and that
 14 the facility is able to perform without catastrophic failure in the event of a maximum design earthquake
 15 (the greatest earthquake reasonably expected to be generated by a specific source on the basis of
 16 seismological and geological evidence).

17 Conformance with these standards and codes are an environmental commitment of the project (see
 18 Appendix 3B, *Environmental Commitments*). The worker safety codes and standards specify protective
 19 measures that must be taken at construction sites to minimize the risk of injury or death from
 20 structural or earth failure (e.g., utilizing personal protective equipment). The relevant codes and
 21 standards represent performance standards that must be met by contractors and these measures are
 22 subject to monitoring by state and local agencies. Cal-OSHA requirements for an IIPP and the terms of
 23 the IIPP to protect worker safety are the principal measures that would be enforced at project sites
 24 during operations.

25 Conformance to these and other applicable design specifications and standards would ensure that
 26 operation of Alternative 1C would not create an increased likelihood of loss of property, personal injury
 27 or death of individuals from structural shaking of surface and subsurface facilities along the Alternative
 28 1C conveyance alignment in the event of strong seismic shaking. Therefore, there would be no adverse
 29 effect.

30 **CEQA Conclusion:** Seismically induced strong ground shaking could damage the canals, pipelines,
 31 culvert siphons, intake facilities, pumping plants, and other facilities. The damage could disrupt the
 32 water supply through the conveyance system. In an extreme event, an uncontrolled release of water
 33 from the damaged conveyance system could cause flooding and inundation of structures. (Please refer
 34 to Chapter 6, *Surface Water*, for a detailed discussion of potential flood impacts.) However, through the
 35 final design process, measures to address this hazard would be required to conform to applicable
 36 design codes, guidelines, and standards. As described in Section 9.3.1, *Methods for Analysis*, and in
 37 Appendix 3B, *Environmental Commitments*, such design codes, guidelines, and standards include the
 38 California Building Code and resource agency and professional engineering specifications, such as the
 39 Division of Safety of Dams *Guidelines for Use of the Consequence Hazard Matrix and Selection of Ground
 40 Motion Parameters*, DWR's Division of Flood Management *FloodSAFE Urban Levee Design Criteria*, and
 41 USACE's *Engineering and Design—Earthquake Design and Evaluation for Civil Works Projects*.

42 Conformance with these codes and standards is an environmental commitment by DWR to ensure that
 43 ground shaking risks are minimized as the Alternative 1C water conveyance features are operated and

1 there would be no increased likelihood of loss of property, personal injury or death of individuals. The
 2 hazard would be controlled to a safe level. The impact would be less than significant. No mitigation is
 3 required.

4 **Impact GEO-8: Loss of Property, Personal Injury, or Death from Structural Failure Resulting**
 5 **from Seismic-Related Ground Failure (Including Liquefaction) during Operation of Water**
 6 **Conveyance Features**

7 Earthquake-induced ground shaking could cause liquefaction, resulting soil slumping or lateral
 8 spreading and subsequent damage to or breaching of water conveyance structures and facilities. The
 9 consequences of liquefaction are manifested in terms of compaction or settlement, loss of bearing
 10 capacity, lateral spreading (soil movement), increased lateral soil pressure, and buoyancy within zones
 11 of liquefaction. Failure of the canal, tunnel, culvert siphons, pipelines, levees, bridges, and other
 12 structures and facilities could result in loss and injury and disrupt SWP and CVP water supply
 13 deliveries. The potential for impacts from flooding as a result of levee or dam failure is also discussed in
 14 Chapter 6, *Surface Water*.

15 The native soils underlying the southern part of the Alternative 1C alignment consist primarily of
 16 alluvial fan and terrace deposits, including clay, silt, sand and gravels of variable density. The northern
 17 part of the alignment is more variable in composition, consisting of natural levee, basin, and Delta mud
 18 deposits. The central portion (Segment 4), through which the tunnel would be constructed, consists of
 19 natural levee, eolian sand, Delta mud, alluvial fans, and dredge spoils. The more recently-deposited,
 20 sandy materials would be more prone to liquefaction. Figure 9-6 shows that the Alternative 1C
 21 alignment has no substantial liquefaction damage potential in its northern part and low to medium-
 22 high damage potential in its central and southern parts.

23 **NEPA Effects:** The potential effect could be substantial because seismically induced ground shaking
 24 could cause liquefaction, which could damage pipelines, tunnel, culvert siphons, intake facilities,
 25 pumping plants, and other facilities. The damage could disrupt the water supply through the
 26 conveyance system. In an extreme event, an uncontrolled release of water from the damaged
 27 conveyance system could cause flooding and inundation of structures. Please refer to Chapter 6, *Surface*
 28 *Water* and Appendix 3E, *Potential Seismicity and Climate Change Risks to SWP/CVP Water Supplies*, for a
 29 detailed discussion of potential flood effects.

30 In the process of preparing final facility designs, site-specific geotechnical and groundwater
 31 investigations would be conducted to identify and characterize the vertical (depth) and horizontal
 32 (spatial) extents of liquefiable soil. Engineering soil parameters that could be used to further assess the
 33 liquefaction potential, such as SPT blow counts, CPT penetration tip pressure/resistance, and gradation
 34 of soil, would also be obtained. SPT blow counts and CPT tip pressure are used to estimate soil
 35 resistance to cyclic loadings by using empirical relationships that were developed based on
 36 occurrences of liquefaction (or lack of them) during past earthquakes. The resistance then can be
 37 compared to cyclic shear stress induced by the design earthquakes. If soil resistance is less than
 38 induced stress, the potential of having liquefaction during the design earthquakes is high. It is also
 39 known that soil with high "fines" (i.e., silt- and clay-sized particles) content are less susceptible to
 40 liquefaction.

41 During final design, site-specific potential for liquefaction would be investigated by a geotechnical
 42 engineer. In areas determined to have a potential for liquefaction, a California-registered civil engineer
 43 or California-certified engineering geologist would develop design measures and construction methods
 44 to meet design criteria established by building codes and construction standards to ensure that design

1 earthquake does not cause damage to or failure of the facility. Such measures and methods include
 2 removing and replacing potentially liquefiable soil, strengthening foundations (for example, and using
 3 post-tensioned slab, reinforced mats, and piles) to resist excessive total and differential settlements,
 4 using *in situ* ground improvement techniques (such as deep dynamic compaction, vibro-compaction,
 5 vibro-replacement, compaction grouting, and other similar methods). The results of the site-specific
 6 evaluation and California-registered civil engineer or California-certified engineering geologist's
 7 recommendations would be documented in a detailed geotechnical report prepared in accordance with
 8 state guidelines, in particular *Guidelines for Evaluating and Mitigating Seismic Hazards in California*
 9 (California Geological Survey 2008). As described in Section 9.3.1, *Methods for Analysis*, and in
 10 Appendix 3B, *Environmental Commitments*, such design codes, guidelines, and standards include
 11 USACE's *Engineering and Design—Earthquake Design and Evaluation for Civil Works Projects* and
 12 *Liquefaction during Earthquakes*, by the Earthquake Engineering Research Institute. Conformance with
 13 these design requirements is an environmental commitment by DWR to ensure that liquefaction risks
 14 are minimized as the water conveyance features are operated.

15 DWR would ensure that the geotechnical design recommendations are included in the design of project
 16 facilities and construction specifications to minimize the potential effects from liquefaction and
 17 associated hazard. DWR would also ensure that the design specifications are properly executed during
 18 construction.

19 In particular, conformance with the following codes and standards would reduce the potential risk for
 20 increased likelihood of loss of property or personal injury from structural failure resulting from strong
 21 seismic shaking of water conveyance features during operations:

- 22 ● DWR Division of Engineering State Water Project – Seismic Loading Criteria Report, Sept 2012.
- 23 ● USACE Engineering and Design – Time-History Dynamic Analysis of Concrete Hydraulic Structure, EM
 24 1110-2-6051, 2003
- 25 ● USACE Engineering and Design – Response Spectra and Seismic Analysis for Concrete Hydraulic
 26 Structures, EM 1110-2-6050, 1999.
- 27 ● American Society of Civil Engineers Minimum Design Loads for Buildings and Other Structures,
 28 ASCE-7-05, 2005.
- 29 ● USACE Engineering and Design - Design of Pile Foundations, EM 1110-2-2906, 1991
- 30 ● California Code of Regulations, Title 8, Section 3203, California Code of Regulations.

31 Generally, the applicable codes require that facilities be built so that if soil in the foundation or
 32 surrounding area are subject to liquefaction, the removal or densification of the liquefiable material
 33 should be considered, along with alternative foundation designs. Additionally, any modification to a
 34 federal levee system would require USACE approval under 33 USC 408 (a 408 Permit) and would have
 35 to pass quality assurance review by the Major Subordinate Command prior to being forwarded to
 36 USACE headquarters for final approval by the Chief of Engineers.

37 The worker safety codes and standards specify protective measures that must be taken at construction
 38 sites to minimize the risk of injury or death from structural or earth failure (e.g., utilizing personal
 39 protective equipment). The relevant codes and standards represent performance standards that must
 40 be met by contractors and these measures are subject to monitoring by state and local agencies. Cal-
 41 OSHA requirements for an IIPP and the terms of the IIPP to protect worker safety are the principal
 42 measures that would be enforced at project sites during operations.

1 Conformance to these and other applicable design specifications and standards would ensure that the
 2 hazard of liquefaction and associated ground movements would not create an increased likelihood of
 3 loss of property, personal injury or death of individuals from structural failure of surface and
 4 subsurface facilities resulting from seismic-related ground failure along the Alternative 1C conveyance
 5 alignment during operation of the water conveyance features. Therefore, the effect would not be
 6 adverse.

7 **CEQA Conclusion:** Seismically induced ground shaking could cause liquefaction, which could result in
 8 loss of property or personal injury. Liquefaction could damage pipelines, tunnel, culvert siphons, intake
 9 facilities, pumping plants, and other facilities, and thereby disrupt the water supply through the
 10 conveyance system. In an extreme event, flooding and inundation of structures could result from an
 11 uncontrolled release of water from the damaged conveyance system. (Please refer to Chapter 6, *Surface*
 12 *Water*, for a detailed discussion of potential flood impacts.) However, through the final design process,
 13 measures to address the liquefaction hazard would be required to conform to applicable design codes,
 14 guidelines, and standards. As described in Section 9.3.1, *Methods for Analysis*, and in Appendix 3B,
 15 *Environmental Commitments*, such design codes, guidelines, and standards include USACE's *Engineering*
 16 *and Design—Stability Analysis of Concrete Structures and Soil Liquefaction during Earthquakes*, by the
 17 Earthquake Engineering Research Institute. Conformance with these design standards is an
 18 environmental commitment by DWR to ensure that liquefaction risks are minimized as the Alternative
 19 1C water conveyance features are operated and there would be no increased likelihood of loss of
 20 property, personal injury or death of individuals. The hazard would be controlled to a safe level. The
 21 impact would be less than significant. No mitigation is required.

22 **Impact GEO-9: Loss of Property, Personal Injury, or Death from Landslides and Other Slope** 23 **Instability during Operation of Water Conveyance Features**

24 Alternative 1C would involve excavation that creates new cut-and-fill slopes and construction of new
 25 embankments and levees. As a result of ground shaking and high soil-water content during heavy
 26 rainfall, existing and new slopes that are not properly engineered and natural stream banks could fail
 27 and cause damage to facilities. Levees can fail for several reasons: 1) high velocities of water flow can
 28 result in high rates of erosion and erode and overtop a levee; 2) the higher velocities of water flow can
 29 also lead to higher rates of erosion along the inner parts of levees and lead to undercutting and
 30 clumping of the levee into the river. Heavy rainfall or seepage into the levee from the river can increase
 31 fluid pressure in the levee and lead to slumping on the outer parts of the levee. If the slumps grow to
 32 the top of the levee, large sections of the levee may slump onto the floodplain and lower the elevation of
 33 the top of the levee, leading to overtopping; 3) increasing levels of water in the river will cause the
 34 water table in the levee to rise which will increase fluid pressure and may result in seepage and
 35 eventually lead to internal erosion called piping. Piping will erode the material under the levee,
 36 undermining it and causing its collapse and failure.

37 With the exception of levee slopes and natural stream banks, the topography along the Alternative 1C
 38 conveyance alignment is nearly level to very gently sloping. The areas that may be susceptible to slope
 39 failure are along existing levee slopes and at intake, pumping plant, forebay, and certain access road
 40 locations. Outside these areas, the land is nearly level and consequently has a negligible potential for
 41 slope failure.

42 Based on review of topographic and a landslide map of Alameda County (Roberts et al. 1999), the
 43 conveyance facilities would not be constructed on, nor would it be adjacent to, slopes that are subject to
 44 mudflows/debris flows from natural slopes.

1 **NEPA Effects:** The effect would be adverse because levee slopes and stream banks may fail, either from
 2 high pore-water pressure caused by high rainfall and weak soil, or from seismic shaking. Structures
 3 constructed on these slopes could be damaged or fail entirely as a result of slope instability. As
 4 discussed in Impact SW-2 in Chapter 6, *Surface Water*, operation of the water conveyance features
 5 under Alternative 1C would not result in an increase in potential risk for flood management compared
 6 to existing conditions. Peak monthly flows under Alternative 1C in the locations considered were
 7 similar to or less than those that would occur under existing conditions. Since flows would not be
 8 substantially greater, the potential for increased rates of erosion or seepage are low. For additional
 9 discussion on the possible exposure of people or structures to a significant risk from flooding due to
 10 levee failure, please refer to Impact SW-6 in Chapter 6, *Surface Water*.

11 During project design, a geotechnical engineer would develop slope stability design criteria (such as
 12 minimum slope safety factors and allowable slope deformation and settlement) for the various
 13 anticipated loading conditions. The design criteria would be documented in a detailed geotechnical
 14 report prepared in accordance with the state guidelines, in particular, *Guidelines for Evaluating and
 15 Mitigating Seismic Hazards in California* (California Geological Survey 2008). As discussed in Chapter 3,
 16 *Description of the Alternatives*, the foundation soil beneath slopes, embankments, or levees could be
 17 improved to increase its strength and to reduce settlement and deformation. Foundation soil
 18 improvement could involve excavation and replacement with engineered fill; preloading; ground
 19 modifications using jet-grouting, compaction grouting, chemical grouting, shallow soil mixing, deep soil
 20 mixing, vibro-compaction, or vibro-replacement; or other methods. Engineered fill also would be used
 21 to construct new slopes, embankments, and levees. Surface and internal drainage systems would be
 22 installed as necessary to reduce erosion and piping (internal erosion) potential.

23 Site-specific geotechnical and hydrological information would be used, and the design would conform
 24 with the current standards and construction practices, as described in Section 9.3.1, *Methods for
 25 Analysis*, such as USACE's *Design and Construction of Levees* and USACE's *EM 1110-2-1902, Slope
 26 Stability*. The design requirements would be presented in a detailed geotechnical report. Conformance
 27 with these design requirements is an environmental commitment by DWR to ensure that slope stability
 28 hazards would be avoided as the water conveyance features are operated.

29 DWR would ensure that the geotechnical design recommendations are included in the design of cut and
 30 fill slopes, embankments, and levees to minimize the potential effects from slope failure. DWR would
 31 also ensure that the design specifications are properly executed during construction.

32 In particular, conformance with the following codes and standards would reduce the potential risk for
 33 increased likelihood of loss of property or personal injury from structural failure resulting from seismic
 34 shaking or from high-pore water pressure:

- 35 ● DWR Division of Engineering State Water Project – Seismic Loading Criteria Report, Sept 2012.
- 36 ● DWR Division of Flood Management FloodSAFE Urban Levee Design Criteria, May 2012.
- 37 ● USACE Slope Stability, EM 1110-2-1902, 2003.
- 38 ● California Code of Regulations, Title 8, Section 3203, California Code of Regulations.

39 Generally, the applicable codes require that facilities be built to certain factors of safety in order to
 40 ensure that facilities perform as designed for the life of the structure despite various soil parameters.

41 The worker safety codes and standards specify protective measures that must be taken at construction
 42 sites to minimize the risk of injury or death from structural or earth failure (e.g., utilizing personal

1 protective equipment). The relevant codes and standards represent performance standards that must
 2 be met by contractors and these measures are subject to monitoring by state and local agencies. Cal-
 3 OSHA requirements for an IIPP and the terms of the IIPP to protect worker safety are the principal
 4 measures that would be enforced at project sites during operations.

5 Conformance to the above and other applicable design specifications and standards would ensure that
 6 the hazard of slope instability would not create an increased likelihood of loss of property, personal
 7 injury or death of individuals along the Alternative 1C conveyance alignment during operation of the
 8 water conveyance features. Therefore, the effect would not be adverse.

9 **CEQA Conclusion:** Unstable levee slopes and natural stream banks may fail, either from high pore-
 10 water pressure caused by high rainfall and weak soil, or from seismic shaking. Structures constructed
 11 on these slopes could be damaged or fail entirely as a result of slope instability. However, through the
 12 final design process, measures to address this hazard would be required to conform to applicable
 13 design codes, guidelines, and standards. The measures would be described in a detailed geotechnical
 14 report prepared in accordance with the state guidelines, in particular, *Guidelines for Evaluating and*
 15 *Mitigating Seismic Hazards in California* (California Geological Survey 2008). As described in Section
 16 9.3.1, *Methods for Analysis*, and in Appendix 3B, *Environmental Commitments*, such design codes,
 17 guidelines, and standards include the California Building Code and resource agency and professional
 18 engineering specifications, such as USACE's *Engineering and Design—Earthquake Design and Evaluation*
 19 *for Civil Works Projects*. Conformance with these codes and standards is an environmental commitment
 20 by DWR to ensure cut and fill slopes and embankments will be stable as the Alternative 1C water
 21 conveyance features are operated and there would be no increased likelihood of loss of property,
 22 personal injury or death of individuals. The impact would be less than significant. No mitigation is
 23 required.

24 **Impact GEO-10: Loss of Property, Personal Injury, or Death from Seiche or Tsunami during** 25 **Operation of Water Conveyance Features**

26 Based on recorded tsunami wave heights at the Golden Gate (Contra Costa Transportation Agency
 27 2009) and in the interior of the San Francisco Bay and on tsunami inundation maps prepared by the
 28 California Department of Conservation (2009), the height of a tsunami wave reaching the Suisun Marsh
 29 and the Delta would be small because of the distance from the ocean and attenuating effect of the San
 30 Francisco Bay. Therefore, the potential hazard of loss of property or personal injury as a result of a
 31 tsunami on the water conveyance facilities is low.

32 Similarly, with the exception of the Clifton Court Forebay and the Byron Tract Forebay, the potential for
 33 a substantial seiche to take place in the Plan Area is considered low because seismic and water body
 34 geometry conditions for a seiche to occur near conveyance facilities are not favorable. Fugro
 35 Consultants, Inc. (2011) identified the potential for a seiche of an unspecified wave height to occur in
 36 the Clifton Court Forebay, caused by strong ground motions along the underlying West Tracy fault,
 37 assuming that this fault is potentially active. Since the fault also exists in the immediate vicinity of the
 38 Byron Tract Forebay, a seiche could also occur in the Byron Tract Forebay.

39 **NEPA Effects:** The effect of a tsunami generated in the Pacific Ocean would not be adverse because the
 40 distance from the ocean and attenuating effect of the San Francisco Bay would likely allow only a low
 41 (i.e., less than 2 feet) tsunami wave height to reach the Delta (Contra Costa Transportation Agency
 42 2009).

1 In most parts of the Plan Area, the effects of a seiche would not be adverse because the seismic hazard
 2 and the geometry of the water bodies (i.e., wide and shallow) near conveyance facilities are not
 3 favorable for a seiche to occur. However, assuming that the West Tracy fault is potentially active, a
 4 potential exists for a seiche to occur in the Clifton Court Forebay and the Byron Tract Forebay. The
 5 effect could be adverse because the waves generated by a seiche could overtop the Byron Tract
 6 Forebay and Clifton Court Forebay embankments, causing erosion of the embankments and subsequent
 7 flooding in the vicinity.

8 However, design-level geotechnical studies would be conducted by a licensed civil engineer who
 9 practices in geotechnical engineering. The studies would determine the peak ground acceleration
 10 caused by movement of the West Tracy fault and the maximum probable seiche wave that could be
 11 generated by the ground shaking. The engineer's recommended measures to address this hazard, as
 12 well as the hazard of a seiche overtopping the Clifton Court Forebay embankment and subsequent
 13 adverse effect on the Byron Tract Forebay embankment, would conform to applicable design codes,
 14 guidelines, and standards. As described in Section 9.3.1, *Methods for Analysis*, and in Appendix 3B,
 15 *Environmental Commitments*, such design codes, guidelines, and standards include the Division of
 16 Safety of Dams *Guidelines for Use of the Consequence Hazard Matrix and Selection of Ground Motion*
 17 *Parameters*, DWR's Division of Flood Management *FloodSAFE Urban Levee Design Criteria*, and USACE's
 18 *Engineering and Design—Earthquake Design and Evaluation for Civil Works Projects*. Conformance with
 19 these codes and standards is an environmental commitment by DWR to ensure that the adverse effects
 20 of a seiche are controlled to an acceptable level while the forebay facility is operated.

21 DWR would ensure that the geotechnical design recommendations are included in the design of project
 22 facilities and construction specifications to minimize the potential effects from seismic events and
 23 consequent seiche waves. DWR would also ensure that the design specifications are properly executed
 24 during construction.

25 In particular, conformance with the following codes and standards would reduce the potential risk for
 26 increased likelihood of loss of property or personal injury tsunami or seiche:

- 27 • U.S. Department of the Interior and USGS Climate Change and Water Resources Management: A
 28 Federal Perspective, Circular 1331.
- 29 • State of California Sea-Level Rise Task Force of the CO-CAT, Sea-Level Rise Interim Guidance
 30 Document, 2010.
- 31 • California Code of Regulations, Title 8, Section 3203, California Code of Regulations.

32 Generally, the applicable codes provide guidance on estimating the effects of climate change and sea
 33 level rise and associated effects when designing a project and ensuring that a project is able to respond
 34 to these effects.

35 The worker safety codes and standards specify protective measures that must be taken at construction
 36 sites to minimize the risk of injury or death from structural or earth failure (e.g., utilizing personal
 37 protective equipment). The relevant codes and standards represent performance standards that must
 38 be met by contractors and these measures are subject to monitoring by state and local agencies. Cal-
 39 OSHA requirements for an IIPP and the terms of the IIPP to protect worker safety are the principal
 40 measures that would be enforced at project sites during operations.

41 Conformance to these and other applicable design specifications and standards would ensure that the
 42 Byron Tract Forebay embankment would be designed and constructed to contain and withstand the
 43 anticipated maximum seiche wave height and would not create an increased likelihood of loss of

1 property, personal injury or death of individuals along the Alternative 1C conveyance alignment during
2 operation of the water conveyance features. Therefore, the effect would not be adverse.

3 **CEQA Conclusion:** Based on recorded tsunami wave heights at the Golden Gate (Contra Costa
4 Transportation Agency 2009) and in the interior of the San Francisco Bay and on tsunami inundation
5 maps prepared by the California Department of Conservation (2009), the height of a tsunami wave
6 reaching the Suisun Marsh and the Delta would be small because of the distance from the ocean and
7 attenuating effect of the San Francisco Bay. The impact would be less than significant. No mitigation is
8 required.

9 Similarly, the potential for a significant seiche to occur in most parts of the Plan Area is considered low
10 because the seismic hazard and the geometry of the water bodies (i.e., wide and shallow) near
11 conveyance facilities are not favorable for a seiche to occur. However, assuming that the West Tracy
12 fault is potentially active, a potential exists for a seiche to occur in the Clifton Court Forebay and the
13 Byron Tract Forebay (Fugro Consultants 2011). The impact would not be significant because the Byron
14 Tract Forebay embankment would be designed and constructed according to applicable design codes,
15 guidelines, and standards to contain and withstand the anticipated maximum seiche wave height and
16 potential seiche waver overtopping of the Clifton Court Forebay and Byron Tract Forebay
17 embankments as the Alternative 1C water conveyance features are operated and there would be no
18 increased likelihood of loss of property, personal injury or death of individuals. The impact would be
19 less than significant. No mitigation is required.

20 **Impact GEO-11: Ground Failure Caused by Increased Groundwater Surface Elevations from**
21 **Unlined Canal Seepage as a Result of Operating the Water Conveyance Facilities**

22 If an unlined canal (as opposed to a lined canal) was constructed, seepage from the sideslopes and
23 bottom of the canal could occur where the normal water level in the canal is higher than the water
24 surface elevation of the adjacent areas. The seepage could raise the water table on the landside of the
25 embankments through more permeable lenses of sand and/or gravel in the foundation soil. Increased
26 water table levels may increase the likelihood of ground settlement and earthquake-induced
27 liquefaction.

28 **NEPA Effects:** The effect would be adverse because seepage from an unlined canal could raise the water
29 table in the area adjacent to the canal and increase the hazard of liquefaction in the vicinity.

30 However, the amount of seepage from the canal is not expected to be substantial because the canal
31 foundation and surface materials, derived from local borrow areas, would be selected based on site-
32 specific geotechnical evaluations. An engineer would design the canal to prevent excessive loss of water
33 from seepage. Additionally, control of excessive seepage may be accomplished through the installation
34 of a slurry cutoff wall in the canal. A cutoff wall would be most effective in areas where the canal is
35 constructed in relatively permeable materials, such as layers of permeable sand and gravels. Additional
36 measures that could be implemented to offset the effects of seepage water include the following:

- 37 ● Use of a drainage ditch parallel to the canal to control seepage. Water in the drainage ditch would
38 then be pumped into the sloughs or back into the canal.
- 39 ● Installation of pressure-relief wells to collect subsurface water and direct it into the parallel
40 drainage ditch.

41 As indicated above and in Chapter 3, a geotechnical engineer would use site-specific geotechnical and
42 hydrological information to design the canal, and the design would conform with the current standards

1 and construction practices specified by USACE and DWR design standards. As described in Section
 2 9.3.1, *Methods for Analysis*, such design codes, guidelines, and standards are considered environmental
 3 commitments by DWR (see also Appendix 3B, *Environmental Commitments*). For construction of the
 4 canal and any required seepage control measures, the codes and standards would include the California
 5 Building Code and resource agency and professional engineering specifications, such as USACE's
 6 *Engineering and Design—Earthquake Design and Evaluation for Civil Works Projects*. These codes and
 7 standards include minimum performance standards for structural design, given site-specific subsurface
 8 conditions.

9 DWR would ensure that the geotechnical design recommendations are included in the canal design to
 10 minimize the potential excessive seepage. DWR would also ensure that the design specifications are
 11 properly executed during construction.

12 In particular, conformance with the following codes and standards would reduce the potential risk for
 13 increased likelihood of loss of property or personal injury as a result of ground failure resulting from
 14 unlined canal seepage:

- 15 • USACE Engineering and Design, Earthquake Design and Evaluation for Civil Works Projects, ER 1110-
 16 2-1806, 1995.
- 17 • USACE Engineering and Design - Settlement Analysis, EM 1110-1-1904, 1990.
- 18 • USACE Slope Stability, EM 1110-2-1902, 2003.
- 19 • DWR Division of Flood Management FloodSAFE Urban Levee Design Criteria, May 2012.
- 20 • California Code of Regulations, Title 8, Section 3203, California Code of Regulations.

21 Generally, the applicable codes require that facilities be built so that they are designed for a landside
 22 slope stability and seepage/underseepage factors of safety greater than 1.0 (i.e., stable) and would
 23 therefore be less impacted in the event of potential excessive seepage and resulting soil instability.

24 The worker safety codes and standards specify protective measures that must be taken at construction
 25 sites to minimize the risk of injury or death from structural or earth failure (e.g., utilizing personal
 26 protective equipment). The relevant codes and standards represent performance standards that must
 27 be met by contractors and these measures are subject to monitoring by state and local agencies. Cal-
 28 OSHA requirements for an IIPP and the terms of the IIPP to protect worker safety are the principal
 29 measures that would be enforced at project sites during operations.

30 Conformance to the applicable design specifications and standards would ensure that the hazard of
 31 seepage from the canal would not cause an excessive increase in the water surface elevation in areas
 32 adjoining the canal resulting in ground failure. Therefore, the effect would not be adverse.

33 **CEQA Conclusion:** Seepage from an unlined canal could raise the water table level along the canal,
 34 thereby increasing the hazard of liquefaction where the water table is not already close to the surface.
 35 The increased hazard of liquefaction could threaten the integrity of the canal in the event that
 36 liquefaction occurs. However, because DWR would conform with applicable design guidelines and
 37 standards, such as USACE design measures there would be no increased likelihood of loss of property,
 38 personal injury or death of individuals from ground failure caused by increased groundwater surface
 39 elevations. The impact would be less than significant. No mitigation is required.

1 **Impact GEO-12: Loss of Property, Personal Injury, or Death Resulting from Structural Failure**
 2 **Caused by Rupture of a Known Earthquake Fault at Restoration Opportunity Areas**

3 According to the available AP Earthquake Fault Zone Maps, only the Suisun Marsh ROA could be
 4 affected by rupture of an earthquake fault. The active Green Valley fault crosses the southwestern
 5 corner of the ROA. The active Cordelia fault extends approximately one mile into the northwestern
 6 corner of the ROA. Rupture of these faults could damage levees and berms constructed as part of the
 7 restoration, which could result in failure of the levees and flooding of otherwise protected areas.

8 Within the Delta, active or potentially active blind thrust faults were identified in the seismic study
 9 (California Department of Water Resources 2007a). The extreme southeastern corner of the Suisun
 10 Marsh ROA is underlain by the Montezuma Blind Thrust zone. Parts of the Cache Slough and Yolo
 11 Bypass ROAs are underlain by part of the North Midland blind thrust zone. The Cosumnes/ Mokelumne
 12 River and East Delta ROAs are underlain by the Thornton Arch zone. Although these blind thrusts are
 13 not expected to rupture to the ground surface during earthquake events, they may produce ground or
 14 near-ground shear zones, bulging, or both. In the seismic study (California Department of Water
 15 Resources 2007a), the Thornton Arch blind thrust was assigned a 20% probability of being active. The
 16 depth to the Thornton Arch blind fault is unknown. Based on limited geologic and seismic survey
 17 information, it appears that the potential of having any shear zones, bulging, or both at the depths of
 18 the habitat levees is low because the depth to the blind thrust faults is generally deep.

19 **NEPA Effects:** The effect of implementing the conservation measures in the ROAs could be substantial
 20 because rupture of the Cordelia and Green Valley faults could occur at the Suisun Marsh ROA and cause
 21 damage or failure of ROA facilities, including levees and berms. Damage to these features could result in
 22 their failure, causing flooding of otherwise protected areas.

23 Because there is limited information regarding the depths of the blind faults mentioned above, seismic
 24 surveys would be performed in the vicinity of the faults as part of final design. These surveys would be
 25 used to verify fault depths where levees and other features would be constructed. Collection of this
 26 depth information would be part of broader, design-level geotechnical studies prepared by a licensed
 27 engineer to support all aspects of site-specific project design. The studies would assess site-specific
 28 conditions at and near all the project facility locations, including the nature and engineering properties
 29 of all soil horizons and underlying geologic strata, and groundwater conditions. The engineer's
 30 information would be used to develop final engineering solutions to any hazardous condition,
 31 consistent with the code and standards requirements of federal, state and local oversight agencies. As
 32 described in Section 9.3.1, *Methods for Analysis*, and in Appendix 3B, *Environmental Commitments*, such
 33 design codes, guidelines, and standards include the California Building Code and resource agency and
 34 professional engineering specifications, such as the Division of Safety of Dams Guidelines for Use of the
 35 Consequence Hazard Matrix and Selection of Ground Motion Parameters, DWR's Division of Flood
 36 Management *FloodSAFE Urban Levee Design Criteria*, and USACE's *Engineering and Design—Earthquake*
 37 *Design and Evaluation for Civil Works Projects*. Conformance with these design standards is an
 38 environmental commitment by the BDCP proponents to ensure that risks from a fault rupture are
 39 minimized as conservation levees are constructed and maintained. The hazard would be controlled to a
 40 safe level by following the proper design standards. The BDCP proponents would ensure that the
 41 geotechnical design recommendations are included in the design of project facilities and construction
 42 specifications to minimize the potential effects from seismic events and the presence of adverse soil
 43 conditions. The BDCP proponents would also ensure that the design specifications are properly
 44 executed during implementation.

1 In particular, conformance with the following codes and standards would reduce the potential risk for
 2 increased likelihood of loss of property or personal injury from structural failure resulting from surface
 3 rupture resulting from a seismic event during operation:

- 4 • DWR Division of Engineering State Water Project – Seismic Loading Criteria Report, Sept 2012.
- 5 • DWR DSOD Guidelines for Use of the Consequence-Hazard Matrix and Selection of Ground Motion
 6 Parameters, 2002.
- 7 • USACE Engineering and Design, Earthquake Design and Evaluation for Civil Works Projects, ER 1110-
 8 2-1806, 1995.
- 9 • USACE Design and Construction of Levees, EM 1110-2-1913, 2000.
- 10 • USACE (Corps, CESP-K-ED-G), Geotechnical Levee Practice, SOP EDG-03, 2004.
- 11 • DWR Division of Flood Management FloodSAFE Urban Levee Design Criteria, May 2012.
- 12 • California Code of Regulations, Title 8, Sections 1509 and 3203, California Code of Regulations.

13 Generally, the applicable codes require that facilities be built so that they incur minimal damage in the
 14 event of a foreseeable seismic event and that they remain functional following such an event and that
 15 the facility is able to perform without catastrophic failure in the event of a maximum design earthquake
 16 (the greatest earthquake reasonably expected to be generated by a specific source on the basis of
 17 seismological and geological evidence).

18 The worker safety codes and standards specify protective measures that must be taken at construction
 19 sites to minimize the risk of injury or death from structural or earth failure (e.g., utilizing personal
 20 protective equipment, practicing crane and scaffold safety measures). The relevant codes and
 21 standards represent performance standards that must be met by contractors and these measures are
 22 subject to monitoring by state and local agencies. Cal-OSHA requirements for an IIPP and the terms of
 23 the IIPP to protect worker safety are the principal measures that would be enforced at construction
 24 sites.

25 Conformance to these and other applicable design specifications and standards would ensure that the
 26 hazard of ground movement in the vicinity of the blind thrusts underlying the ROAs would not
 27 jeopardize the integrity of the levees and other features constructed in the ROAs and would not create
 28 an increased likelihood of loss of property, personal injury or death of individuals in the ROAs. This
 29 effect would not be adverse.

30 **CEQA Conclusion:** Rupture of the Cordelia and Green Valley faults could occur at the Suisun Marsh ROA
 31 and damage ROA facilities, such as levees and berms. Damage to these features could result in their
 32 failure, causing flooding of otherwise protected areas. However, through the final design process for
 33 conservation measures in the ROAs, measures to address the fault rupture hazard would be required to
 34 conform to applicable design codes, guidelines, and standards. As described in Section 9.3.1, *Methods*
 35 *for Analysis*, and in Appendix 3B, *Environmental Commitments*, such design codes, guidelines, and
 36 standards include the Division of Safety of Dams Guidelines for Use of the Consequence Hazard Matrix
 37 and Selection of Ground Motion Parameters, DWR's Division of Flood Management *FloodSAFE Urban*
 38 *Levee Design Criteria*, and USACE's *Engineering and Design—Earthquake Design and Evaluation for Civil*
 39 *Works Projects*. Conformance with these design standards is an environmental commitment by the
 40 BDCP proponents to ensure that fault rupture risks are minimized as the conservation measures are
 41 implemented. The hazard would be controlled to a safe level and there would be no increased

1 likelihood of loss of property, personal injury or death of individuals in the ROAs. The impact would be
2 less than significant. No mitigation is required.

3 **Impact GEO-13: Loss of Property, Personal Injury, or Death from Structural Failure Resulting**
4 **from Strong Seismic Shaking at Restoration Opportunity Areas**

5 Earthquake events may occur on the local and regional seismic sources at or near the ROAs. Because of
6 its proximity to these faults, the Suisun Marsh ROA would be especially subject to ground shaking
7 caused by the Concord-Green Valley fault. The Cache Slough ROA would be subject to shaking from the
8 Northern Midland fault zone, which underlies the ROA. Although more distant from these sources, the
9 other ROAs would be subject to shaking from the San Andreas, Hayward-Rodgers Creek, Calaveras,
10 Concord-Green Valley, San Gregorio, Greenville, and Mt. Diablo Thrust faults and the more proximate
11 blind thrusts in the Delta.

12 Among all the ROAs, the Suisun Marsh ROA would be most subject to ground shaking because of its
13 proximity to active faults. The Suisun Marsh ROA is subject to a PGA of approximately 0.31 to 0.35 g for
14 200-year return interval, while the PGA for the other ROAs ranges from approximately 0.11 to 0.26 g.
15 The ground shaking could damage levees and other structures, and in an extreme event cause levees to
16 fail such that protected areas flood.

17 **NEPA Effects:** All temporary facilities would be designed and built to meet the safety and
18 collapse-prevention requirements for the above-anticipated seismic loads. Therefore, this effect is
19 considered not adverse. No additional mitigation measures are required. All facilities would be
20 designed and constructed in accordance with the requirements of the design measures described in
21 Chapter 3, *Description of the Alternatives*. Site-specific geotechnical information would be used to
22 further assess the effects of local soil on the OBE and MDE ground shaking and to develop design
23 criteria that minimize the potential of damage.

24 Design-level geotechnical studies would be prepared by a geotechnical engineer licensed in the state of
25 California during project design. The studies would assess site-specific conditions at and near all the
26 project facility locations and provide the basis for designing the levees and other features to withstand
27 the peak ground acceleration caused by fault movement in the region. The geotechnical engineer's
28 recommended measures to address this hazard would conform to applicable design codes, guidelines,
29 and standards. Potential design strategies or conditions could include avoidance (deliberately
30 positioning structures and lifelines to avoid crossing identified shear rupture zones), geotechnical
31 engineering (using the inherent capability of unconsolidated geomaterials to "locally absorb" and
32 distribute distinct bedrock fault movements) and structural engineering (engineering the facility to
33 undergo some limited amount of ground deformation without collapse or significant damage).

34 As described in Section 9.3.1, *Methods for Analysis*, and in Appendix 3B, *Environmental Commitments*,
35 such design codes, guidelines, and standards include the California Building Code and resource agency
36 and professional engineering specifications, such as the Division of Safety of Dams *Guidelines for Use of*
37 *the Consequence Hazard Matrix and Selection of Ground Motion Parameters*, DWR's Division of Flood
38 Management *FloodSAFE Urban Levee Design Criteria*, and USACE's *Engineering and Design—Earthquake*
39 *Design and Evaluation for Civil Works Projects*. Conformance with these design standards is an
40 environmental commitment by the BDCP proponents to ensure that strong seismic shaking risks are
41 minimized as the conservation measures are implemented.

42 The BDCP proponents would ensure that the geotechnical design recommendations are included in the
43 design of project features and construction specifications to minimize the potential effects from seismic

1 events and the presence of adverse soil conditions. The BDCP proponents would also ensure that the
2 design specifications are properly executed during implementation.

3 In particular, conformance with the following codes and standards would reduce the potential risk for
4 increased likelihood of loss of property or personal injury from structural failure resulting from surface
5 rupture resulting from a seismic event during operation:

- 6 • DWR Division of Engineering State Water Project – Seismic Loading Criteria Report, Sept 2012.
- 7 • DWR DSOD Guidelines for Use of the Consequence-Hazard Matrix and Selection of Ground Motion
8 Parameters, 2002.
- 9 • USACE Engineering and Design, Earthquake Design and Evaluation for Civil Works Projects, ER 1110-
10 2-1806, 1995.
- 11 • USACE Design and Construction of Levees, EM 1110-2-1913, 2000.
- 12 • USACE (Corps, CESP-K-ED-G), Geotechnical Levee Practice, SOP EDG-03, 2004.
- 13 • DWR Division of Flood Management FloodSAFE Urban Levee Design Criteria, May 2012.
- 14 • California Code of Regulations, Title 8, Sections 1509 and 3203, California Code of Regulations.

15 Generally, the applicable codes require that facilities be built so that they incur minimal damage in the
16 event of a foreseeable seismic event and that they remain functional following such an event and that
17 the facility is able to perform without catastrophic failure in the event of a maximum design earthquake
18 (the greatest earthquake reasonably expected to be generated by a specific source on the basis of
19 seismological and geological evidence).

20 The worker safety codes and standards specify protective measures that must be taken at construction
21 sites to minimize the risk of injury or death from structural or earth failure (e.g., utilizing personal
22 protective equipment, practicing crane and scaffold safety measures). The relevant codes and
23 standards represent performance standards that must be met by contractors and these measures are
24 subject to monitoring by state and local agencies. Cal-OSHA requirements for an IIPP and the terms of
25 the IIPP to protect worker safety are the principal measures that would be enforced at construction
26 sites.

27 Conformance to these and other applicable design specifications and standards would ensure that the
28 hazard of seismic shaking would not jeopardize the integrity of levees and other features at the ROAs
29 and would not create an increased likelihood of loss of property or personal injury in the ROAs. This
30 effect would not be adverse.

31 **CEQA Conclusion:** Ground shaking could damage levees, berms, and other structures, Among all the
32 ROAs, the Suisun Marsh ROA would be the most subject to ground shaking because of its proximity to
33 active faults. The Suisun Marsh ROA is subject to a PGA of approximately 0.31 to 0.35 g for 200-year
34 return interval, while the PGA for the other ROAs ranges from approximately 0.11 to 0.26 g. Damage to
35 these features could result in their failure, causing flooding of otherwise protected areas. However, as
36 described in Section 9.3.1, *Methods for Analysis*, and in Appendix 3B, *Environmental Commitments*,
37 design codes, guidelines, and standards, including the California Building Code and resource agency
38 and professional engineering specifications, such as DWR's Division of Flood Management *FloodSAFE*
39 *Urban Levee Design Criteria* and USACE's *Engineering and Design—Earthquake Design and Evaluation*
40 *for Civil Works Projects* would be used for final design of conservation features. Conformance with these
41 design standards is an environmental commitment by the BDCP proponents to ensure that strong

1 seismic shaking risks are minimized as the conservation measures are operated and there would be no
 2 increased likelihood of loss of property, personal injury or death of individuals in the ROAs. The impact
 3 would be less than significant. No mitigation is required.

4 **Impact GEO-14: Loss of Property, Personal Injury, or Death from Structural Failure Resulting**
 5 **from Seismic-Related Ground Failure (Including Liquefaction) Beneath Restoration Opportunity**
 6 **Areas**

7 New structural features are proposed at the ROAs, such as levees as part of CM4, setback levees as part
 8 of CM5 and CM6, and experimental ramps and fish ladders at the Fremont Weir as part of CM2.

9 Earthquake-induced ground shaking could cause liquefaction, resulting in damage to or failure of
 10 levees and other features constructed at the restoration areas. The consequences of liquefaction are
 11 manifested in terms of compaction or settlement, loss of bearing capacity, lateral spreading (soil
 12 movement), and increased lateral soil pressure. Failure of levees and other features could result in
 13 flooding of otherwise protected areas.

14 The ROAs vary with respect to their liquefaction hazard (Figure 9-6). The Suisun Marsh ROA generally
 15 has a moderate liquefaction hazard. The liquefaction damage potential among the other ROAs is
 16 generally low to medium.

17 **NEPA Effects:** This potential effect would be substantial because earthquake-induced liquefaction could
 18 damage ROA facilities, such as levees and berms. Damage to these features could result in their failure,
 19 causing flooding of otherwise protected areas.

20 During final design, of conservation facilities site-specific geotechnical and groundwater investigations
 21 would be conducted to identify and characterize the vertical (depth) and horizontal (spatial) extents of
 22 liquefiable soil. Engineering soil parameters that could be used to assess the liquefaction potential, such
 23 as SPT blow counts, CPT penetration tip pressure/resistance, and gradation of soil, would also be
 24 obtained. SPT blow counts and CPT tip pressure are used to estimate soil resistance to cyclic loadings
 25 by using empirical relationships that were developed based on occurrences of liquefaction (or lack of
 26 them) during past earthquakes. The resistance then can be compared to cyclic shear stress induced by
 27 the design earthquakes. If soil resistance is less than induced stress, the potential of having liquefaction
 28 during the design earthquakes is high. It is also known that soil with high “fines” (i.e., silt- and clay-
 29 sized particles) content is less susceptible to liquefaction.

30 During final design, the facility-specific potential for liquefaction would be investigated by a
 31 geotechnical engineer. In areas determined to have a potential for liquefaction, the engineer would
 32 develop design parameters and construction methods to meet the design criteria established to ensure
 33 that design earthquake does not cause damage to or failure of the facility. Such measures and methods
 34 include removing and replacing potentially liquefiable soil, strengthening foundations (for example,
 35 using post-tensioned slab, reinforced mats, and piles) to resist excessive total and differential
 36 settlements, using *in situ* ground improvement techniques (such as deep dynamic compaction, vibro-
 37 compaction, vibro-replacement, compaction grouting, and other similar methods), and conforming with
 38 current seismic design codes and requirements, as described in Section 9.3.1, *Methods for Analysis*, and
 39 in Appendix 3B, *Environmental Commitments*, such design codes, guidelines, and standards include
 40 USACE’s *Engineering and Design—Stability Analysis of Concrete Structures and Soil Liquefaction during*
 41 *Earthquakes*, by the Earthquake Engineering Research Institute. Conformance with these design
 42 standards is an environmental commitment by the BDCP proponents to ensure that liquefaction risks
 43 are minimized as the conservation measures are implemented. The hazard would be controlled to a
 44 safe level.

1 In particular, conformance with the following codes and standards would reduce the potential risk for
 2 increased likelihood of loss of property or personal injury from structural failure resulting from
 3 seismic-related ground failure:

- 4 • USACE Engineering and Design - Design of Pile Foundations, EM 1110-2-2906, 1991
- 5 • USACE Engineering and Design – Stability Analysis of Concrete Structures, EM 1110-2-2100, 2005
- 6 • USACE Engineering and Design, Earthquake Design and Evaluation for Civil Works Projects, ER 1110-
 7 2-1806, 1995
- 8 • California Code of Regulations, Title 8, Sections 1509 and 3203, California Code of Regulations.

9 Generally, the applicable codes require that facilities be built so that if soil in the foundation or
 10 surrounding area are subject to liquefaction, the removal or densification of the liquefiable material
 11 should be considered, along with alternative foundation designs.

12 The worker safety codes and standards specify protective measures that must be taken at construction
 13 sites to minimize the risk of injury or death from structural or earth failure (e.g., utilizing personal
 14 protective equipment, practicing crane and scaffold safety measures). The relevant codes and
 15 standards represent performance standards that must be met by contractors and these measures are
 16 subject to monitoring by state and local agencies. Cal-OSHA requirements for an IIPP and the terms of
 17 the IIPP to protect worker safety are the principal measures that would be enforced at construction
 18 sites.

19 The BDCP proponents would ensure that the geotechnical design recommendations are included in the
 20 design of levees and construction specifications to minimize the potential effects from liquefaction and
 21 associated hazard. The BDCP proponents would also ensure that the design specifications are properly
 22 executed during implementation and there would be no increased likelihood of loss of property,
 23 personal injury or death of individuals in the ROAs. This effect would not be adverse.

24 **CEQA Conclusion:** Earthquake-induced ground shaking could cause liquefaction, resulting in damage to
 25 or failure of levees, berms, and other features constructed at the restoration areas. Failure of levees and
 26 other structures could result in flooding of otherwise protected areas. However, through the final
 27 design process, measures to address the liquefaction hazard would be required to conform to
 28 applicable design codes, guidelines, and standards. As described in Section 9.3.1, *Methods for Analysis*,
 29 and in Appendix 3B, *Environmental Commitments*, such design codes, guidelines, and standards include
 30 USACE's *Engineering and Design—Stability Analysis of Concrete Structures and Soil Liquefaction during*
 31 *Earthquakes*, by the Earthquake Engineering Research Institute. Conformance with these design
 32 standards is an environmental commitment by the BDCP proponents to ensure that liquefaction risks
 33 are minimized as the water conservation features are implemented. The hazard would be controlled to
 34 a safe level and there would be no increased likelihood of loss of property, personal injury or death of
 35 individuals in the ROAs. The impact would be less than significant. No mitigation is required.

36 **Impact GEO-15: Loss of Property, Personal Injury, or Death from Landslides and Other Slope** 37 **Instability at Restoration Opportunity Areas**

38 Implementation of CM2–CM7, would involve breaching, modification or removal of existing levees and
 39 construction of new levees and embankments. CM4 which provides for the restoration of up to 65,000
 40 acres of tidal perennial aquatic, tidal mudflat, tidal freshwater emergent wetland, and tidal brackish
 41 emergent wetland natural communities within the ROAs involves the greatest amount of modifications
 42 to levees. Levee modifications, including levee breaching or lowering, may be performed to reintroduce

1 tidal exchange, reconnect remnant sloughs, restore natural remnant meandering tidal channels,
2 encourage development of dendritic channel networks, and improve floodwater conveyance.

3 Levee modifications could involve the removal of vegetation and excavation of levee materials. Excess
4 earthen materials could be temporarily stockpiled, then re-spread on the surface of the new levee
5 slopes where applicable or disposed of offsite. Any breaching or other modifications would be required
6 to be designed and implemented to maintain the integrity of the levee system and to conform with
7 flood management standards and permitting processes. This would be coordinated with the
8 appropriate flood management agencies. Those agencies may include USACE, DWR, CVFPB, and other
9 flood management agencies. For more detail on potential modifications to levees as a part of
10 conservation measures, please refer to Chapter 3, *Description of Alternatives*.

11 New and existing levee slopes and stream/channel banks could fail and damage facilities as a result of
12 seismic shaking and as a result of high soil-water content during heavy rainfall.

13 With the exception of levee slopes, natural stream banks, and part of the Suisun Marsh ROA, the
14 topography of ROAs is nearly level to gently sloping. The areas that may be susceptible to slope failure
15 are along existing Sacramento and San Joaquin River and Delta island levees and stream/channel
16 banks, particularly those levees that consist of non-engineered fill and those streambanks that are
17 steep and consist of low strength soil.

18 The structures associated with conservation measures would not be constructed in, nor would they be
19 adjacent to, areas that are subject to mudflows/debris flows from natural slopes.

20 **NEPA Effects:** The potential effect could be substantial because levee slopes and embankments may fail,
21 either from high pore-water pressure caused by high rainfall and weak soil, or from seismic shaking.
22 Failure of these features could result in flooding of otherwise protected areas.

23 As outlined in Chapter 3, *Description of Alternatives*, erosion protection measures and protection
24 against related failure of adjacent levees would be taken where levee breaches were developed.
25 Erosion protection could include geotextile fabrics, rock revetments, riprap, or other material selected
26 during future evaluations for each location. Aggregate rock could be placed on the remaining levees to
27 provide an access road to the breach location. Erosion protection measures would also be taken where
28 levee lowering is done for the purposes of allowing seasonal or periodic inundation of lands during
29 high flows or high tides to improve habitat or to reduce velocities and elevations of floodwaters. To
30 reduce erosion potential on the new levee crest, a paved or gravel access road could be constructed
31 with short (approximately 1 foot) retaining walls on each edge of the crest to reduce undercutting of
32 the roadway by high tides. Levee modifications could also include excavation of watersides of the
33 slopes to allow placement of slope protection, such as riprap or geotextile fabric, and to modify slopes
34 to provide levee stability. Erosion and scour protection could be placed on the landside of the levee and
35 continued for several feet onto the land area away from the levee toe. Neighboring levees could require
36 modification to accommodate increased flows or to reduce effects of changes in water elevation or
37 velocities along channels following inundation of tidal marshes. Hydraulic modeling would be used
38 during subsequent analyses to determine the need for such measures.

39 New levees would be constructed to separate lands to be inundated for tidal marsh from non-
40 inundated lands, including lands with substantial subsidence. Levees could be constructed as described
41 for the new levees at intake locations. Any new levees would be required to be designed and
42 implemented to conform with applicable flood management standards and permitting processes. This

1 would be coordinated with the appropriate flood management agencies, which may include USACE,
2 DWR, CVFPB, and local flood management agencies.

3 Additionally, during project design, a geotechnical engineer would develop slope stability design
4 criteria (such as minimum slope safety factors and allowable slope deformation and settlement) for the
5 various anticipated loading conditions. During project design, a geotechnical engineer would develop
6 slope stability design criteria (such as minimum slope safety factors and allowable slope deformation
7 and settlement) for the various anticipated loading conditions. As required by design standards and
8 building codes (see Appendix 3B, *Environmental Commitments*), foundation soil beneath embankments
9 and levees could be improved to increase its strength and to reduce settlement and deformation.
10 Foundation soil improvement could involve excavation and replacement with engineered fill;
11 preloading; ground modifications using jet-grouting, compaction grouting, chemical grouting, shallow
12 soil mixing, deep soil mixing, vibro-compaction, or vibro-replacement; or other methods. Engineered
13 fill could also be used to construct new embankments and levees.

14 Site-specific geotechnical and hydrological information would be used, and the design would conform
15 with the current standards and construction practices, as described in Chapter 3, such as USACE's—
16 *Design and Construction of Levees* and USACE's—*EM 1110-2-1902, Slope Stability*.

17 The BDCP proponents would ensure that the geotechnical design recommendations are included in the
18 design of embankments and levees to minimize the potential effects from slope failure. The BDCP
19 proponents would also ensure that the design specifications are properly executed during
20 implementation.

21 In particular, conformance with the following codes and standards would reduce the potential risk for
22 increased likelihood of loss of property or personal injury from structural failure resulting from
23 landslides or other slope instability:

- 24 • DWR Division of Engineering State Water Project – Seismic Loading Criteria Report, Sept 2012.
- 25 • DWR Division of Flood Management FloodSAFE Urban Levee Design Criteria, May 2012.
- 26 • USACE Slope Stability, EM 1110-2-1902, 2003.
- 27 • California Code of Regulations, Title 8, Section 3203, California Code of Regulations.

28 Generally, the applicable codes require that facilities be built to certain factors of safety in order to
29 ensure that facilities perform as designed for the life of the structure despite various soil parameters.

30 The worker safety codes and standards specify protective measures that must be taken at construction
31 sites to minimize the risk of injury or death from structural or earth failure (e.g., utilizing personal
32 protective equipment). The relevant codes and standards represent performance standards that must
33 be met by contractors and these measures are subject to monitoring by state and local agencies. Cal-
34 OSHA requirements for an IIPP and the terms of the IIPP to protect worker safety are the principal
35 measures that would be enforced at project sites during operations.

36 Conformance to the above and other applicable design specifications and standards would ensure that
37 the hazard of slope instability would not jeopardize the integrity of levee and other features at the
38 ROAs and would not create an increased likelihood of loss of property, personal injury or death of
39 individuals in the ROAs. This effect would not be adverse.

40 **CEQA Conclusion:** Unstable new and existing levee and embankment slopes could fail as a result of
41 seismic shaking and as a result of high soil-water content during heavy rainfall and cause flooding of

1 otherwise protected areas. However, because the BDCP proponents would conform with applicable
 2 design guidelines and standards, such as USACE design measures, the hazard would be controlled to a
 3 safe level and there would be no an increased likelihood of loss of property, personal injury or death of
 4 individuals in the ROAs. The impact would be less than significant. No mitigation is required.

5 **Impact GEO-16: Loss of Property, Personal Injury, or Death from Seiche or Tsunami at**
 6 **Restoration Opportunity Areas as a Result of Implementing the Conservation Actions**

7 *NEPA Effects:* The distance from the ocean and attenuating effect of the San Francisco Bay would likely
 8 allow only a low tsunami wave height to reach the Suisun Marsh and the Delta. Conditions for a seiche
 9 to occur at the ROAs are not favorable. Therefore, the effect would not be adverse.

10 *CEQA Conclusion:* Based on recorded tsunami wave heights at the Golden Gate, the height of a tsunami
 11 wave reaching the ROAs would be small because of the distance from the ocean and attenuating effect
 12 of the San Francisco Bay. Similarly, the potential for a significant seiche to occur in the Plan Area that
 13 would cause loss of property, personal injury, or death at the ROAs is considered low because
 14 conditions for a seiche to occur at the ROAs are not favorable. The impact would be less than
 15 significant. No mitigation is required.

16 **9.3.3.5 Alternative 2A—Dual Conveyance with Pipeline/Tunnel and Five**
 17 **Intakes (15,000 cfs; Operational Scenario B)**

18 **Impact GEO-1: Loss of Property, Personal Injury, or Death from Structural Failure Resulting**
 19 **from Strong Seismic Shaking of Water Conveyance Features during Construction**

20 *NEPA Effects:* Alternative 2A would include the same physical/structural components as Alternative
 21 1A, but could entail two different intake and intake pumping plant locations. These locations would be
 22 where the intakes have a similar hazard of ground shaking and would not substantially change the
 23 hazard of loss of property, personal injury, or death during construction. The effects of Alternative 2A
 24 would, therefore, be the same as 1A. See the discussion of Impact GEO-1 under Alternative 1A. There
 25 would be no adverse effect.

26 *CEQA Conclusion:* Seismically induced ground shaking could cause collapse or other failure of project
 27 facilities while under construction. However, DWR would conform with Cal-OSHA and other state code
 28 requirements, such as shoring, bracing, lighting, excavation depth restrictions, required slope angles,
 29 and other measures, to protect worker safety and there would be no increased likelihood of loss of
 30 property, personal injury or death due to construction of Alternative 2A. The impact would be less than
 31 significant. No additional mitigation is required.

32 **Impact GEO-2: Loss of Property, Personal Injury, or Death from Settlement or Collapse Caused**
 33 **by Dewatering during Construction of Water Conveyance Features**

34 Alternative 2A would include the same physical/structural components as Alternative 1A, but could
 35 entail two different intake and intake pumping plant locations. If Intakes 6 and 7, north of Vorden, are
 36 chosen, settlement of excavations could occur as a result of dewatering at Alternative 2A construction
 37 sites with shallow groundwater. Soil excavation in areas with shallow or perched groundwater levels
 38 would require the pumping of groundwater from excavations to allow for construction of facilities. This
 39 can be anticipated at all intake locations and pumping plant sites adjacent to the Sacramento River.
 40 Similar dewatering may be necessary where intake and forebay pipelines cross waterways and major
 41 irrigation canals east of the Sacramento River and north of the proposed intermediate forebay. The

1 conveyance pipeline built between Intake 7 and the intermediate forebay would cross six canals or
2 ditches prior to joining with the conveyance pipeline for Intake 6. All of these crossings occur north of
3 the facility grounds for Intake 7 and range in their distance from the intake site from 0.3 miles to one
4 mile. The combined conveyance pipeline for Intakes 6 and 7 leading to the intermediate forebay would
5 cross four canals or ditches. The northern two crossings would be 0.3 to 0.4 miles west of Lambert
6 Road and the southern two would be 0.5 miles west and northwest (respectively) of Russell Road. This
7 pipeline would also cross the Reclamation District 551 borrow canal.

8 **NEPA Effects:** These changes in locations would result in a similar hazard of settlement or collapse and
9 would not substantially change the hazard of loss of property, personal injury, or death during
10 construction. The effects of Alternative 2A would, therefore, be the same as 1A. See the description and
11 findings under Alternative 1A. There would be no adverse effect.

12 **CEQA Conclusion:** Settlement or failure of excavations during construction could result in loss of
13 property or personal injury. However, DWR would conform with Cal-OSHA and other state code
14 requirements, such as using seepage cutoff walls, shoring, and other measures, to protect worker
15 safety. DWR has made an environmental commitment to use the appropriate code and standard
16 requirements to minimize potential risks (Appendix 3B, *Environmental Commitments*) and there would
17 be no increased likelihood of loss of property, personal injury or death due to construction of
18 Alternative 2A. The impact would be less than significant. No mitigation is required.

19 **Impact GEO-3: Loss of Property, Personal Injury, or Death from Ground Settlement during** 20 **Construction of Water Conveyance Features**

21 **NEPA Effects:** Alternative 2A would include the same physical/structural components as Alternative
22 1A, but could entail two different intake and intake pumping plant locations. These changes in locations
23 would have no bearing on the hazard of ground settlement of tunnels and would not change the hazard
24 of loss of property, personal injury, or death during construction. The effects of Alternative 2A would,
25 therefore, be the same as 1A. See the description and findings under Alternative 1A. There would be no
26 adverse effect.

27 **CEQA Conclusion:** Ground settlement above the tunneling operation could result in loss of property or
28 personal injury during construction. However, DWR would conform with Cal-OSHA, USACE, and other
29 design requirements to protect worker safety. DWR would also ensure that the design specifications
30 are properly executed during construction. DWR has made an environmental commitment to use the
31 appropriate code and standard requirements to minimize potential risks (Appendix 3B, *Environmental*
32 *Commitments*). Hazards to workers and project structures would be controlled at safe levels and there
33 would be no increased likelihood of loss of property, personal injury or death due to construction of
34 Alternative 2A. The impact would be less than significant. No mitigation is required.

35 **Impact GEO-4: Loss of Property, Personal Injury, or Death from Slope Failure during** 36 **Construction of Water Conveyance Features**

37 **NEPA Effects:** Alternative 2A would include the same physical/structural components as Alternative
38 1A, but could entail two different intake and intake pumping plant locations. These changes in locations
39 would have no bearing on the hazard of slope failure at borrow and storage sites and would not change
40 the hazard of loss of property, personal injury, or death during construction. The effects of Alternative
41 2A would, therefore, be the same as 1A. See the description and findings under Alternative 1A. There
42 would be no adverse effect.

1 **CEQA Conclusion:** Settlement/failure of cutslopes of borrow sites and failure of soil/RTM fill slopes
 2 could result in loss of property or personal injury during construction. However, because DWR would
 3 conform with Cal-OSHA and other state code requirements and conform to applicable geotechnical
 4 design guidelines and standards, such as USACE design measures, the hazard would be controlled to a
 5 safe level and there would be no increased likelihood of loss of property, personal injury or death due
 6 to construction of Alternative 2A. The impact would be less than significant. No mitigation is required.

7 **Impact GEO-5: Loss of Property, Personal Injury, or Death from Structural Failure Resulting**
 8 **from Construction-Related Ground Motions during Construction of Water Conveyance Features**

9 **NEPA Effects:** Alternative 2A would include the same physical/structural components as Alternative
 10 1A, but could entail two different intake and intake pumping plant locations. These changes in locations
 11 would have no bearing on the hazard of structural failure from construction-related ground motions
 12 and would not change the hazard of loss of property, personal injury, or death during operation of the
 13 water conveyance features. The effects of Alternative 2A would, therefore, be the same as 1A. See the
 14 description and findings under Alternative 1A. There would be no adverse effect.

15 **CEQA Conclusion:** Construction-related ground motions could initiate liquefaction, which could cause
 16 failure of structures during construction. However, because DWR would conform with Cal-OSHA and
 17 other state code requirements and conform to applicable design guidelines and standards, such as
 18 USACE design measures, the hazard would be controlled to a level that would protect worker safety
 19 (see Appendix 3B, *Environmental Commitments*) and there would be no increased likelihood of loss of
 20 property, personal injury or death due to construction of Alternative 2A. The impact would be less than
 21 significant. No mitigation is required.

22 **Impact GEO-6: Loss of Property, Personal Injury, or Death from Structural Failure Resulting**
 23 **from Rupture of a Known Earthquake Fault during Operation of Water Conveyance Features**

24 **NEPA Effects:** Alternative 2A would include the same physical/structural components as Alternative
 25 1A, but could entail two different intake and intake pumping plant locations. These changes in locations
 26 would have no bearing on the hazard of fault rupture and would not change the hazard of loss of
 27 property, personal injury, or death during operation of the water conveyance features. The effects of
 28 Alternative 2A would, therefore, be the same as 1A. See the description and findings under Alternative
 29 1A. There would be no adverse effect.

30 **CEQA Conclusion:** There are no active faults capable of surface rupture that extend into the Alternative
 31 2A alignment. Although the Thornton Arch and West Tracy blind thrusts occur beneath the Alternative
 32 2A alignment, based on available information, they do not present a hazard of surface rupture and
 33 there would be no increased likelihood of loss of property, personal injury or death due to operation of
 34 Alternative 2A. There would be no impact. No mitigation is required.

35 **Impact GEO-7: Loss of Property, Personal Injury, or Death from Structural Failure Resulting**
 36 **from Strong Seismic Shaking during Operation of Water Conveyance Features**

37 **NEPA Effects:** Alternative 2A would include the same physical/structural components as Alternative
 38 1A, but could entail two different intake and intake pumping plant locations. These changes in locations
 39 would have no bearing on the hazard of structural failure from seismic shaking and would not change
 40 the hazard of loss of property, personal injury, or death during operation of the water conveyance
 41 features. The effects of Alternative 2A would, therefore, be the same as 1A. See the description and
 42 findings under Alternative 1A. There would be no adverse effect.

1 **CEQA Conclusion:** Seismically induced strong ground shaking could damage pipelines, tunnels, intake
 2 facilities, pumping plants, and other facilities. The damage could disrupt the water supply through the
 3 conveyance system. In an extreme event, an uncontrolled release of water from the damaged
 4 conveyance system could cause flooding and inundation of structures. (Please refer to Chapter 6,
 5 *Surface Water*, for a detailed discussion of potential flood impacts.) However, through the final design
 6 process, measures to address this hazard would be required to conform to applicable design codes,
 7 guidelines, and standards. As described in Section 9.3.1, *Methods for Analysis*, and in Appendix 3B,
 8 *Environmental Commitments*, such design codes, guidelines, and standards include the California
 9 Building Code and resource agency and professional engineering specifications, such as the Division of
 10 Safety of Dams *Guidelines for Use of the Consequence Hazard Matrix and Selection of Ground Motion*
 11 *Parameters*, DWR's Division of Flood Management *FloodSAFE Urban Levee Design Criteria*, and USACE's
 12 *Engineering and Design—Earthquake Design and Evaluation for Civil Works Projects*. Conformance with
 13 these codes and standards is an environmental commitment by DWR to ensure that ground shaking
 14 risks are minimized as the water conveyance features are operated. The hazard would be controlled to
 15 a safe level and there would be no increased likelihood of loss of property, personal injury or death due
 16 to operation of Alternative 2A. The impact would be less than significant. No mitigation is required.

17 **Impact GEO-8: Loss of Property, Personal Injury, or Death from Structural Failure Resulting**
 18 **from Seismic-Related Ground Failure (Including Liquefaction) during Operation of Water**
 19 **Conveyance Features**

20 **NEPA Effects:** Alternative 2A would include the same physical/structural components as Alternative
 21 1A, but could entail two different intake and intake pumping plant locations. These changes in locations
 22 would have no bearing on the hazard of structural failure from ground failure and would not change
 23 the hazard of loss of property, personal injury, or death during operation of the water conveyance
 24 features. The effects of Alternative 2A would, therefore, be the same as 1A. See the description and
 25 findings under Alternative 1A. There would be no adverse effect.

26 **CEQA Conclusion:** Seismically induced ground shaking could cause liquefaction. Liquefaction could
 27 damage pipelines, tunnels, intake facilities, pumping plants, and other facilities, and thereby disrupt the
 28 water supply through the conveyance system. In an extreme event, an uncontrolled release of water
 29 from the damaged conveyance system could cause flooding and inundation of structures. (Please refer
 30 to Chapter 6, *Surface Water*, for a detailed discussion of potential flood impacts.) However, through the
 31 final design process, measures to address the liquefaction hazard would be required to conform to
 32 applicable design codes, guidelines, and standards. As described in Section 9.3.1, *Methods for Analysis*,
 33 and in Appendix 3B, *Environmental Commitments*, such design codes, guidelines, and standards include
 34 USACE's *Engineering and Design—Stability Analysis of Concrete Structures and Soil Liquefaction during*
 35 *Earthquakes*, by the Earthquake Engineering Research Institute. Conformance with these design
 36 standards is an environmental commitment by DWR to ensure that liquefaction risks are minimized as
 37 the water conveyance features are operated. The hazard would be controlled to a safe level and there
 38 would be no increased likelihood of loss of property, personal injury or death due to operation of
 39 Alternative 2A. The impact would be less than significant. No mitigation is required.

40 **Impact GEO-9: Loss of Property, Personal Injury, or Death from Landslides and Other Slope**
 41 **Instability during Operation of Water Conveyance Features**

42 **NEPA Effects:** Alternative 2A would include the same physical/structural components as Alternative
 43 1A, but could entail two different intake and intake pumping plant locations. These changes in locations
 44 would have no bearing on the hazard of landslides and other slope instability and would not change the

1 hazard of loss of property, personal injury, or death during operation of the water conveyance features.
 2 The effects of Alternative 2A would, therefore, be the same as 1A. See the description and findings
 3 under Alternative 1A. There would be no adverse effect.

4 **CEQA Conclusion:** Unstable levee slopes and natural stream banks may fail, either from high pore-
 5 water pressure caused by high rainfall and weak soil, or from seismic shaking. Structures constructed
 6 on these slopes could be damaged or fail entirely as a result of slope instability. However, through the
 7 final design process, measures to address this hazard would be required to conform to applicable
 8 design codes, guidelines, and standards. As described in Section 9.3.1, *Methods for Analysis*, and in
 9 Appendix 3B, *Environmental Commitments*, such design codes, guidelines, and standards include the
 10 California Building Code and resource agency and professional engineering specifications, such as
 11 USACE's *Engineering and Design—Earthquake Design and Evaluation for Civil Works Projects*.
 12 Conformance with these codes and standards is an environmental commitment by DWR to ensure cut
 13 and fill slopes and embankments will be stable as the water conveyance features are operated and
 14 there would be no increased likelihood of loss of property, personal injury or death due to operation of
 15 Alternative 2A. The impact would be less than significant. No mitigation is required.

16 **Impact GEO-10: Loss of Property, Personal Injury, or Death from Seiche or Tsunami during**
 17 **Operation of Water Conveyance Features**

18 **NEPA Effects:** Alternative 2A would include the same physical/structural components as Alternative
 19 1A, but could entail two different intake and intake pumping plant locations. These changes in locations
 20 would have no bearing on the hazard of seiche or tsunami and would not change the hazard of loss of
 21 property, personal injury, or death during operation of the water conveyance features. The effects of
 22 Alternative 2A would, therefore, be the same as 1A. See the description and findings under Alternative
 23 1A. There would be no adverse effect.

24 **CEQA Conclusion:** Based on recorded tsunami wave heights at the Golden Gate (Contra Costa
 25 Transportation Agency 2009) and in the interior of the San Francisco Bay and on tsunami inundation
 26 maps prepared by the California Department of Conservation (2009), the height of a tsunami wave
 27 reaching the Suisun Marsh and the Delta would be small because of the distance from the ocean and
 28 attenuating effect of the San Francisco Bay. Similarly, the potential for a significant seiche to occur in
 29 most parts of the Plan Area is considered low because the seismic hazard and the geometry of the
 30 water bodies (i.e., wide and shallow) near conveyance facilities are not favorable for a seiche to occur.
 31 However, assuming the West Tracy fault is potentially active, a potential exists for a seiche to occur in
 32 the Clifton Court Forebay and the Byron Tract Forebay (Fugro Consultants 2011). The impact would
 33 not be significant because the Byron Tract Forebay embankment would be designed and constructed
 34 according to applicable design codes, guidelines, and standards to contain and withstand the
 35 anticipated maximum seiche wave height. There would be no increased likelihood of loss of property,
 36 personal injury or death from seiche or tsunami due to operation of Alternative 2A. The impact would
 37 be less than significant. No mitigation is required.

38 **Impact GEO-11: Ground Failure Caused by Increased Groundwater Surface Elevations from**
 39 **Unlined Canal Seepage as a Result of Operating the Water Conveyance Facilities**

40 **NEPA Effects:** Alternative 2A would not involve construction of unlined canals; therefore, there would
 41 be no increase in groundwater surface elevations and consequently no effect caused by canal seepage.
 42 There would be no adverse effect.

1 **CEQA Conclusion:** Alternative 2A would not involve construction of unlined canals; therefore, there
2 would be no increase in groundwater surface elevations and consequently no impact caused by canal
3 seepage and there would be no increased likelihood of loss of property, personal injury or death due to
4 operation of Alternative 2A. The impact would be less than significant. No mitigation is required.

5 **Impact GEO-12: Loss of Property, Personal Injury, or Death Resulting from Structural Failure**
6 **Caused by Rupture of a Known Earthquake Fault at Restoration Opportunity Areas**

7 **NEPA Effects:** Conservation measures would be the same under Alternative 2A as under 1A. See
8 description and findings under Alternative 1A. There would be no adverse effect.

9 **CEQA Conclusion:** Rupture of the Cordelia and Green Valley faults could occur at the Suisun Marsh ROA
10 and damage ROA facilities, such as levees and berms. Damage to these features could result in their
11 failure, causing flooding of otherwise protected areas. However, through the final design process for
12 conservation measures in the ROAs, measures to address the fault rupture hazard would be required to
13 conform to applicable design codes, guidelines, and standards. As described in Section 9.3.1, *Methods*
14 *for Analysis*, and in Appendix 3B, *Environmental Commitments*, such design codes, guidelines, and
15 standards include the Division of Safety of Dams *Guidelines for Use of the Consequence Hazard Matrix*
16 *and Selection of Ground Motion Parameters*, DWR's Division of Flood Management *FloodSAFE Urban*
17 *Levee Design Criteria*, and USACE's *Engineering and Design—Earthquake Design and Evaluation for Civil*
18 *Works Projects*. Conformance with these design standards is an environmental commitment by the
19 BDCP proponents to ensure that fault rupture risks are minimized as the conservation measures are
20 implemented. The hazard would be controlled to a safe level and would not create an increased
21 likelihood of loss of property, personal injury or death of individuals in the ROAs. The impact would be
22 less than significant. No mitigation is required.

23 **Impact GEO-13: Loss of Property, Personal Injury, or Death from Structural Failure Resulting**
24 **from Strong Seismic Shaking at Restoration Opportunity Areas**

25 **NEPA Effects:** Conservation measures would be the same under Alternative 2A as under 1A. See
26 description and findings under Alternative 1A. There would be no adverse effect.

27 **CEQA Conclusion:** Ground shaking could damage levees, berms, and other structures. Among all the
28 ROAs, the Suisun Marsh ROA would be the most subject to ground shaking because of its proximity to
29 active faults. The Suisun Marsh ROA is subject to a PGA of approximately 0.31 to 0.35 g for 200-year
30 return interval, while the PGA for the other ROAs ranges from approximately 0.11 to 0.26 g. Damage to
31 these features could result in their failure, causing flooding of otherwise protected areas. However, as
32 described in Section 9.3.1, *Methods for Analysis*, and in Appendix 3B, *Environmental Commitments*,
33 design codes, guidelines, and standards, including the California Building Code and resource agency
34 and professional engineering specifications, such as DWR's Division of Flood Management *FloodSAFE*
35 *Urban Levee Design Criteria* and USACE's *Engineering and Design—Earthquake Design and Evaluation*
36 *for Civil Works Projects* would be used for final design of conservation features. Conformance with these
37 design standards is an environmental commitment by the BDCP proponents to ensure that strong
38 seismic shaking risks are minimized as the conservation measures are operated and would not create
39 an increased likelihood of loss of property, personal injury or death of individuals in the ROAs. The
40 impact would be less than significant. No mitigation is required.

1 **Impact GEO-14: Loss of Property, Personal Injury, or Death from Structural Failure Resulting**
 2 **from Seismic-Related Ground Failure (Including Liquefaction) Beneath Restoration Opportunity**
 3 **Areas**

4 *NEPA Effects:* Conservation measures would be the same under Alternative 2A as under 1A. See
 5 description and findings under Alternative 1A. There would be no adverse effect.

6 *CEQA Conclusion:* Earthquake-induced ground shaking could cause liquefaction, resulting in damage to
 7 or failure of levees, berms, and other features constructed at the restoration areas. Failure of levees and
 8 other structures could result in flooding of otherwise protected areas. However, through the final
 9 design process, measures to address the liquefaction hazard would be required to conform to
 10 applicable design codes, guidelines, and standards. As described in Section 9.3.1, *Methods for Analysis*,
 11 and in Appendix 3B, *Environmental Commitments*, such design codes, guidelines, and standards include
 12 USACE's *Engineering and Design—Stability Analysis of Concrete Structures and Soil Liquefaction during*
 13 *Earthquakes*, by the Earthquake Engineering Research Institute. Conformance with these design
 14 standards is an environmental commitment by the BDCP proponents to ensure that liquefaction risks
 15 are minimized as the water conservation features are implemented. The hazard would be controlled to
 16 a safe level and would not create an increased likelihood of loss of property, personal injury or death of
 17 individuals in the ROAs. The impact would be less than significant. No mitigation is required.

18 **Impact GEO-15: Loss of Property, Personal Injury, or Death from Landslides and Other Slope**
 19 **Instability at Restoration Opportunity Areas**

20 *NEPA Effects:* Conservation measures would be the same under Alternative 2A as under 1A. See
 21 description and findings under Alternative 1A. There would be no adverse effect.

22 *CEQA Conclusion:* Unstable new and existing levee and embankment slopes could fail as a result of
 23 seismic shaking and as a result of high soil-water content during heavy rainfall and cause flooding of
 24 otherwise protected areas. However, because BDCP proponents would conform with applicable design
 25 guidelines and standards, such as USACE design measures, the hazard would be controlled to a safe
 26 level and would not create an increased likelihood of loss of property, personal injury or death of
 27 individuals in the ROAs. The impact would be less than significant. No mitigation is required.

28 **Impact GEO-16: Loss of Property, Personal Injury, or Death from Seiche or Tsunami at**
 29 **Restoration Opportunity Areas as a Result of Implementing the Conservation Actions**

30 *NEPA Effects:* Conservation measures under Alternative 2A would be similar to that as under
 31 Alternative 1A. See description and findings under Alternative 1A. The distance from the ocean and
 32 attenuating effect of the San Francisco Bay would likely allow only a low tsunami wave height to reach
 33 the Suisun Marsh and the Delta. Conditions for a seiche to occur at the ROAs are not favorable. There
 34 would be no adverse effect.

35 *CEQA Conclusion:* Based on professional judgment, the height of a tsunami wave reaching the ROAs
 36 would be small because of the distance from the ocean and attenuating effect of the San Francisco Bay.
 37 Similarly, the potential for a significant seiche to occur in the Plan Area that would cause loss of
 38 property, personal injury, or death at the ROAs is considered low because conditions for a seiche to
 39 occur at the ROAs are not favorable. The impact would be less than significant. No mitigation is
 40 required.

9.3.3.6 Alternative 2B—Dual Conveyance with East Alignment and Five Intakes (15,000 cfs; Operational Scenario B)

Impact GEO-1: Loss of Property, Personal Injury, or Death from Structural Failure Resulting from Strong Seismic Shaking of Water Conveyance Features during Construction

NEPA Effects: Alternative 2B would include the same physical/structural components as Alternative 1B, but could entail two different intake and intake pumping plant locations. These changes in locations would result in a similar hazard of ground shaking and would not substantially change the hazard of loss of property, personal injury, or death during construction. The effects of Alternative 2B would, therefore, be the same as 1B. See the description and findings under Alternative 1B. There would be no adverse effect.

CEQA Conclusion: Seismically induced ground shaking could cause collapse or other failure of project facilities while under construction. However, DWR would conform with Cal-OSHA and other state code requirements, such as shoring, bracing, lighting, excavation depth restrictions, required slope angles, and other measures, to protect worker safety. Conformance with these standards and codes is an environmental commitment of the project (see Appendix 3B, *Environmental Commitments*). Conformance with these health and safety requirements and the application of accepted, proven construction engineering practices would reduce this risk and there would be no increased likelihood of loss of property, personal injury or death due to construction of Alternative 2B. This impact is less than significant. No mitigation is required.

Impact GEO-2: Loss of Property, Personal Injury, or Death from Settlement or Collapse Caused by Dewatering during Construction of Water Conveyance Features

Alternative 2B would include the same physical/structural components as Alternative 1B, but could entail two different intake and intake pumping plant locations. If Intakes 6 and 7, north of Vorden, are chosen, settlement of excavations could occur as a result of dewatering at Alternative 2B construction sites with shallow groundwater. Soil excavation in areas with shallow or perched groundwater levels would require the pumping of groundwater from excavations to allow for construction of facilities. This can be anticipated at all intake locations and pumping plant sites adjacent to the Sacramento River. Similar dewatering may be necessary where intake and forebay pipelines cross waterways and major irrigation canals east of the Sacramento River and north of the proposed intermediate forebay. The conveyance pipeline built between Intake 6 and the canal would cross Snodgrass Slough, an adjacent body of water, and seven irrigation canals or drainage ditches prior to joining with the canal. The crossings closest to the intake would occur approximately 0.25 miles to 0.5 miles southeast of Russell Road. Snodgrass Slough would be crossed approximately 0.5 miles north of Alfalfa Plant Road. Intersections with three canals or ditches would then be located west of Snodgrass Slough and east of the proposed canal. The conveyance pipeline built between Intake 7 and the canal would cross Snodgrass Slough, an adjacent body of water, and eleven irrigation canals or drainage ditches prior to joining with the canal. The five crossings closest to the intake would occur approximately 0.3 miles to 1.1 miles northeast of the facility grounds proposed for Intake 7. Three crossings would be located 0.1 to 0.2 miles south of Alfalfa Plant Road, in addition to the crossing with Snodgrass Slough and an associated waterway. Intersections with four canals or ditches would then be located west of Snodgrass Slough and east of the proposed canal.

NEPA Effects: These changes in locations would result in a similar hazard of settlement or collapse and would not substantially change the hazard of loss of property, personal injury, or death during

1 construction. The effects of Alternative 2B would, therefore, be the same as 1B. See the description and
2 findings under Alternative 1B. There would be no adverse effect.

3 **CEQA Conclusion:** Settlement or failure of excavations during construction could result in loss of
4 property or personal injury. However, DWR would conform with Cal-OSHA and other state code
5 requirements, such as seepage cutoff walls, shoring, and other measures, to protect worker safety. DWR
6 would also ensure that the design specifications are properly executed during construction. DWR has
7 made an environmental commitment to use the appropriate code and standard requirements to
8 minimize potential risks (Appendix 3B, *Environmental Commitments*) and there would be no increased
9 likelihood of loss of property, personal injury or death due to construction of Alternative 2B. The
10 impact would be less than significant. No mitigation is required.

11 **Impact GEO-3: Loss of Property, Personal Injury, or Death from Ground Settlement during** 12 **Construction of Water Conveyance Features**

13 **NEPA Effects:** Alternative 2B would include the same physical/structural components as Alternative
14 1B, but could entail two different intake and intake pumping plant locations. These changes in locations
15 would have no bearing on the hazard of ground settlement of tunnel siphons and would not change the
16 hazard of loss of property, personal injury, or death during construction. The effects of Alternative 2B
17 would, therefore, be the same as 1B. See the description and findings under Alternative 1B. There
18 would be no adverse effect.

19 **CEQA Conclusion:** Ground settlement above the tunneling operation could result in loss of property or
20 personal injury during construction. However, DWR would conform with Cal-OSHA, USACE, and other
21 design requirements to protect worker safety. DWR would also ensure that the design specifications
22 are properly executed during construction. DWR has made an environmental commitment to use the
23 appropriate code and standard requirements to minimize potential risks (Appendix 3B, *Environmental*
24 *Commitments*) and there would be no increased likelihood of loss of property, personal injury or death
25 due to construction of Alternative 2B. Hazards to workers and project structures would be controlled at
26 safe levels and the impact would be less than significant. No mitigation is required.

27 **Impact GEO-4: Loss of Property, Personal Injury, or Death from Slope Failure during** 28 **Construction of Water Conveyance Features**

29 **NEPA Effects:** Alternative 2B would include the same physical/structural components as Alternative
30 1B, but could entail two different intake and intake pumping plant locations. These changes in locations
31 would have no bearing on the hazard of slope failure at borrow and storage sites and would not change
32 the hazard of loss of property, personal injury, or death during construction. The effects of Alternative
33 2B would, therefore, be the same as 1B. See the description and findings under Alternative 1B. There
34 would be no adverse effect.

35 **CEQA Conclusion:** Settlement/failure of cutslopes of borrow sites and failure of soil/RTM fill slopes
36 could result in loss of property or personal injury during construction. However, because DWR would
37 conform with Cal-OSHA and other state code requirements and conform to applicable geotechnical
38 design guidelines and standards, such as USACE design measures, the hazard would be controlled to a
39 safe level and there would be no increased likelihood of loss of property, personal injury or death due
40 to construction of Alternative 2B. The impact would be less than significant. No mitigation is required.

1 **Impact GEO-5: Loss of Property, Personal Injury, or Death from Structural Failure Resulting**
 2 **from Construction-Related Ground Motions during Construction of Water Conveyance Features**

3 *NEPA Effects:* Alternative 2B would include the same physical/structural components as Alternative
 4 1B, but could entail two different intake and intake pumping plant locations. These changes in locations
 5 would have no bearing on the hazard of structural failure from construction-related ground motions
 6 and would not change the hazard of loss of property, personal injury, or death during operation of the
 7 water conveyance features. The effects of Alternative 2B would, therefore, be the same as 1B. See the
 8 description and findings under Alternative 1B. There would be no adverse effect.

9 *CEQA Conclusion:* Construction-related ground motions could initiate liquefaction, which could cause
 10 failure of structures during construction. However, because DWR would conform with Cal-OSHA and
 11 other state code requirements and conform to applicable design guidelines and standards, such as
 12 USACE design measures, the hazard would be controlled to a level that would protect worker safety
 13 (see Appendix 3B, *Environmental Commitments*) and there would be no increased likelihood of loss of
 14 property, personal injury or death due to construction of Alternative 2B. The impact would be less than
 15 significant. No mitigation is required.

16 **Impact GEO-6: Loss of Property, Personal Injury, or Death from Structural Failure Resulting**
 17 **from Rupture of a Known Earthquake Fault during Operation of Water Conveyance Features**

18 *NEPA Effects:* Alternative 2B would include the same physical/structural components as Alternative
 19 1B, but could entail two different intake and intake pumping plant locations. These changes in locations
 20 would have no bearing on the hazard of fault rupture and would not change the hazard of loss of
 21 property, personal injury, or death during operation of the water conveyance features. The effects of
 22 Alternative 2B would, therefore, be the same as 1B. See the description and findings under Alternative
 23 1B. There would be no adverse effect

24 *CEQA Conclusion:* There are no active faults capable of surface rupture that extend into the East
 25 alignment. Although the Thornton Arch and West Tracy blind thrusts occur beneath the East alignment,
 26 based on available information, they do not present a hazard of surface rupture and there would be no
 27 increased likelihood of loss of property, personal injury or death due to operation of Alternative 2B.
 28 There would be no impact. No mitigation is required.

29 **Impact GEO-7: Loss of Property, Personal Injury, or Death from Structural Failure Resulting**
 30 **from Strong Seismic Shaking during Operation of Water Conveyance Features**

31 *NEPA Effects:* Alternative 2B would include the same physical/structural components as Alternative
 32 1B, but could entail two different intake and intake pumping plant locations. These changes in locations
 33 would have no bearing on the hazard of structural failure from seismic shaking and would not change
 34 the hazard of loss of property, personal injury, or death during operation of the water conveyance
 35 features. The effects of Alternative 2B would, therefore, be the same as 1B. See the description and
 36 findings under Alternative 1B. There would be no adverse effect.

37 *CEQA Conclusion:* Seismically induced strong ground shaking could damage the canals, pipelines,
 38 tunnel siphons, intake facilities, pumping plants, and other facilities. The damage could disrupt the
 39 water supply through the conveyance system. In an extreme event, an uncontrolled release of water
 40 from the damaged conveyance system could cause flooding and inundation of structures. (Please refer
 41 to Chapter 6, *Surface Water*, for a detailed discussion of potential flood impacts.) However, through the
 42 final design process, measures to address this hazard would be required to conform to applicable

1 design codes, guidelines, and standards. As described in Section 9.3.1, *Methods for Analysis*, and in
 2 Appendix 3B, *Environmental Commitments*, such design codes, guidelines, and standards include the
 3 California Building Code and resource agency and professional engineering specifications, such as the
 4 Division of Safety of Dams *Guidelines for Use of the Consequence Hazard Matrix and Selection of Ground*
 5 *Motion Parameters*, DWR's Division of Flood Management *FloodSAFE Urban Levee Design Criteria*, and
 6 USACE's *Engineering and Design—Earthquake Design and Evaluation for Civil Works Projects*.
 7 Conformance with these codes and standards is an environmental commitment by DWR to ensure that
 8 ground shaking risks are minimized as the water conveyance features are operated. The hazard would
 9 be controlled to a safe level and there would be no increased likelihood of loss of property, personal
 10 injury or death due to operation of Alternative 2B. The impact would be less than significant. No
 11 mitigation is required.

12 **Impact GEO-8: Loss of Property, Personal Injury, or Death from Structural Failure Resulting**
 13 **from Seismic-Related Ground Failure (Including Liquefaction) during Operation of Water**
 14 **Conveyance Features**

15 **NEPA Effects:** Alternative 2B would include the same physical/structural components as Alternative
 16 1B, but could entail two different intake and intake pumping plant locations. These changes in locations
 17 would have no bearing on the hazard of structural failure from ground failure and would not change
 18 the hazard of loss of property, personal injury, or death during operation of the water conveyance
 19 features. The effects of Alternative 2B would, therefore, be the same as 1B. See the description and
 20 findings under Alternative 1B. There would be no adverse effect.

21 **CEQA Conclusion:** Seismically induced ground shaking could cause liquefaction. Liquefaction could
 22 damage the canals, pipelines, tunnel siphons, intake facilities, pumping plants, and other facilities, and
 23 thereby disrupt the water supply through the conveyance system. In an extreme event, flooding and
 24 inundation of structures could result from an uncontrolled release of water from the damaged
 25 conveyance system. (Please refer to Chapter 6, *Surface Water*, for a detailed discussion of potential
 26 flood impacts.) However, through the final design process, measures to address the liquefaction hazard
 27 would be required to conform to applicable design codes, guidelines, and standards. As described in
 28 Section 9.3.1, *Methods for Analysis*, and in Appendix 3B, *Environmental Commitments*, such design
 29 codes, guidelines, and standards include USACE's *Engineering and Design—Stability Analysis of Concrete*
 30 *Structures and Soil Liquefaction during Earthquakes*, by the Earthquake Engineering Research Institute.
 31 Conformance with these design standards is an environmental commitment by DWR to ensure that
 32 liquefaction risks are minimized as the water conveyance features are operated. The hazard would be
 33 controlled to a safe level and there would be no increased likelihood of loss of property, personal injury
 34 or death due to operation of Alternative 2B. The impact would be less than significant. No mitigation is
 35 required.

36 **Impact GEO-9: Loss of Property, Personal Injury, or Death from Landslides and Other Slope**
 37 **Instability during Operation of Water Conveyance Features**

38 **NEPA Effects:** Alternative 2B would include the same physical/structural components as Alternative
 39 1B, but could entail two different intake and intake pumping plant locations. These changes in locations
 40 would have no bearing on the hazard of landslides and other slope instability and would not change the
 41 hazard of loss of property, personal injury, or death during operation of the water conveyance features.
 42 The effects of Alternative 2B would, therefore, be the same as 1B. See the description and findings
 43 under Alternative 1B. There would be no adverse effect.

1 **CEQA Conclusion:** Unstable levee slopes and natural stream banks may fail, either from high pore-
 2 water pressure caused by high rainfall and weak soil, or from seismic shaking. Structures constructed
 3 on these slopes could be damaged or fail entirely as a result of slope instability. However, through the
 4 final design process, measures to address this hazard would be required to conform to applicable
 5 design codes, guidelines, and standards. As described in Section 9.3.1, *Methods for Analysis*, and in
 6 Appendix 3B, *Environmental Commitments*, such design codes, guidelines, and standards include the
 7 California Building Code and resource agency and professional engineering specifications, such as
 8 USACE's *Engineering and Design—Earthquake Design and Evaluation for Civil Works Projects*.
 9 Conformance with these codes and standards is an environmental commitment by DWR to ensure cut
 10 and fill slopes and embankments will be stable as the water conveyance features are operated and
 11 there would be no increased likelihood of loss of property, personal injury or death due to operation of
 12 Alternative 2B. The impact would be less than significant. No mitigation is required.

13 **Impact GEO-10: Loss of Property, Personal Injury, or Death from Seiche or Tsunami during**
 14 **Operation of Water Conveyance Features**

15 **NEPA Effects:** Alternative 2B would include the same physical/structural components as Alternative
 16 1B, but could entail two different intake and intake pumping plant locations. These changes in locations
 17 would have no bearing on the hazard of seiche or tsunami and would not change the hazard of loss of
 18 property, personal injury, or death during operation of the water conveyance features. The effects of
 19 Alternative 2B would, therefore, be the same as 1B. See the description and findings under Alternative
 20 1B. There would be no adverse effect.

21 **CEQA Conclusion:** Based on recorded tsunami wave heights at the Golden Gate (Contra Costa
 22 Transportation Agency 2009) and in the interior of the San Francisco Bay and on tsunami inundation
 23 maps prepared by the California Department of Conservation (2009), the height of a tsunami wave
 24 reaching the Suisun Marsh and the Delta would be small because of the distance from the ocean and
 25 attenuating effect of the San Francisco Bay. Similarly, the potential for a significant seiche to occur in
 26 most parts of the Plan Area is considered low because the seismic hazard and the geometry of the
 27 water bodies (i.e., wide and shallow) near conveyance facilities are not favorable for a seiche to occur.
 28 However, assuming that the West Tracy fault is potentially active, a potential exists for a seiche to occur
 29 in the Clifton Court Forebay and the Byron Tract Forebay (Fugro Consultants 2011). The impact would
 30 not be significant because the Byron Tract Forebay embankment would be designed and constructed
 31 according to applicable design codes, guidelines, and standards to contain and withstand the
 32 anticipated maximum seiche wave height. There would be no increased likelihood of loss of property,
 33 personal injury or death due to operation of Alternative 2B from seiche or tsunami. The impact would
 34 be less than significant. No mitigation is required.

35 **Impact GEO-11: Ground Failure Caused by Increased Groundwater Surface Elevations from**
 36 **Unlined Canal Seepage as a Result of Operating the Water Conveyance Facilities**

37 **NEPA Effects:** Alternative 2B would include the same physical/structural components as Alternative
 38 1B, but could entail two different intake and intake pumping plant locations. These changes in locations
 39 would result in a similar hazard of ground shaking and would not substantially change the hazard of
 40 loss of property, personal injury, or death during construction. The effects of Alternative 2B would,
 41 therefore, be the same as 1B. See the description and findings under Alternative 1B. There would be no
 42 adverse effect.

1 **CEQA Conclusion:** Seepage from an unlined canal could raise the water table level along the canal,
 2 thereby increasing the hazard of liquefaction where the water table is not already close to the surface.
 3 The increased hazard of liquefaction could threaten the integrity of the canal in the event that
 4 liquefaction occurs. However, because DWR would conform with applicable design guidelines and
 5 standards, such as USACE design measures, the hazard would be controlled to a safe level and there
 6 would be no increased likelihood of loss of property, personal injury or death due to operation of
 7 Alternative 2B. The impact would be less than significant. No mitigation is required.

8 **Impact GEO-12: Loss of Property, Personal Injury, or Death Resulting from Structural Failure**
 9 **Caused by Rupture of a Known Earthquake Fault at Restoration Opportunity Areas**

10 **NEPA Effects:** Conservation measures would be the same under Alternative 2B as under 1A. See
 11 description and findings under Alternative 1A. There would be no adverse effect.

12 **CEQA Conclusion:** Rupture of the Cordelia and Green Valley faults could occur at the Suisun Marsh ROA
 13 and damage ROA facilities, such as levees and berms. Damage to these features could result in their
 14 failure, causing flooding of otherwise protected areas. However, through the final design process for
 15 conservation measures in the ROAs, measures to address the fault rupture hazard would be required to
 16 conform to applicable design codes, guidelines, and standards. As described in Section 9.3.1, *Methods*
 17 *for Analysis*, and in Appendix 3B, *Environmental Commitments*, such design codes, guidelines, and
 18 standards include the Division of Safety of Dams *Guidelines for Use of the Consequence Hazard Matrix*
 19 *and Selection of Ground Motion Parameters*, DWR's Division of Flood Management *FloodSAFE Urban*
 20 *Levee Design Criteria*, and USACE's *Engineering and Design—Earthquake Design and Evaluation for Civil*
 21 *Works Projects*. Conformance with these design standards is an environmental commitment by the
 22 BDCP proponents to ensure that fault rupture risks are minimized as the conservation measures are
 23 implemented. The hazard would be controlled to a safe level and there would be no increased
 24 likelihood of loss of property, personal injury or death in the ROAs. The impact would be less than
 25 significant. No mitigation is required.

26 **Impact GEO-13: Loss of Property, Personal Injury, or Death from Structural Failure Resulting**
 27 **from Strong Seismic Shaking at Restoration Opportunity Areas**

28 **NEPA Effects:** Conservation measures would be the same under Alternative 2B as under 1A. See
 29 description and findings under Alternative 1A. There would be no adverse effect.

30 **CEQA Conclusion:** Ground shaking could damage levees, berms, and other structures. Among all the
 31 ROAs, the Suisun Marsh ROA would be the most subject to ground shaking because of its proximity to
 32 active faults. The Suisun Marsh ROA is subject to a PGA of approximately 0.31 to 0.35 g for 200-year
 33 return interval, while the PGA for the other ROAs ranges from approximately 0.11 to 0.26 g. Damage to
 34 these features could result in their failure, causing flooding of otherwise protected areas. However, as
 35 described in Section 9.3.1, *Methods for Analysis*, and in Appendix 3B, *Environmental Commitments*,
 36 design codes, guidelines, and standards, including the California Building Code and resource agency
 37 and professional engineering specifications, such as DWR's Division of Flood Management *FloodSAFE*
 38 *Urban Levee Design Criteria* and USACE's *Engineering and Design—Earthquake Design and Evaluation*
 39 *for Civil Works Projects* would be used for final design of conservation features. Conformance with these
 40 design standards is an environmental commitment by the BDCP proponents to ensure that strong
 41 seismic shaking risks are minimized as the conservation measures are operated and there would be no
 42 increased likelihood of loss of property, personal injury or death in the ROAs. The impact would be less
 43 than significant. No mitigation is required.

1 **Impact GEO-14: Loss of Property, Personal Injury, or Death from Structural Failure Resulting**
 2 **from Seismic-Related Ground Failure (Including Liquefaction) Beneath Restoration Opportunity**
 3 **Areas**

4 **NEPA Effects:** Conservation measures would be the same under Alternative 2B as under 1A. See
 5 description and findings under Alternative 1A. There would be no adverse effect.

6 **CEQA Conclusion:** Earthquake-induced ground shaking could cause liquefaction, resulting in damage to
 7 or failure of levees, berms, and other features constructed at the restoration areas. Failure of levees and
 8 other structures could result in flooding of otherwise protected areas. However, through the final
 9 design process, measures to address the liquefaction hazard would be required to conform to
 10 applicable design codes, guidelines, and standards. As described in Section 9.3.1, *Methods for Analysis*,
 11 and in Appendix 3B, *Environmental Commitments*, such design codes, guidelines, and standards include
 12 USACE's *Engineering and Design—Stability Analysis of Concrete Structures and Soil Liquefaction during*
 13 *Earthquakes*, by the Earthquake Engineering Research Institute. Conformance with these design
 14 standards is an environmental commitment by the BDCP proponents to ensure that liquefaction risks
 15 are minimized as the water conservation features are implemented. The hazard would be controlled to
 16 a safe level and there would be no increased likelihood of loss of property, personal injury or death in
 17 the ROAs. The impact would be less than significant. No mitigation is required.

18 **Impact GEO-15: Loss of Property, Personal Injury, or Death from Landslides and Other Slope**
 19 **Instability at Restoration Opportunity Areas**

20 **NEPA Effects:** Conservation measures would be the same under Alternative 2B as under 1A. See
 21 description and findings under Alternative 1A. There would be no adverse effect.

22 **CEQA Conclusion:**

23 Unstable new and existing levee and embankment slopes could fail as a result of seismic shaking and as
 24 a result of high soil-water content during heavy rainfall and cause flooding of otherwise protected
 25 areas. However, because the BDCP proponents would conform with applicable design guidelines and
 26 standards, such as USACE design measures, the hazard would be controlled to a safe level and there
 27 would be no increased likelihood of loss of property, personal injury or death in the ROAs. The impact
 28 would be less than significant. No mitigation is required.

29 **Impact GEO-16: Loss of Property, Personal Injury, or Death from Seiche or Tsunami at**
 30 **Restoration Opportunity Areas as a Result of Implementing the Conservation Actions**

31 **NEPA Effects:** Conservation measures under Alternative 2B would be similar to that as under
 32 Alternative 1A. See description and findings under Alternative 1A. There would be no adverse effect.

33 **CEQA Conclusion:** Based recorded tsunami wave heights at the Golden Gate, the height of a tsunami
 34 wave reaching the ROAs would be small because of the distance from the ocean and attenuating effect
 35 of the San Francisco Bay. The impact would be less than significant. No mitigation is required. Similarly,
 36 the potential for a significant seiche to occur in the Plan Area that would cause loss of property,
 37 personal injury, or death at the ROAs is considered low because conditions for a seiche to occur at the
 38 ROAs are not favorable. The impact would be less than significant. No mitigation is required.

9.3.3.7 Alternative 2C—Dual Conveyance with West Alignment and Intakes W1–W5 (15,000 cfs; Operational Scenario B)

Impact GEO-1: Loss of Property, Personal Injury, or Death from Structural Failure Resulting from Strong Seismic Shaking of Water Conveyance Features during Construction

NEPA Effects: Alternative 2C would include the same physical/structural components as Alternative 1C, but could entail two different intake and intake pumping plant locations. These alternative intakes would be located where there is a similar hazard of ground shaking and would not substantially change the hazard of loss of property, personal injury, or death during construction. The effects of Alternative 2C would, therefore, be the same as 1C. See the description and findings under Alternative 1C. There would be no adverse effect.

CEQA Conclusion: Seismically induced ground shaking could cause collapse or other failure of project facilities while under construction. However, DWR would conform with Cal-OSHA and other state code requirements, such as shoring, bracing, lighting, excavation depth restrictions, required slope angles, and other measures, to protect worker safety. Conformance with these standards and codes is an environmental commitment of the project (see Appendix 3B, *Environmental Commitments*). Conformance with these health and safety requirements and the application of accepted, proven construction engineering practices would reduce this risk and there would be no increased likelihood of loss of property, personal injury or death due to construction of Alternative 2C. This impact would be less than significant. No mitigation is required.

Impact GEO-2: Loss of Property, Personal Injury, or Death from Settlement or Collapse Caused by Dewatering during Construction of Water Conveyance Features

NEPA Effects: Alternative 2C would include the same physical/structural components as Alternative 1C, but could entail two different intake and intake pumping plant locations. These changes in locations would result in a similar hazard of settlement or collapse and would not substantially change the hazard of loss of property, personal injury, or death during construction. The effects of Alternative 2C would, therefore, be the same as 1C. See the description and findings under Alternative 1C. There would be no adverse effect.

CEQA Conclusion: Settlement or failure of excavations during construction could result in loss of property or personal injury. However, DWR would conform with Cal-OSHA and other state code requirements, such as using seepage cutoff walls, shoring, and other measures, to protect worker safety. DWR would also ensure that the design specifications are properly executed during construction. DWR has made an environmental commitment to use the appropriate code and standard requirements to minimize potential risks (Appendix 3B, *Environmental Commitments*) and there would be no increased likelihood of loss of property, personal injury or death due to construction of Alternative 2C. The impact would be less than significant. No mitigation is required.

Impact GEO-3: Loss of Property, Personal Injury, or Death from Ground Settlement during Construction of Water Conveyance Features

NEPA Effects: Alternative 2C would include the same physical/structural components as Alternative 1C, but could entail two different intake and intake pumping plant locations. These changes in locations would have no bearing on the hazard of ground settlement of tunnels and culvert siphons and would not change the hazard of loss of property, personal injury, or death during construction. The effects of

1 Alternative 2C would, therefore, be the same as 1C. See the description and findings under Alternative
2 1C. There would be no adverse effect.

3 **CEQA Conclusion:** Ground settlement above the tunneling operation could result in loss of property or
4 personal injury during construction. However, DWR would conform with Cal-OSHA, USACE and other
5 design requirements to protect worker safety. DWR would also ensure that the design specifications
6 are properly executed during construction. DWR has made an environmental commitment to use the
7 appropriate code and standard requirements to minimize potential risks (Appendix 3B, *Environmental*
8 *Commitments*). Hazards to workers and project structures would be controlled at safe levels and there
9 would be no increased likelihood of loss of property, personal injury or death due to construction of
10 Alternative 2C. The impact would be less than significant. No mitigation is required.

11 **Impact GEO-4: Loss of Property, Personal Injury, or Death from Slope Failure during** 12 **Construction of Water Conveyance Features**

13 **NEPA Effects:** Alternative 2C would include the same physical/structural components as Alternative
14 1C, but could entail two different intake and intake pumping plant locations. These changes in locations
15 would have no bearing on the hazard of slope failure at borrow sites and storage sites and would not
16 change the hazard of loss of property, personal injury, or death during construction. The effects of
17 Alternative 2C would, therefore, be the same as 1C. See the description and findings under Alternative
18 1C. There would be no adverse effect.

19 **CEQA Conclusion:** Settlement/failure of cutslopes of borrow sites and failure of soil/RTM fill slopes
20 could result in loss of property or personal injury during construction. However, because DWR would
21 conform with Cal-OSHA requirements and conform to applicable geotechnical design guidelines and
22 standards, such as USACE design measures, the hazard would be controlled to a safe level and there
23 would be no increased likelihood of loss of property, personal injury or death due to construction of
24 Alternative 2C. The impact would be less than significant. No mitigation is required.

25 **Impact GEO-5: Loss of Property, Personal Injury, or Death from Structural Failure Resulting** 26 **from Construction-Related Ground Motions during Construction of Water Conveyance Features**

27 **NEPA Effects:** Alternative 2C would include the same physical/structural components as Alternative
28 1C, but could entail two different intake and intake pumping plant locations. These changes in locations
29 would have no bearing on the hazard of structural failure from construction-related ground motions
30 and would not change the hazard of loss of property, personal injury, or death during operation of the
31 water conveyance features. The effects of Alternative 2C would, therefore, be the same as 1C. See the
32 description and findings under Alternative 1C. There would be no adverse effect.

33 **CEQA Conclusion:** Construction-related ground motions could initiate liquefaction, which could cause
34 failure of structures during construction. However, because DWR has committed to conform with Cal-
35 OSHA and other state code requirements and conform to applicable design guidelines and standards,
36 such as USACE design measures, the hazard would be controlled to a level that would protect worker
37 safety (see Appendix 3B, *Environmental Commitments*) and there would be no increased likelihood of
38 loss of property, personal injury or death due to construction of Alternative 2C. The impact would be
39 less than significant. No mitigation is required.

1 **Impact GEO-6: Loss of Property, Personal Injury, or Death from Structural Failure Resulting**
 2 **from Rupture of a Known Earthquake Fault during Operation of Water Conveyance Features**

3 *NEPA Effects:* Alternative 2C would include the same physical/structural components as Alternative
 4 1C, but could entail two different intake and intake pumping plant locations. These changes in locations
 5 would have no bearing on the hazard of fault rupture and would not change the hazard of loss of
 6 property, personal injury, or death during operation of the water conveyance features. The effects of
 7 Alternative 2C would, therefore, be the same as 1C. See the description and findings under Alternative
 8 1C. There would be no adverse effect.

9 *CEQA Conclusion:* There are no active faults capable of surface rupture that extend into the West
 10 alignment. Although the Thornton Arch and West Tracy blind thrusts occur beneath the West
 11 alignment, based on available information, they do not present a hazard of surface rupture and there
 12 would be no increased likelihood of loss of property, personal injury or death due to operation of
 13 Alternative 2C. There would be no impact. No mitigation is required.

14 **Impact GEO-7: Loss of Property, Personal Injury, or Death from Structural Failure Resulting**
 15 **from Strong Seismic Shaking during Operation of Water Conveyance Features**

16 *NEPA Effects:* Alternative 2C would include the same physical/structural components as Alternative
 17 1C, but could entail two different intake and intake pumping plant locations. These changes in locations
 18 would have no bearing on the hazard of structural failure from seismic shaking and would not change
 19 the hazard of loss of property, personal injury, or death during operation of the water conveyance
 20 features. The effects of Alternative 2C would, therefore, be the same as 1C. See the description and
 21 findings under Alternative 1C. There would be no adverse effect.

22 *CEQA Conclusion:* Seismically induced strong ground shaking could damage the canal, pipelines,
 23 tunnels, culvert siphons, intake facilities, pumping plants, and other facilities. The damage could disrupt
 24 the water supply through the conveyance system. In an extreme event, an uncontrolled release of water
 25 from the damaged conveyance system could cause flooding and inundation of structures. (Please refer
 26 to Chapter 6, *Surface Water*, for a detailed discussion of potential flood impacts.) However, through the
 27 final design process, measures to address this hazard would be required to conform to applicable
 28 design codes, guidelines, and standards. As described in Section 9.3.1, *Methods for Analysis*, and in
 29 Appendix 3B, *Environmental Commitments*, such design codes, guidelines, and standards include the
 30 California Building Code and resource agency and professional engineering specifications, such as the
 31 Division of Safety of Dams *Guidelines for Use of the Consequence Hazard Matrix and Selection of Ground*
 32 *Motion Parameters*, DWR's Division of Flood Management *FloodSAFE Urban Levee Design Criteria*, and
 33 USACE's *Engineering and Design—Earthquake Design and Evaluation for Civil Works Projects*.
 34 Conformance with these codes and standards is an environmental commitment by DWR to ensure that
 35 ground shaking risks are minimized as the water conveyance features are operated. The hazard would
 36 be controlled to a safe level and there would be no increased likelihood of loss of property, personal
 37 injury or death due to operation of Alternative 2C. The impact would be less than significant. No
 38 mitigation is required.

39 **Impact GEO-8: Loss of Property, Personal Injury, or Death from Structural Failure Resulting**
 40 **from Seismic-Related Ground Failure (Including Liquefaction) during Operation of Water**
 41 **Conveyance Features**

42 *NEPA Effects:* Alternative 2C would include the same physical/structural components as Alternative
 43 1C, but could entail two different intake and intake pumping plant locations. These changes in locations

1 would have no bearing on the hazard of structural failure from ground failure and would not change
 2 the hazard of loss of property, personal injury, or death during operation of the water conveyance
 3 features. The effects of Alternative 2C would, therefore, be the same as 1C. See the description and
 4 findings under Alternative 1C. There would be no adverse effect.

5 **CEQA Conclusion:** Seismically induced ground shaking could cause liquefaction. Liquefaction could
 6 damage pipelines, tunnels, culvert siphons, intake facilities, pumping plants, and other facilities, and
 7 thereby disrupt the water supply through the conveyance system. In an extreme event, flooding and
 8 inundation of structures could result from an uncontrolled release of water from the damaged
 9 conveyance system. (Please refer to Chapter 6, *Surface Water*, for a detailed discussion of potential
 10 flood impacts.) However, through the final design process, measures to address the liquefaction hazard
 11 would be required to conform to applicable design codes, guidelines, and standards. As described in
 12 Section 9.3.1, *Methods for Analysis*, and in Appendix 3B, *Environmental Commitments*, such design
 13 codes, guidelines, and standards include USACE's *Engineering and Design—Stability Analysis of Concrete
 14 Structures and Soil Liquefaction during Earthquakes*, by the Earthquake Engineering Research Institute.
 15 Conformance with these design standards is an environmental commitment by DWR to ensure that
 16 liquefaction risks are minimized as the water conveyance features are operated. The hazard would be
 17 controlled to a safe level and there would be no increased likelihood of loss of property, personal injury
 18 or death due to operation of Alternative 2C. The impact would be less than significant. No mitigation is
 19 required.

20 **Impact GEO-9: Loss of Property, Personal Injury, or Death from Landslides and Other Slope**
 21 **Instability during Operation of Water Conveyance Features**

22 **NEPA Effects:** Alternative 2C would include the same physical/structural components as Alternative
 23 1C, but could entail two different intake and intake pumping plant locations. These changes in locations
 24 would have no bearing on the hazard of landslides and other slope instability and would not change the
 25 hazard of loss of property, personal injury, or death during operation of the water conveyance features.
 26 The effects of Alternative 2C would, therefore, be the same as 1C. See the description and findings
 27 under Alternative 1C. There would be no adverse effect.

28 **CEQA Conclusion:** Unstable levee slopes and natural stream banks may fail, either from high pore-
 29 water pressure caused by high rainfall and weak soil, or from seismic shaking. Structures constructed
 30 on these slopes could be damaged or fail entirely as a result of slope instability. However, through the
 31 final design process, measures to address this hazard would be required to conform to applicable
 32 design codes, guidelines, and standards. As described in Section 9.3.1, *Methods for Analysis*, and in
 33 Appendix 3B, *Environmental Commitments*, such design codes, guidelines, and standards include the
 34 California Building Code and resource agency and professional engineering specifications, such as
 35 USACE's *Engineering and Design—Earthquake Design and Evaluation for Civil Works Projects*.
 36 Conformance with these codes and standards is an environmental commitment by DWR to ensure cut
 37 and fill slopes and embankments will be stable as the water conveyance features are operated and
 38 there would be no increased likelihood of loss of property, personal injury or death due to operation of
 39 Alternative 2C. The impact would be less than significant. No mitigation is required.

40 **Impact GEO-10: Loss of Property, Personal Injury, or Death from Seiche or Tsunami during**
 41 **Operation of Water Conveyance Features**

42 **NEPA Effects:** Alternative 2C would include the same physical/structural components as Alternative
 43 1C, but could entail two different intake and intake pumping plant locations. These changes in locations

1 would have no bearing on the hazard of seiche or tsunami and would not change the hazard of loss of
 2 property, personal injury, or death during operation of the water conveyance features. The effects of
 3 Alternative 2C would, therefore, be the same as 1C. See the description and findings under Alternative
 4 1C. There would be no adverse effect.

5 **CEQA Conclusion:** Based on recorded tsunami wave heights at the Golden Gate (Contra Costa
 6 Transportation Agency 2009) and in the interior of the San Francisco Bay and on tsunami inundation
 7 maps prepared by the California Department of Conservation (2009), the height of a tsunami wave
 8 reaching the Suisun Marsh and the Delta would be small because of the distance from the ocean and
 9 attenuating effect of the San Francisco Bay. Similarly, the potential for a significant seiche to occur in
 10 most parts of the Plan Area is considered low because the seismic hazard and the geometry of the
 11 water bodies (i.e., wide and shallow) near conveyance facilities are not favorable for a seiche to occur.
 12 However, assuming that the West Tracy fault is potentially active, a potential exists for a seiche to occur
 13 in the Clifton Court Forebay and the Byron Tract Forebay (Fugro Consultants 2011). The impact would
 14 not be significant because the Byron Tract Forebay embankment would be designed and constructed
 15 according to applicable design codes, guidelines, and standards to contain and withstand the
 16 anticipated maximum seiche wave height. There would be no increased likelihood of loss of property,
 17 personal injury or death due to operation of Alternative 2C from seiche or tsunami. The impact would
 18 be less than significant. No additional mitigation is required.

19 **Impact GEO-11: Ground Failure Caused by Increased Groundwater Surface Elevations from**
 20 **Unlined Canal Seepage as a Result of Operating the Water Conveyance Facilities**

21 **NEPA Effects:** Alternative 2C would include the same physical/structural components as Alternative
 22 1C, but could entail two different intake and intake pumping plant locations. These changes in locations
 23 would result in a similar hazard of ground shaking and would not substantially change the hazard of
 24 loss of property, personal injury, or death during construction. The effects of Alternative 2C would,
 25 therefore, be the same as 1C. See the description and findings under Alternative 1C. There would be no
 26 adverse effect.

27 **CEQA Conclusion:** Seepage from an unlined canal could raise the water table level along the canal,
 28 thereby increasing the hazard of liquefaction where the water table is not already close to the surface.
 29 The increased hazard of liquefaction could threaten the integrity of the canal in the event that
 30 liquefaction occurs. However, because DWR would conform with applicable design guidelines and
 31 standards, such as USACE design measures, the hazard would be controlled to a safe level and there
 32 would be no increased likelihood of loss of property, personal injury or death due to operation of
 33 Alternative 2C. The impact would be less than significant. No mitigation is required.

34 **Impact GEO-12: Loss of Property, Personal Injury, or Death Resulting from Structural Failure**
 35 **Caused by Rupture of a Known Earthquake Fault at Restoration Opportunity Areas**

36 **NEPA Effects:** Conservation measures would be the same under Alternative 2C as under 1A. See
 37 description and findings under Alternative 1A. There would be no adverse effect.

38 **CEQA Conclusion:** Rupture of the Cordelia and Green Valley faults could occur at the Suisun Marsh ROA
 39 and damage ROA facilities, such as levees and berms. Damage to these features could result in their
 40 failure, causing flooding of otherwise protected areas. However, through the final design process for
 41 conservation measures in the ROAs, measures to address the fault rupture hazard would be required to
 42 conform to applicable design codes, guidelines, and standards. As described in Section 9.3.1, *Methods*
 43 *for Analysis*, and in Appendix 3B, *Environmental Commitments*, such design codes, guidelines, and

standards include the Division of Safety of Dams *Guidelines for Use of the Consequence Hazard Matrix and Selection of Ground Motion Parameters*, DWR's Division of Flood Management *FloodSAFE Urban Levee Design Criteria*, and USACE's *Engineering and Design—Earthquake Design and Evaluation for Civil Works Projects*. Conformance with these design standards is an environmental commitment by the BDCP proponents to ensure that fault rupture risks are minimized as the conservation measures are implemented. The hazard would be controlled to a safe level and there would be no increased likelihood of loss of property, personal injury or death in the ROAs. The impact would be less than significant. No mitigation is required.

Impact GEO-13: Loss of Property, Personal Injury, or Death from Structural Failure Resulting from Strong Seismic Shaking at Restoration Opportunity Areas

NEPA Effects: Conservation measures would be the same under Alternative 2C as under 1A. See description and findings under Alternative 1A. There would be no adverse effect.

CEQA Conclusion: Ground shaking could damage levees, berms, and other structures. Among all the ROAs, the Suisun Marsh ROA would be the most subject to ground shaking because of its proximity to active faults. The Suisun Marsh ROA is subject to a PGA of approximately 0.31 to 0.35 g for 200-year return interval, while the PGA for the other ROAs ranges from approximately 0.11 to 0.26 g. Damage to these features could result in their failure, causing flooding of otherwise protected areas.

However, as described in Section 9.3.1, *Methods for Analysis*, and in Appendix 3B, *Environmental Commitments*, design codes, guidelines, and standards, including the California Building Code and resource agency and professional engineering specifications, such as DWR's Division of Flood Management *FloodSAFE Urban Levee Design Criteria* and USACE's *Engineering and Design—Earthquake Design and Evaluation for Civil Works Projects* would be used for final design of conservation features. Conformance with these design standards is an environmental commitment by the BDCP proponents to ensure that strong seismic shaking risks are minimized as the conservation measures are operated and there would be no increased likelihood of loss of property, personal injury or death in the ROAs. The impact would be less than significant. No mitigation is required.

Impact GEO-14: Loss of Property, Personal Injury, or Death from Structural Failure Resulting from Seismic-Related Ground Failure (Including Liquefaction) Beneath Restoration Opportunity Areas

NEPA Effects: Conservation measures would be the same under Alternative 2C as under 1A. See description and findings under Alternative 1A. There would be no adverse effect.

CEQA Conclusion: Earthquake-induced ground shaking could cause liquefaction, resulting in damage to or failure of levees, berms, and other features constructed at the restoration areas. Failure of levees and other structures could result in flooding of otherwise protected areas. However, through the final design process, measures to address the liquefaction hazard would be required to conform to applicable design codes, guidelines, and standards. As described in Section 9.3.1, *Methods for Analysis*, and in Appendix 3B, *Environmental Commitments*, such design codes, guidelines, and standards include USACE's *Engineering and Design—Stability Analysis of Concrete Structures and Soil Liquefaction during Earthquakes*, by the Earthquake Engineering Research Institute. Conformance with these design standards is an environmental commitment by the BDCP proponents to ensure that liquefaction risks are minimized as the water conservation features are implemented. The hazard would be controlled to a safe level and there would be no increased likelihood of loss of property, personal injury or death in the ROAs. The impact would be less than significant. No mitigation is required.

1 **Impact GEO-15: Loss of Property, Personal Injury, or Death from Landslides and Other Slope**
 2 **Instability at Restoration Opportunity Areas**

3 *NEPA Effects:* Conservation measures would be the same under Alternative 2C as under 1A. See
 4 description and findings under Alternative 1A. There would be no adverse impact.

5 *CEQA Conclusion:* Unstable new and existing levee and embankment slopes could fail as a result of
 6 seismic shaking and as a result of high soil-water content during heavy rainfall and cause flooding of
 7 otherwise protected areas. However, because the BDCP proponents would conform with applicable
 8 design guidelines and standards, such as USACE design measures, the hazard would be controlled to a
 9 safe level and there would be no increased likelihood of loss of property, personal injury or death in the
 10 ROAs. The impact would be less than significant. No mitigation is required.

11 **Impact GEO-16: Loss of Property, Personal Injury, or Death from Seiche or Tsunami at**
 12 **Restoration Opportunity Areas as a Result of Implementing the Conservation Actions**

13 *NEPA Effects:* Conservation measures under Alternative 2C would be similar to that as under
 14 Alternative 1A. See description and findings under Alternative 1A. There would be no adverse impact.

15 *CEQA Conclusion:* Based on recorded tsunami wave heights at the Golden Gate, the height of a tsunami
 16 wave reaching the ROAs would be small because of the distance from the ocean and attenuating effect
 17 of the San Francisco Bay. Similarly, the potential for a significant seiche to occur in the Plan Area is
 18 considered low because conditions for a seiche to occur near conveyance facilities are not favorable.
 19 There would be no increased likelihood of loss of property, personal injury or death in the ROAs from
 20 seiche or tsunami. The impact would be less than significant. No mitigation is required.

21 **9.3.3.8 Alternative 3—Dual Conveyance with Pipeline/Tunnel and Intakes**
 22 **1 and 2 (6,000 cfs; Operational Scenario A)**

23 **Impact GEO-1: Loss of Property, Personal Injury, or Death from Structural Failure Resulting**
 24 **from Strong Seismic Shaking of Water Conveyance Features during Construction**

25 *NEPA Effects:* Alternative 3 would include the same physical/structural components as Alternative 1A,
 26 but would entail three less intakes and three less pumping plants. These differences would present a
 27 slightly lower hazard of structural failure from seismic shaking and would not substantially change the
 28 hazard of loss of property, personal injury, or death during construction compared to Alternative 1A.
 29 The effects of Alternative 3 would, therefore, be the same as 1A. See the description and findings under
 30 Alternative 1A. There would be no adverse effect.

31 *CEQA Conclusion:* Seismically induced ground shaking could cause collapse or other failure of project
 32 facilities while under construction. However, DWR would conform with Cal-OSHA and other state code
 33 requirements, such as shoring, bracing, lighting, excavation depth restrictions, required slope angles,
 34 and other measures, to protect worker safety. Conformance with these standards and codes is an
 35 environmental commitment of the project (see Appendix 3B, *Environmental Commitments*).
 36 Conformance with these health and safety requirements and the application of accepted, proven
 37 construction engineering practices would reduce this risk and there would be no increased likelihood
 38 of loss of property, personal injury or death due to construction of Alternative 3. This impact would be
 39 less than significant. No additional mitigation is required.

1 **Impact GEO-2: Loss of Property, Personal Injury, or Death from Settlement or Collapse Caused**
 2 **by Dewatering during Construction of Water Conveyance Features**

3 **NEPA Effects:** Alternative 3 would include the same physical/structural components as Alternative 1A,
 4 but would entail three less intakes and three less pumping plants. These differences would present a
 5 slightly lower hazard of settlement or collapse caused by dewatering and would not substantially
 6 change the hazard of loss of property, personal injury, or death during construction compared to
 7 Alternative 1A. The effects of Alternative 3 would, therefore, be the same as 1A. See the description and
 8 findings under Alternative 1A. There would be no adverse effect.

9 **CEQA Conclusion:** Settlement or failure of excavations during construction could result in loss of
 10 property or personal injury. However, DWR would conform with Cal-OSHA and other state code
 11 requirements, such as using seepage cutoff walls, shoring, and other measures, to protect worker
 12 safety. DWR would also ensure that the design specifications are properly executed during
 13 construction. DWR has made an environmental commitment to use the appropriate code and standard
 14 requirements to minimize potential risks (Appendix 3B, *Environmental Commitments*) and there would
 15 be no increased likelihood of loss of property, personal injury or death due to construction of
 16 Alternative 3. The impact would be less than significant. No mitigation is required.

17 **Impact GEO-3: Loss of Property, Personal Injury, or Death from Ground Settlement during**
 18 **Construction of Water Conveyance Features**

19 **NEPA Effects:** Alternative 3 would include the same physical/structural components as Alternative 1A,
 20 but would entail three less intakes and three less pumping plants. These differences would present a
 21 slightly lower hazard of ground settlement hazard on the tunnel and would not substantially change
 22 the hazard of loss of property, personal injury, or death during construction compared to Alternative
 23 1A. The effects of Alternative 3 would, therefore, be the same as 1A. See the description and findings
 24 under Alternative 1A. There would be no adverse effect.

25 **CEQA Conclusion:** Ground settlement above the tunneling operation could result in loss of property or
 26 personal injury during construction. However, DWR would conform with Cal-OSHA, USACE, and other
 27 design requirements to protect worker safety. DWR would also ensure that the design specifications
 28 are properly executed during construction. DWR has made an environmental commitment to use the
 29 appropriate code and standard requirements to minimize potential risks (Appendix 3B, *Environmental*
 30 *Commitments*). Hazards to workers and project structures would be controlled at safe levels and there
 31 would be no increased likelihood of loss of property, personal injury or death due to construction of
 32 Alternative 3. The impact would be less than significant. No mitigation is required.

33 **Impact GEO-4: Loss of Property, Personal Injury, or Death from Slope Failure during**
 34 **Construction of Water Conveyance Features**

35 **NEPA Effects:** Alternative 3 would include the same physical/structural components as Alternative 1A,
 36 but would entail three less intakes and three less pumping plants. These differences would present a
 37 slightly lower hazard of slope failure at borrow and spoils storage sites and would not substantially
 38 change the hazard of loss of property, personal injury, or death during construction compared to
 39 Alternative 1A. The effects of Alternative 3 would, therefore, be the same as 1A. See the description and
 40 findings under Alternative 1A. There would be no adverse effect.

41 **CEQA Conclusion:** Settlement/failure of cutslopes of borrow sites and failure of soil/RTM fill slopes
 42 could result in loss of property or personal injury during construction. However, because DWR would

1 conform with Cal-OSHA and other state code requirements and conform to applicable geotechnical
2 design guidelines and standards, such as USACE design measures, the hazard would be controlled to a
3 safe level and there would be no increased likelihood of loss of property, personal injury or death due
4 to construction of Alternative 3. The impact would be less than significant. No mitigation is required.

5 **Impact GEO-5: Loss of Property, Personal Injury, or Death from Structural Failure Resulting**
6 **from Construction-Related Ground Motions during Construction of Water Conveyance Features**

7 *NEPA Effects:* Alternative 3 would include the same physical/structural components as Alternative 1A,
8 but would entail three less intakes and three less pumping plants. These differences would present a
9 slightly lower hazard of structural failure from construction-related ground motions and would not
10 substantially change the hazard of loss of property, personal injury, or death during construction
11 compared to Alternative 1A. The effects of Alternative 3 would, therefore, be the same as 1A. See the
12 description and findings under Alternative 1A. There would be no adverse effect.

13 *CEQA Conclusion:* Construction-related ground motions could initiate liquefaction, which could cause
14 failure of structures during construction, which could result in injury of workers at the construction
15 sites. However, because DWR would conform with Cal-OSHA and other state code requirements and
16 conform to applicable design guidelines and standards, such as USACE design measures, the hazard
17 would be controlled to a level that would protect worker safety (see Appendix 3B, *Environmental*
18 *Commitments*) and there would be no increased likelihood of loss of property, personal injury or death
19 due to construction of Alternative 3. The impact would be less than significant. No mitigation is
20 required.

21 **Impact GEO-6: Loss of Property, Personal Injury, or Death from Structural Failure Resulting**
22 **from Rupture of a Known Earthquake Fault during Operation of Water Conveyance Features**

23 *NEPA Effects:* Alternative 3 would include the same physical/structural components as Alternative 1A,
24 but would entail three less intakes and three less pumping plants. These differences would not present
25 a difference in the hazard of an earthquake fault and would not substantially change the hazard of loss
26 of property, personal injury, or death during construction compared to Alternative 1A. The effects of
27 Alternative 3 would, therefore, be the same as 1A. See the description and findings under Alternative
28 1A. There would be no adverse effect.

29 *CEQA Conclusion:* There are no active faults capable of surface rupture that extend into the
30 pipeline/tunnel alignment. Although the Thornton Arch and West Tracy blind thrusts occur beneath
31 the pipeline/tunnel alignment, based on available information, they do not present a hazard of surface
32 rupture and there would be no increased likelihood of loss of property, personal injury or death due to
33 operation of Alternative 3. There would be no impact. No mitigation is required.

34 **Impact GEO-7: Loss of Property, Personal Injury, or Death from Structural Failure Resulting**
35 **from Strong Seismic Shaking during Operation of Water Conveyance Features**

36 *NEPA Effects:* Alternative 3 would include the same physical/structural components as Alternative 1A,
37 but would entail three less intakes and three less pumping plants. These differences would present a
38 slightly lower hazard of seismic shaking but would not substantially change the hazard of loss of
39 property, personal injury, or death during construction compared to Alternative 1A. The effects of
40 Alternative 3 would, therefore, be the same as 1A. See the description and findings under Alternative
41 1A. There would be no adverse effect.

1 **CEQA Conclusion:** Seismically induced strong ground shaking could damage pipelines, tunnels, intake
 2 facilities, pumping plants, and other facilities. The damage could disrupt the water supply through the
 3 conveyance system. In an extreme event, flooding and inundation of structures could result from an
 4 uncontrolled release of water from the damaged conveyance system. (Please refer to Chapter 6, *Surface*
 5 *Water*, for a detailed discussion of potential flood impacts.) However, through the final design process,
 6 measures to address this hazard would be required to conform to applicable design codes, guidelines,
 7 and standards. As described in Section 9.3.1, *Methods for Analysis*, and in Appendix 3B, *Environmental*
 8 *Commitments*, such design codes, guidelines, and standards include the California Building Code and
 9 resource agency and professional engineering specifications, such as the Division of Safety of Dams
 10 *Guidelines for Use of the Consequence Hazard Matrix and Selection of Ground Motion Parameters*, DWR's
 11 Division of Flood Management *FloodSAFE Urban Levee Design Criteria*, and USACE's *Engineering and*
 12 *Design—Earthquake Design and Evaluation for Civil Works Projects*. Conformance with these codes and
 13 standards is an environmental commitment by DWR to ensure that ground shaking risks are minimized
 14 as the water conveyance features are operated. The hazard would be controlled to a safe level and
 15 there would be no increased likelihood of loss of property, personal injury or death due to operation of
 16 Alternative 3. The impact would be less than significant. No mitigation is required.

17 **Impact GEO-8: Loss of Property, Personal Injury, or Death from Structural Failure Resulting**
 18 **from Seismic-Related Ground Failure (Including Liquefaction) during Operation of Water**
 19 **Conveyance Features**

20 **NEPA Effects:** Alternative 3 would include the same physical/structural components as Alternative 1A,
 21 but would entail three less intakes and three less pumping plants. These differences would present a
 22 slightly lower hazard of structural failure from liquefaction but would not substantially change the
 23 hazard of loss of property or personal injury during construction compared to Alternative 1A. The
 24 effects of Alternative 3 would, therefore, be the same as 1A. See the description and findings under
 25 Alternative 1A. There would be no adverse effect.

26 **CEQA Conclusion:** Seismically induced ground shaking could cause liquefaction. Liquefaction could
 27 damage pipelines, tunnels, intake facilities, pumping plants, and other facilities, and thereby disrupt the
 28 water supply through the conveyance system. In an extreme event, flooding and inundation of
 29 structures could result from an uncontrolled release of water from the damaged conveyance system.
 30 (Please refer to Chapter 6, *Surface Water*, for a detailed discussion of potential flood impacts.) However,
 31 through the final design process, measures to address the liquefaction hazard would be required to
 32 conform to applicable design codes, guidelines, and standards. As described in Section 9.3.1, *Methods*
 33 *for Analysis*, and in Appendix 3B, *Environmental Commitments*, such design codes, guidelines, and
 34 standards include USACE's *Engineering and Design—Stability Analysis of Concrete Structures and Soil*
 35 *Liquefaction during Earthquakes*, by the Earthquake Engineering Research Institute. Conformance with
 36 these design standards is an environmental commitment by DWR to ensure that liquefaction risks are
 37 minimized as the water conveyance features are operated. The hazard would be controlled to a safe
 38 level and there would be no increased likelihood of loss of property, personal injury or death due to
 39 operation of Alternative 3. The impact would be less than significant. No mitigation is required.

40 **Impact GEO-9: Loss of Property, Personal Injury, or Death from Landslides and Other Slope**
 41 **Instability during Operation of Water Conveyance Features**

42 **NEPA Effects:** Alternative 3 would include the same physical/structural components as Alternative 1A,
 43 but would entail three less intakes and three less pumping plants. These differences would present a
 44 slightly lower hazard of landslides and other slope instability but would not substantially change the

1 hazard of loss of property, personal injury, or death during construction compared to Alternative 1A.
 2 The effects of Alternative 3 would, therefore, be the same as 1A. See the description and findings under
 3 Alternative 1A. There would be no adverse effect.

4 **CEQA Conclusion:** Unstable levee slopes and natural stream banks may fail, either from high pore-
 5 water pressure caused by high rainfall and weak soil, or from seismic shaking. Structures constructed
 6 on these slopes could be damaged or fail entirely as a result of slope instability. However, through the
 7 final design process, measures to address this hazard would be required to conform to applicable
 8 design codes, guidelines, and standards. As described in Section 9.3.1, *Methods for Analysis*, and in
 9 Appendix 3B, *Environmental Commitments*, such design codes, guidelines, and standards include the
 10 California Building Code and resource agency and professional engineering specifications, such as
 11 USACE's *Engineering and Design—Earthquake Design and Evaluation for Civil Works Projects*.
 12 Conformance with these codes and standards is an environmental commitment by DWR to ensure cut
 13 and fill slopes and embankments will be stable as the water conveyance features are operated and
 14 there would be no increased likelihood of loss of property, personal injury or death due to operation of
 15 Alternative 3. The impact would be less than significant. No mitigation is required.

16 **Impact GEO-10: Loss of Property, Personal Injury, or Death from Seiche or Tsunami during**
 17 **Operation of Water Conveyance Features**

18 **NEPA Effects:** Alternative 3 would include the same physical/structural components as Alternative 1A,
 19 but would entail three less intakes and three less pumping plants. These differences would present a
 20 slightly lower hazard of a seiche or tsunami but would not substantially change the hazard of loss of
 21 property, personal injury, or death during construction compared to Alternative 1A. The effects of
 22 Alternative 3 would, therefore, be the same as 1A. See the description and findings under Alternative
 23 1A. There would be no adverse effect.

24 **CEQA Conclusion:** Based on recorded tsunami wave heights at the Golden Gate (Contra Costa
 25 Transportation Agency 2009) and in the interior of the San Francisco Bay and on tsunami inundation
 26 maps prepared by the California Department of Conservation (2009), the height of a tsunami wave
 27 reaching the Suisun Marsh and the Delta would be small because of the distance from the ocean and
 28 attenuating effect of the San Francisco Bay. Similarly, the potential for a significant seiche to occur in
 29 most parts of the Plan Area is considered low because the seismic hazard and the geometry of the
 30 water bodies (i.e., wide and shallow) near conveyance facilities are not favorable for a seiche to occur.
 31 However, assuming the West Tracy fault is potentially active, a potential exists for a seiche to occur in
 32 the Clifton Court Forebay and the Byron Tract Forebay (Fugro Consultants 2011). The impact would
 33 not be significant because the Byron Tract Forebay embankment would be designed and constructed
 34 according to applicable design codes, guidelines, and standards to contain and withstand the
 35 anticipated maximum seiche wave height. There would be no increased likelihood of loss of property,
 36 personal injury or death due to operation of Alternative 3 from seiche or tsunami. The impact would be
 37 less than significant. No additional mitigation is required.

38 **Impact GEO-11: Ground Failure Caused by Increased Groundwater Surface Elevations from**
 39 **Unlined Canal Seepage as a Result of Operating the Water Conveyance Facilities**

40 **NEPA Effects:** Alternative 3 would not involve construction of unlined canals; therefore, there would be
 41 no increase in groundwater surface elevations and consequently no effect caused by canal seepage.
 42 There would be no adverse effect.

1 **CEQA Conclusion:** Alternative 3 would not involve construction of unlined canals; therefore, there
 2 would be no increase in groundwater surface elevations and consequently no impact caused by canal
 3 seepage. The impact would be less than significant. No mitigation is required.

4 **Impact GEO-12: Loss of Property, Personal Injury, or Death Resulting from Structural Failure**
 5 **Caused by Rupture of a Known Earthquake Fault at Restoration Opportunity Areas**

6 **NEPA Effects:** Conservation measures would be the same under Alternative 3 as under 1A. See
 7 description and findings under Alternative 1A. There would be no adverse effect.

8 **CEQA Conclusion:** Rupture of the Cordelia and Green Valley faults could occur at the Suisun Marsh ROA
 9 and damage ROA facilities, such as levees and berms. Damage to these features could result in their
 10 failure, causing flooding of otherwise protected areas. However, through the final design process for
 11 conservation measures in the ROAs, measures to address the fault rupture hazard would be required to
 12 conform to applicable design codes, guidelines, and standards. As described in Section 9.3.1, *Methods*
 13 *for Analysis*, and in Appendix 3B, *Environmental Commitments*, such design codes, guidelines, and
 14 standards include the Division of Safety of Dams *Guidelines for Use of the Consequence Hazard Matrix*
 15 *and Selection of Ground Motion Parameters*, DWR's Division of Flood Management *FloodSAFE Urban*
 16 *Levee Design Criteria*, and USACE's *Engineering and Design—Earthquake Design and Evaluation for Civil*
 17 *Works Projects*. Conformance with these design standards is an environmental commitment by the
 18 BDCP proponents to ensure that fault rupture risks are minimized as the conservation measures are
 19 implemented. The hazard would be controlled to a safe level and there would be no increased
 20 likelihood of loss of property, personal injury or death in the ROAs. The impact would be less than
 21 significant. No mitigation is required.

22 **Impact GEO-13: Loss of Property, Personal Injury, or Death from Structural Failure Resulting**
 23 **from Strong Seismic Shaking at Restoration Opportunity Areas**

24 **NEPA Effects:** Conservation measures would be the same under Alternative 3 as under 1A. See
 25 description and findings under Alternative 1A. There would be no adverse effect.

26 **CEQA Conclusion:** Ground shaking could damage levees, berms, and other structures. Among all the
 27 ROAs, the Suisun Marsh ROA would be the most subject to ground shaking because of its proximity to
 28 active faults. The Suisun Marsh ROA is subject to a PGA of approximately 0.31 to 0.35 g for 200-year
 29 return interval, while the PGA for the other ROAs ranges from approximately 0.11 to 0.26 g. Damage to
 30 these features could result in their failure, causing flooding of otherwise protected areas. However, as
 31 described in Section 9.3.1, *Methods for Analysis*, and in Appendix 3B, *Environmental Commitments*,
 32 design codes, guidelines, and standards, including the California Building Code and resource agency
 33 and professional engineering specifications, such as DWR's Division of Flood Management *FloodSAFE*
 34 *Urban Levee Design Criteria* and USACE's *Engineering and Design—Earthquake Design and Evaluation*
 35 *for Civil Works Projects* would be used for final design of conservation features. Conformance with these
 36 design standards is an environmental commitment by the BDCP proponents to ensure that strong
 37 seismic shaking risks are minimized as the conservation measures are operated and there would be no
 38 increased likelihood of loss of property, personal injury or death in the ROAs. The impact would be less
 39 than significant. No mitigation is required.

1 **Impact GEO-14: Loss of Property, Personal Injury, or Death from Structural Failure Resulting**
 2 **from Seismic-Related Ground Failure (Including Liquefaction) Beneath Restoration Opportunity**
 3 **Areas**

4 **NEPA Effects:** Conservation measures would be the same under Alternative 3 as under 1A. See
 5 description and findings under Alternative 1A. There would be no adverse effect.

6 **CEQA Conclusion:** Earthquake-induced ground shaking could cause liquefaction, resulting in damage to
 7 or failure of levees, berms, and other features constructed at the restoration areas. Failure of levees and
 8 other structures could result in flooding of otherwise protected areas.

9 However, through the final design process, measures to address the liquefaction hazard would be
 10 required to conform to applicable design codes, guidelines, and standards. As described in Section
 11 9.3.1, *Methods for Analysis*, and in Appendix 3B, *Environmental Commitments*, such design codes,
 12 guidelines, and standards include USACE's *Engineering and Design—Stability Analysis of Concrete*
 13 *Structures and Soil Liquefaction during Earthquakes*, by the Earthquake Engineering Research Institute.
 14 Conformance with these design standards is an environmental commitment by the BDCP proponents to
 15 ensure that liquefaction risks are minimized as the water conservation features are implemented and
 16 there would be no increased likelihood of loss of property, personal injury or death in the ROAs. The
 17 impact would be less than significant. No mitigation is required.

18 **Impact GEO-15: Loss of Property, Personal Injury, or Death from Landslides and Other Slope**
 19 **Instability at Restoration Opportunity Areas**

20 **NEPA Effects:** Conservation measures would be the same under Alternative 3 as under 1A. See
 21 description and findings under Alternative 1A. There would be no adverse effect.

22 **CEQA Conclusion:** Unstable new and existing levee and embankment slopes could fail as a result of
 23 seismic shaking and as a result of high soil-water content during heavy rainfall and cause flooding of
 24 otherwise protected areas. However, because the BDCP proponents would conform with applicable
 25 design guidelines and standards, such as USACE design measures, the hazard would be controlled to a
 26 safe level and there would be no increased likelihood of loss of property, personal injury or death in the
 27 ROAs. The impact would be less than significant. Therefore, no mitigation is required.

28 **Impact GEO-16: Loss of Property, Personal Injury, or Death from Seiche or Tsunami at**
 29 **Restoration Opportunity Areas as a Result of Implementing the Conservation Actions**

30 **NEPA Effects:** Conservation measures under Alternative 3 would be similar to that as under Alternative
 31 1A. See description and findings under Alternative 1A. There would be no adverse effect.

32 **CEQA Conclusion:** Based on recorded tsunami heights at the Golden Gate, the height of a tsunami wave
 33 reaching the construction areas would be small because of the distance from the ocean and attenuating
 34 effect of the San Francisco Bay. Similarly, the potential for a significant seiche to occur in the Plan Area
 35 that would cause loss of property, personal injury, or death at the ROAs is considered low because
 36 conditions for a seiche to occur near conveyance facilities are not favorable. The impact would be less
 37 than significant. No mitigation is required.

9.3.3.9 Alternative 4—Dual Conveyance with Modified Pipeline/Tunnel and Intakes 2, 3, and 5 (9,000 cfs; Operational Scenario H)

Impact GEO-1: Loss of Property, Personal Injury, or Death from Structural Failure Resulting from Strong Seismic Shaking of Water Conveyance Features during Construction

Earthquakes could be generated from local and regional seismic sources during construction of the Alternative 4 water conveyance facilities. Seismically induced ground shaking could cause injury of workers at the construction sites as a result of collapse of facilities.

The potential for experiencing earthquake ground shaking during construction in 2020 (during the project's near-term implementation stage) was estimated using the results of the seismic study (California Department of Water Resources 2007a). The seismic study also computed seismic ground shaking hazards at six locations in the Delta for 2005, 2050, 2100, and 2200. The results of these analyses show that the ground shakings in the Delta are not sensitive to the elapsed time since the last major earthquake (i.e., the projected shaking hazard results for 2005, 2050, 2100, and 2200 are similar).

Table 9-14 lists the expected PGA and 1.0- S_a values in 2020 at selected facility locations along the pipeline/tunnel alignment. These would also be applicable to the modified pipeline/tunnel alignment under Alternative 4. For the construction period, a ground motion return period of 72 years was assumed, corresponding to approximately 50% probability of being exceeded in 50 years. Values were estimated for a stiff soil site, as predicted by the seismic study (California Department of Water Resources 2007a), and for the anticipated soil conditions at the facility locations. No seismic study computational modeling was conducted for 2020, so the ground shaking that was computed for 2005 was used to represent the construction near-term period (i.e., 2020). Alternative 4 would include the same physical/structural components as Alternative 1A, but would entail two less intakes and two less pumping plants. These differences would present a slightly lower hazard of structural failure from seismic shaking but would not substantially change the hazard of loss of property, personal injury, or death during construction compared to Alternative 1A.

NEPA Effects: The seismic study employed time-dependent seismic source models for several major faults in the region. These models were characterized based on the elapsed times since the last major seismic events on the faults. Therefore, the exposure risks predicted by the seismic study would increase if no major events take place on these faults through 2020. The effect could be substantial because seismically-induced ground shaking could cause loss of property or personal injury at the Alternative 4 construction sites (including intake locations, pipelines from intakes to the intermediate forebay, the tunnel, and the expanded Clifton Court Forebay) as a result of collapse of facilities. For example, facilities lying directly on or near active blind faults, such as the concrete batch plants and fuel stations near Twin Cities Road and Interstate 5 and at the expanded Clifton Court Forebay, as well as the expanded Forebay itself for Alternative 4 and may have an increased likelihood of loss of property or personal injury in the event of seismically-induced ground shaking. Although these blind thrusts are not expected to rupture to the ground surface under the forebays during earthquake events, they may produce ground or near-ground shear zones, bulging, or both (California Department of Water Resources 2007a). For a map of all permanent facilities and temporary work areas associated with this conveyance alignment, see Figure M3-4 in the Mapbook Volume.

However, during construction, all active construction sites would be designed and managed to meet the safety and collapse-prevention requirements of the relevant state codes and standards listed earlier in

1 this chapter and expanded upon in Appendix 3B, *Environmental Commitments*, for the above-
2 anticipated seismic loads.

3 In particular, conformance with the following codes and standards would reduce the potential risk for
4 increased likelihood of loss of property or personal injury from structural failure resulting from strong
5 seismic shaking of water conveyance features during construction:

- 6 • DWR Division of Engineering State Water Project – Seismic Loading Criteria Report, Sept 2012.
- 7 • USACE Engineering and Design, Earthquake Design and Evaluation for Civil Works Projects, ER 1110-
8 2-1806, 1995.
- 9 • USACE Engineering and Design – Earthquake Design and Evaluation of Concrete Hydraulic Structures,
10 EM 1110-2-6053, 2007.
- 11 • USACE Engineering and Design – Response Spectra and Seismic Analysis for Concrete Hydraulic
12 Structures, EM 1110-2-6050, 1999.
- 13 • USACE Engineering and Design – Stability Analysis of Concrete Structures, EM 1110-2-2100, 2005.
- 14 • California Code of Regulations, Title 8, Sections 1509 and 3203, California Code of Regulations.

15 Generally, the applicable codes require that facilities be built so that they incur minimal damage in the
16 event of a foreseeable seismic event and that they remain functional following such an event and that
17 the facility is able to perform without catastrophic failure in the event of a maximum design earthquake
18 (the greatest earthquake reasonably expected to be generated by a specific source on the basis of
19 seismological and geological evidence). The safety requirements could include shoring, specified slope
20 angles, excavation depth restrictions for workers, lighting and other similar controls. Conformance
21 with these standards and codes are an environmental commitment of the project (see Appendix 3B,
22 *Environmental Commitments*).

23 The worker safety codes and standards specify protective measures that must be taken at construction
24 sites to minimize the risk of injury or death from structural or earth failure (e.g., utilizing personal
25 protective equipment, practicing crane and scaffold safety measures). The relevant codes and
26 standards represent performance standards that must be met by contractors and these measures are
27 subject to monitoring by state and local agencies. Cal-OSHA requirements for an IIPP and the terms of
28 the IIPP to protect worker safety are the principal measures that would be enforced at construction
29 sites.

30 Conformance with these health and safety requirements and the application of accepted, proven
31 construction engineering practices would reduce any potential risk such that construction of
32 Alternative 4 would not create an increased likelihood of loss of property, personal injury or death of
33 individuals. Therefore, there would be no adverse effect.

34 **CEQA Conclusion:** Seismically induced ground shaking that is estimated to occur and the resultant
35 ground motion anticipated at Alternative 4 construction sites, including the intake locations, the tunnel,
36 the pipelines and the forebays, could cause collapse or other failure of project facilities while under
37 construction. For example, facilities lying directly on or near active blind faults, such as the concrete
38 batch plants and fuel stations near Twin Cities Road and Interstate 5 and at the expanded Clifton Court
39 Forebay, as well as the expanded Forebay itself for Alternative 4, may have an increased likelihood of
40 loss of property or personal injury at these sites in the event of seismically-induced ground shaking.
41 However, DWR would conform with Cal-OSHA and other state code requirements, such as shoring,
42 bracing, lighting, excavation depth restrictions, required slope angles, and other measures, to protect

1 worker safety. Conformance with these standards and codes is an environmental commitment of the
 2 project (see Appendix 3B, *Environmental Commitments*). Conformance with these health and safety
 3 requirements and the application of accepted, proven construction engineering practices would reduce
 4 this risk and there would be no increased likelihood of loss of property, personal injury or death due to
 5 construction of Alternative 4. This impact would be less than significant. No mitigation is required.

6 **Impact GEO-2: Loss of Property, Personal Injury, or Death from Settlement or Collapse Caused**
 7 **by Dewatering during Construction of Water Conveyance Features**

8 Settlement of excavations could occur as a result of dewatering at Alternative 4 construction sites with
 9 shallow groundwater. Soil excavation in areas with shallow or perched groundwater levels would
 10 require the pumping of groundwater from excavations to allow for construction of facilities. This can be
 11 anticipated at all intake locations (Sites 2, 3, and 5) and pumping plant sites adjacent to the Sacramento
 12 River, where 70% of the dewatering for Alternative 4 would take place. All of the intake locations and
 13 adjacent pumping plants for Alternative 4 are located on alluvial floodbasin deposits, alluvial floodplain
 14 deposits and natural levee deposits. Similar dewatering may be necessary where intake and forebay
 15 pipelines cross waterways and major irrigation canals east of the Sacramento River and north of the
 16 proposed intermediate forebay. Unlike the pipeline/tunnel alternatives, the conveyance tunnels
 17 constructed between the three intakes and the intermediate forebay would not be anticipated to
 18 require dewatering prior to construction and would not have any associated impact.

19 Dewatering can stimulate settlement in excavation and tunneling sites. The settlement could cause the
 20 slopes of excavations to fail.

21 **NEPA Effects:** This potential effect could be substantial because settlement or collapse during
 22 dewatering could cause injury of workers at the construction sites as a result of collapse of excavations.

23 The hazard of settlement and subsequent collapse of excavations would be evaluated by assessing site-
 24 specific geotechnical and hydrological conditions at intake locations and adjacent pumping plants, as
 25 well as where intake and forebay pipelines cross waterways and major irrigation canals. A California-
 26 registered civil engineer or California-certified engineering geologist would recommend measures in a
 27 geotechnical report to address these hazards, such as seepage cutoff walls and barriers, shoring,
 28 grouting of the bottom of the excavation, and strengthening of nearby structures, existing utilities, or
 29 buried structures. As described in Section 9.3.1, *Methods for Analysis*, the measures would conform to
 30 applicable design and building codes, guidelines, and standards, such as the California Building Code
 31 and USACE's *Engineering and Design—Structural Design and Evaluation of Outlet Works*. See Appendix
 32 3B, *Environmental Commitments*.

33 In particular, conformance with the following codes and standards would reduce the potential risk for
 34 increased likelihood of loss of property or personal injury from structural failure resulting from
 35 settlement or collapse at the construction site caused by dewatering during construction:

- 36 ● DWR Division of Flood Management FloodSAFE Urban Levee Design Criteria, May 2012.
- 37 ● USACE Engineering and Design - Settlement Analysis, EM 1110-1-1904, 1990.
- 38 ● California Code of Regulations, Title 8, Sections 1509 and 3203, California Code of Regulations.

39 Generally, the applicable codes require that facilities be built in such a way that settlement is
 40 minimized. DWR would ensure that the geotechnical design recommendations are included in the
 41 design of project facilities and construction specifications to minimize the potential effects from
 42 settlement and failure of excavations. DWR would also ensure that the design specifications are

1 properly executed during construction. DWR has made an environmental commitment to conform with
 2 appropriate code and standard requirements to minimize potential risks (Appendix 3B, *Environmental*
 3 *Commitments*).

4 The worker safety codes and standards specify protective measures that must be taken at construction
 5 sites to minimize the risk of injury or death from structural or earth failure (e.g., utilizing personal
 6 protective equipment, practicing crane and scaffold safety measures). The relevant codes and
 7 standards represent performance standards that must be met by contractors and these measures are
 8 subject to monitoring by state and local agencies. Cal-OSHA requirements for an IIPP and the terms of
 9 the IIPP to protect worker safety are the principal measures that would be enforced at construction
 10 sites.

11 Conformance to these and other applicable design specifications and standards would ensure that
 12 construction of Alternative 4 would not create an increased likelihood of loss of property, personal
 13 injury or death of individuals from settlement or collapse caused by dewatering. Therefore, there
 14 would be no adverse effect.

15 **CEQA Conclusion:** Settlement or failure of excavations during construction could result in loss of
 16 property or personal injury. However, DWR would conform with Cal-OSHA and other state code
 17 requirements, such as using seepage cutoff walls, shoring, and other measures, to protect worker
 18 safety. DWR would also ensure that the design specifications are properly executed during
 19 construction. DWR has made an environmental commitment to use the appropriate code and standard
 20 requirements to minimize potential risks (Appendix 3B, *Environmental Commitments*) and there would
 21 be no increased likelihood of loss of property, personal injury or death due to construction of
 22 Alternative 4. The impact would be less than significant. No mitigation is required.

23 **Impact GEO-3: Loss of Property, Personal Injury, or Death from Ground Settlement during** 24 **Construction of Water Conveyance Features**

25 Two types of ground settlement could be induced during tunneling operations: large settlement and
 26 systematic settlement. Large settlement occurs primarily as a result of over-excavation by the
 27 tunneling shield. The over-excavation is caused by failure of the tunnel boring machine to control
 28 unexpected or adverse ground conditions (for example, running, raveling, squeezing, and flowing
 29 ground) or operator error. Large settlement can lead to the creation of voids and/or sinkholes above
 30 the tunnel. In extreme circumstances, this settlement can affect the ground surface, potentially causing
 31 loss of property or personal injury above the tunneling operation.

32 Systematic settlement usually results from ground movements that occur before tunnel supports can
 33 exit the shield and the tunnel to make full contact with the ground. Soil with higher silt and clay content
 34 tend to experience less settlement than sandy soil. Additional ground movements can occur with the
 35 deflection of the tunnel supports and over-excavation caused by steering/plowing of the tunnel boring
 36 machine at horizontal and vertical curves. A deeper tunnel induces less ground surface settlement
 37 because a greater volume of soil material is available above the tunnel to fill any systematic void space.

38 The geologic units in the area of the Alternative 4 modified pipeline/tunnel alignment are shown on
 39 Figure 9-3 and summarized in Table 9-26. The characteristics of each unit would affect the potential for
 40 settlement during tunneling operations. Segments 1 and 3, located in the Clarksburg area and the area
 41 west of Locke, respectively, contain higher amounts of sand than the other segments, so they pose a
 42 greater risk of settlement.

1 **Table 9-26. Surficial Geology Underlying Alternative 4/ Modified Pipeline/Tunnel Alignment by Segments**

Segment ^a	Geologic Unit	Geologic Unit Description
Segment 1 and Segment 2	Ql	Natural levee deposits: moderately- to well-sorted sand, with some silt and clay.
	Qb	Flood basin deposits: firm to stiff silty clay, clayey silt, and silt
	Qro	Riverbank Formation: alluvial fans from glaciated basins that consist of moderately sorted to well sort sand, gravel, silt and minor clay
	Qm2e	Eolian sand: well-sorted fine- to medium-grained sand
Segment 3	Ql	Natural levee deposits: moderately- to well-sorted sand, with some silt and clay.
	Qb	Flood basin deposits: firm to stiff silty clay, clayey silt, and silt
	Qfp	Floodplain deposits: dense, sandy to silty clay
	Qpm	Delta mud: mud and peat with minor silt or sand
Segment 4	Qpm	Delta mud: mud and peat with minor silt or sand
	Qb	Flood basin deposits: firm to stiff silty clay, clayey silt, and silt.
Segment 5 and Segment 6	Qpm	Delta mud: mud and peat with minor silt or sand
Segment 7	Qpm	Delta mud: mud and peat with minor silt or sand
	Qfp	Floodplain deposits: dense, sandy to silty clay
Segment 8	Qfp	Floodplain deposits: dense, sandy to silty clay
	Qch	Alluvial fans and terraces from non-glaciated drainage basins: clay, silt, sand, and gravel.

Sources: Hansen et al. 2001 and Atwater 1982.

^a The segments are shown on Figure 9-3.

2
3 Given the likely design depth of the tunnel, the potential for excessive systematic settlement expressed
4 at the ground surface caused by tunnel installation is thought to be relatively low. Operator errors or
5 highly unfavorable/unexpected ground conditions could result in larger settlement. Large ground
6 settlements caused by tunnel construction are almost always the result of using inappropriate
7 tunneling equipment (incompatible with the ground conditions), improperly operating the machine, or
8 encountering sudden or unexpected changes in ground conditions.

9 **NEPA Effects:** The potential effect could be substantial because ground settlement could occur during
10 the tunneling operation. During detailed project design, a site-specific subsurface geotechnical
11 evaluation would be conducted along the modified pipeline/tunnel alignment to verify or refine the
12 findings of the preliminary geotechnical investigation The tunneling equipment and drilling methods
13 would be reevaluated and refined based on the results of the investigations, and field procedures for
14 sudden changes in ground conditions would be implemented to minimize or avoid ground settlement.
15 A California-registered civil engineer or California-certified engineering geologist would recommend
16 measures to address these hazards, such as specifying the type of tunnel boring machine to be used in a
17 given segment. The results of the site-specific evaluation and the engineer's recommendations would
18 be documented in a detailed geotechnical report prepared in accordance with state guidelines, in
19 particular *Guidelines for Evaluating and Mitigating Seismic Hazards in California* (California Geological
20 Survey 2008).

1 As described in Section 9.3.1, *Methods for Analysis*, the measures would conform to applicable design
 2 and building codes, guidelines, and standards, such as USACE design measures. See Appendix 3B,
 3 *Environmental Commitments*.

4 In particular, conformance with the following codes and standards would reduce the potential risk for
 5 increased likelihood of loss of property or personal injury from ground settlement above the tunneling
 6 operation during construction:

- 7 • DWR Division of Engineering State Water Project – Seismic Loading Criteria Report, Sept 2012.
- 8 • DWR Division of Flood Management FloodSAFE Urban Levee Design Criteria, May 2012.
- 9 • California Code of Regulations, Title 8, Sections 1509 and 3203, California Code of Regulations.

10 As described in detail in Impacts GEO-1 and GEO-2, DWR would ensure that the geotechnical design
 11 recommendations are included in the design of project facilities and construction specifications to
 12 minimize the potential effects from settlement. DWR would also ensure that the design specifications
 13 are properly executed during construction. DWR has made this conformance and monitoring process
 14 an environmental commitment of the BDCP (Appendix 3B, *Environmental Commitments*).

15 Generally, the applicable codes require that facilities be built so that they are designed for a landside
 16 slope stability and seepage/underseepage factors of safety greater than 1.0 (i.e., stable) and would
 17 therefore be less impacted in the event of ground settlement. The worker safety codes and standards
 18 specify protective measures that must be taken at construction sites to minimize the risk of injury or
 19 death from structural or earth failure (e.g., utilizing personal protective equipment, practicing crane
 20 and scaffold safety measures). The relevant codes and standards represent performance standards that
 21 must be met by contractors and these measures are subject to monitoring by state and local agencies.
 22 Cal-OSHA requirements for an IIPP and the terms of the IIPP to protect worker safety are the principal
 23 measures that would be enforced at construction sites.

24 Conformance to these and other applicable design specifications and standards would ensure that
 25 construction of Alternative 4 would not create an increased likelihood of loss of property, personal
 26 injury or death of individuals from ground settlement. Therefore, there would be no adverse effect.

27 **CEQA Conclusion:** Ground settlement above the tunneling operation could result in loss of property or
 28 personal injury during construction. However, DWR would conform with Cal-OSHA, USACE, and other
 29 design requirements to protect worker safety. DWR would also ensure that the design specifications
 30 are properly executed during construction. DWR has made an environmental commitment to use the
 31 appropriate code and standard requirements to minimize potential risks (Appendix 3B, *Environmental*
 32 *Commitments*). Hazards to workers and project structures would be controlled at safe levels and there
 33 would be no increased likelihood of loss of property, personal injury or death due to construction of
 34 Alternative 4. The impact would be less than significant. No mitigation is required.

35 **Impact GEO-4: Loss of Property, Personal Injury, or Death from Slope Failure during** 36 **Construction of Water Conveyance Features**

37 Excavation of borrow material could result in failure of cut slopes and application of temporary spoils
 38 and RTM at storage sites could cause excessive settlement in the spoils, potentially causing injury of
 39 workers at the construction sites. Soil and sediment, especially those consisting of loose alluvium and
 40 soft peat or mud, would be particularly prone to failure and movement. Additionally, groundwater is
 41 expected to be within a few feet of the ground surface in these areas; this may make excavations more
 42 prone to failure.

1 While specific borrow sources have not yet been secured near the Alternative 4 alignment, several
 2 potential locations within the project area have been identified based on geologic data presented
 3 through the DRMS study. Borrow site locations identified outside the project area were based on
 4 reviews of published geologic maps, specifically the California Geological Survey Map No. 1A
 5 Sacramento Quadrangle (1981) and Map No. 5A San Francisco-San Jose Quadrangle (1991). Borrow
 6 areas for construction of intakes, sedimentation basins, pumping plants, forebays, and other supporting
 7 facilities would be sited near the locations of these structures (generally within 10 miles). Along the
 8 modified pipeline/tunnel alignment, selected areas would also be used for disposing of the byproduct
 9 (RTM) of tunneling operations. Table 9-27 describes the geology of these areas as mapped by Atwater
 10 (1982) (Figure 9-3).

11 **Table 9-27. Geology Underlying Borrow and Reusable Tunnel Material Storage Areas—Alternative 4**

Segment ^a	Geologic Unit	Geologic Unit Description
Segment 1 Borrow and/or Spoil Area	Ql	Natural levee deposits: moderately to well-sorted sand, with some silt and clay
	Qb	Flood basin deposits: firm to stiff silty clay, clayey silt, and silt
Onsite Borrow Areas	Ql	Natural levee deposits: moderately to well-sorted sand, with some silt and clay
	Qb	Flood basin deposits: firm to stiff silty clay, clayey silt, and silt
	Qymc	Alluvial fans and terraces from non-glaciated drainage basins: sand, silt and gravel
	Qfp	Floodplain deposits: dense, sandy to silty clay
	Qch	Alluvial fans and terraces from non-glaciated drainage basins: clay, silt, sand, and gravel.
Segment 2 Reusable Tunnel Material Area	Ql	Natural levee deposits: moderately to well-sorted sand, with some silt and clay
	Qb	Flood basin deposits: firm to stiff silty clay, clayey silt, and silt
	Qry	Riverbank Formation: alluvial fans from glaciated basins that consist of moderately sorted to well-sorted sand, gravel, silt, and minor clay
Segment 3 Reusable Tunnel Material Area	Qb	Flood basin deposits: firm to stiff silty clay, clayey silt, and silt
	Qfp	Floodplain deposits: dense sandy to silty clay
Segment 4 Reusable Tunnel Material Area	Qb	Flood basin deposits: firm to stiff silty clay, clayey silt, and silt
	Ql	Natural levee deposits: moderately to well-sorted sand, with some silt and clay
	Qpm	Delta mud: mud and peat with minor silt or sand
Segment 7 Reusable Tunnel Material Area	Qymc	Alluvial fans and terraces from non-glaciated drainage basins: sand, silt and gravel
	Qfp	Floodplain deposits: dense sandy to silty clay
	Qch	Alluvial fans and terraces from non-glaciated drainage basins: clay, silt, sand, and gravel

Source: Hansen et al. 2001; Atwater 1982.

^a The segments are shown on Figure 9-3.

12

13 **NEPA Effects:** The potential effect could be substantial because excavation of borrow material and the
 14 resultant cutslopes and potential failure of spoils/RTM fill slopes could cause injury of workers at the
 15 construction sites.

1 Excavations in borrow areas would be designed to avoid excessive ground movements on adjacent
2 areas and soil “boiling” (i.e., upwelling of groundwater) at the bottom of the excavation. Spoils would be
3 placed in 12-inch lifts with proper compaction and stored no higher than 12 feet above preconstruction
4 ground elevation with maximum side slopes of 5H:1V. During design, the potential for native ground
5 settlement below the spoils would be evaluated by a geotechnical engineer using site-specific
6 geotechnical and hydrological information. The use of shoring, seepage cutoff walls, and ground
7 modifications to prevent slope instability, soil boiling, or excessive settlement would be considered in
8 the design. As described in Section 9.3.1, *Methods for Analysis*, the measures would conform to
9 applicable design and building codes, guidelines, and standards, such as the California Building Code
10 and USACE’s *Engineering and Design—Structural Design and Evaluation of Outlet Works*.

11 In addition to the risk of slope failure at borrow sites and spoils and RTM sites, there are also potential
12 impacts on levee stability resulting from construction of Alternative 4 water conveyance facilities. The
13 intakes would be sited along the existing Sacramento River levee system, requiring reconstruction of
14 levees to provide continued flood management. At each intake pumping plant site, a new setback levee
15 (ring levee) would be constructed. The space enclosed by the setback levee would be filled up to the
16 elevation of the top of the setback levee, creating a building pad for the adjacent pumping plant.

17 As discussed in Chapter 3, *Description of the Alternatives*, the new levees would be designed to provide
18 an adequate Sacramento River channel cross section and to provide the same level of flood protection
19 as the existing levee and would be constructed to geometries that meet or exceed PL 84-99 standards.
20 CALFED and DWR have adopted PL 84-99 as the preferred design standard for Delta levees. Transition
21 levees would be constructed to connect the existing levees to the new setback levees. A typical new
22 levee would have a broad-based, generally asymmetrical triangular cross section. The levee height
23 considered wind and wave erosion. As measured from the adjacent ground surface on the landside
24 vertically up to the elevation of the levee crest, would range from approximately 20 to 45 feet to
25 provide adequate freeboard above anticipated water surface elevations. The width of the levee (toe of
26 levee to toe of levee) would range from approximately 180 to 360 feet. The minimum crest width of the
27 levee would be 20 feet; however, in some places it would be larger to accommodate roadways and
28 other features. Cut-off walls would be constructed to avoid seepage, and the minimum slope of levee
29 walls would be three units horizontal to one unit vertical. All levee reconstruction will conform with
30 applicable state and federal flood management engineering and permitting requirements.

31 Depending on foundation material, foundation improvements would require excavation and
32 replacement of soil below the new levee footprint and potential ground improvement. The levees
33 would be armored with riprap—small to large angular boulders—on the waterside. Intakes would be
34 constructed using a sheetpile cofferdam in the river to create a dewatered construction area that would
35 encompass the intake site. The cofferdam would lie approximately 10–35 feet from the footprint of the
36 intake and would be built from upstream to downstream, with the downstream end closed last. The
37 distance between the face of the intake and the face of the cofferdam would be dependent on the
38 foundation design and overall dimensions. The length of each temporary cofferdam would vary by
39 intake location, but would range from 740 to 2,440 feet. Cofferdams would be supported by steel sheet
40 piles and/or king piles (heavy H-section steel piles). Installation of these piles may require both impact
41 and vibratory pile drivers. Some clearing and grubbing of levees would be required prior to installation
42 of the sheet pile cofferdam, depending on site conditions. Additionally, if stone bank protection, riprap,
43 or mature vegetation is present at intake construction site, it would be removed prior to sheet pile
44 installation.

1 DWR would ensure that the geotechnical design recommendations are included in the design of project
 2 facilities and construction specifications to minimize the potential effects from failure of excavations
 3 and settlement. DWR would also ensure that the design specifications are properly executed during
 4 construction.

5 In particular, conformance with the following codes and standards would reduce the potential risk for
 6 increased likelihood of loss of property or personal injury from settlement/failure of cutslopes of
 7 borrow sites and failure of soil or RTM fill slopes during construction:

- 8 • DWR Division of Engineering State Water Project – Seismic Loading Criteria Report, Sept 2012.
- 9 • DWR Division of Flood Management FloodSAFE Urban Levee Design Criteria, May 2012.
- 10 • California Code of Regulations, Title 8, Sections 1509 and 3203, California Code of Regulations.

11 Generally, the applicable codes require that facilities be built to certain factors of safety in order to
 12 ensure that facilities perform as designed for the life of the structure despite various soil parameters.
 13 The worker safety codes and standards specify protective measures that must be taken at construction
 14 sites to minimize the risk of injury or death from structural or earth failure (e.g., utilizing personal
 15 protective equipment, practicing crane and scaffold safety measures). The relevant codes and
 16 standards represent performance standards that must be met by contractors and these measures are
 17 subject to monitoring by state and local agencies. Cal-OSHA requirements for an IIPP and the terms of
 18 the IIPP to protect worker safety are the principal measures that would be enforced at construction
 19 sites.

20 Conformance to these and other applicable design specifications and standards would ensure that
 21 construction of Alternative 4 would not create an increased likelihood of loss of property, personal
 22 injury or death of individuals from slope failure at borrow sites and spoils and RTM storage sites. The
 23 reconstruction of levees would improve levee stability over existing conditions due to improved side
 24 slopes, erosion countermeasures (geotextile fabrics, rock revetments, riprap, or other material),
 25 seepage reduction measures, and overall mass. Therefore, there would be no adverse effect.

26 **CEQA Conclusion:** Settlement/failure of cutslopes of borrow sites and failure of soil/RTM fill slopes
 27 could result in loss of property or personal injury during construction. However, because DWR would
 28 conform with Cal-OSHA and other state code requirements and conform to applicable geotechnical
 29 design guidelines and standards, such as USACE design measures, the hazard would be controlled to a
 30 safe level and there would be no increased likelihood of loss of property, personal injury or death due
 31 to construction of Alternative 4 at borrow sites and spoils and RTM storage sites. The reconstruction of
 32 levees would improve levee stability over existing conditions due to improved side slopes, erosion
 33 countermeasures, seepage reduction measures, and overall mass. The impact would be less than
 34 significant. No mitigation is required.

35 **Impact GEO-5: Loss of Property, Personal Injury, or Death from Structural Failure Resulting** 36 **from Construction-Related Ground Motions during Construction of Water Conveyance Features**

37 Pile driving and other heavy equipment operations would cause vibrations that could initiate
 38 liquefaction and associated ground movements in places where soil and groundwater conditions are
 39 present to allow liquefaction to occur. The consequences of liquefaction could be manifested in terms of
 40 compaction or settlement, loss of bearing capacity, lateral spreading (horizontal soil movement),
 41 increased lateral soil pressure, and buoyancy within zones of liquefaction. These consequences could
 42 damage nearby structures and levees.

1 The lateral extent (or influenced distance) of damage potential caused by pile driving and heavy
2 equipment operations depends on many factors, including soil conditions, the piling hammer used,
3 frequency of piling, and the vibration tolerance of structures and levees.

4 Pile driving would be conducted at the intakes, where, based on boring logs, soil materials subject to
5 liquefaction (e.g., saturated, poorly graded sand) are present. During project design, site-specific
6 geotechnical and groundwater investigations would be conducted to build upon existing data (e.g.,
7 California Department of Water Resources 2010a, 2010b, 2011) to identify and characterize the
8 vertical (depth) and horizontal (spatial) variability in soil bearing capacity and extent of liquefiable soil.
9 Engineering soil parameters that could be used to assess the liquefaction potential, such as (SPT) blow
10 counts, (CPT) penetration tip pressure/resistance, and gradation of soil, would also be obtained. SPT
11 blow counts and CPT tip pressure are used to estimate soil resistance to cyclic loadings by using
12 empirical relationships that were developed based on occurrences of liquefaction (or lack of them)
13 during past earthquakes. The resistance then can be compared to cyclic shear stress induced by the
14 design earthquake (i.e., the earthquake that is expected to produce the strongest level of ground
15 shaking at a site to which it is appropriate to design a structure to withstand). If soil resistance is less
16 than induced stress, the potential of having liquefaction during the design earthquakes is high. It is also
17 known that soil with high “fines” (i.e., silt- and clay-sized particles) content are less susceptible to
18 liquefaction.

19 **NEPA Effects:** The potential effect could be substantial because construction-related ground motions
20 could initiate liquefaction, which could cause failure of structures during construction, which could
21 result in injury of workers at the construction sites.

22 During design, the facility-specific potential for liquefaction would be investigated by a geotechnical
23 engineer. The potential effects of construction vibrations on nearby structures, levees, and utilities
24 would be evaluated using specific piling information (such as pile type, length, spacing, and pile-driving
25 hammer to be used). In areas determined to have a potential for liquefaction, the California-registered
26 civil engineer or California-certified engineering geologist would develop design strategies and
27 construction methods to ensure that pile driving and heavy equipment operations do not damage
28 facilities under construction and surrounding structures, and do not threaten the safety of workers at
29 the site. As shown in Figure 9-6, the area south of the Sacramento River all the way across Woodward
30 Island, which Alternative 4 crosses through, has medium to medium-high potential for levee
31 liquefaction damage. Three barge unloading facilities are located in this medium to medium-high
32 potential for levee liquefaction damage area. Design measures may include predrilling or jetting, using
33 open-ended pipe piles to reduce the energy needed for pile penetration, using CIDH piles/piers that do
34 not require driving, using pile jacking to press piles into the ground by means of a hydraulic system, or
35 driving piles during the drier summer months. Field data collected during design also would be
36 evaluated to determine the need for and extent of strengthening levees, embankments, and structures
37 to reduce the effect of vibrations. These construction methods would conform with current seismic
38 design codes and requirements, as described in Appendix 3B, *Environmental Commitments*. Such design
39 standards include USACE’s *Engineering and Design—Stability Analysis of Concrete Structures and Soil*
40 *Liquefaction during Earthquakes*, by the Earthquake Engineering Research Institute.

41 DWR has made the environmental commitment (see Appendix 3B, *Environmental Commitments*) that
42 the construction methods recommended by the geotechnical engineer are included in the design of
43 project facilities and construction specifications to minimize the potential for construction-induced
44 liquefaction. DWR also has committed to ensure that these methods are followed during construction.

1 In particular, conformance with the following codes and standards would reduce the potential risk for
 2 increased likelihood of loss of property or personal injury from structural failure resulting from
 3 construction-related ground motions:

- 4 • USACE Engineering and Design - Design of Pile Foundations, EM 1110-2-2906, 1991
- 5 • USACE Engineering and Design, Earthquake Design and Evaluation for Civil Works Projects, ER 1110-
 6 2-1806, 1995
- 7 • California Code of Regulations, Title 8, Sections 1509 and 3203, California Code of Regulations.

8 Generally, the applicable codes require that facilities be built so that if soil in the foundation or
 9 surrounding area are subject to liquefaction, the removal or densification of the liquefiable material
 10 should be considered, along with alternative foundation designs. Additionally, any modification to a
 11 federal levee system would require USACE approval under 33 USC 408 (a 408 Permit) and would have
 12 to pass quality assurance review by the Major Subordinate Command prior to being forwarded to
 13 USACE headquarters for final approval by the Chief of Engineers.

14 The worker safety codes and standards specify protective measures that must be taken at construction
 15 sites to minimize the risk of injury or death from structural or earth failure (e.g., utilizing personal
 16 protective equipment, practicing crane and scaffold safety measures). The relevant codes and
 17 standards represent performance standards that must be met by contractors and these measures are
 18 subject to monitoring by state and local agencies. Cal-OSHA requirements for an IIPP and the terms of
 19 the IIPP to protect worker safety are the principal measures that would be enforced at construction
 20 sites.

21 Conformance to construction method recommendations and other applicable specifications would
 22 ensure that construction of Alternative 4 would not create an increased likelihood of loss of property,
 23 personal injury or death of individuals due to construction-related ground motion and resulting
 24 potential liquefaction in the work area. Therefore, there would be no adverse effect.

25 **CEQA Conclusion:** Construction-related ground motions could initiate liquefaction, which could cause
 26 failure of structures during construction. However, because DWR would conform with Cal-OSHA and
 27 other state code requirements and conform to applicable design guidelines and standards, such as
 28 USACE design measures, the hazard would be controlled to a level that would protect worker safety
 29 (see Appendix 3B, *Environmental Commitments*) and there would be no increased likelihood of loss of
 30 property, personal injury or death due to construction of Alternative 4. The impact would be less than
 31 significant. No mitigation is required.

32 **Impact GEO-6: Loss of Property, Personal Injury, or Death from Structural Failure Resulting** 33 **from Rupture of a Known Earthquake Fault during Operation of Water Conveyance Features**

34 According to the available AP Fault Zone Maps, none of the Alternative 4 facilities would cross or be
 35 within any known active fault zones. However, numerous AP fault zones have been mapped west of the
 36 conveyance alignment (Figure 9-5). The closest AP fault zone would be the Greenville fault, located
 37 approximately 7.6 miles west of the conveyance facilities. Because none of the Alternative 4
 38 constructed facilities would be within any of the fault zones (which include the area approximately
 39 200 to 500 feet on each side of the mapped surface trace to account for potential branches of active
 40 faults), the potential that the facilities would be directly subject to fault offsets is negligible.

41 In the Delta, active or potentially active blind thrust faults were identified in the seismic study.
 42 Segments 3, and 4 of the Alternative 4 conveyance alignment (which is the same as the Modified

1 Pipeline/Tunnel Alignment in Figure 9-3) would cross the Thornton Arch fault zone. The western part
2 of the proposed expanded Clifton Court Forebay is underlain by the West Tracy fault. Although these
3 blind thrusts are not expected to rupture to the ground surface under the forebays during earthquake
4 events, they may produce ground or near-ground shear zones, bulging, or both (California Department
5 of Water Resources 2007a). If the West Tracy fault is potentially active, it could cause surface
6 deformation in the western part of the existing Clifton Court Forebay. Because the western part of the
7 expanded Clifton Court Forebay is also underlain by the hanging wall of the fault, this part of the
8 forebay may also experience uplift and resultant surface deformation (Fugro Consultants 2011). In the
9 seismic study (California Department of Water Resources 2007a), the Thornton Arch and West Tracy
10 blind thrusts have been assigned 20% and 90% probabilities of being active, respectively. The depth to
11 the Thornton Arch blind fault is unknown. The seismic study indicates that the West Tracy fault dies
12 out as a discernible feature within approximately 3,000 to 6,000 feet bgs [in the upper 1- to 2-second
13 depth two-way time, estimated to be approximately 3,000 to 6,000 feet using the general velocity
14 function as published in the Association of Petroleum Geologists Pacific Section newsletter (Tolmachoff
15 1993)].

16 It appears that the potential of having any shear zones, bulging, or both at the depths of the modified
17 pipeline/tunnel is low because the depth to the blind thrust faults is generally deep and there is no
18 credible evidence to indicate that the faults could experience displacement within the depth of the
19 modified pipeline/tunnel.

20 **NEPA Effects:** The effect would not be adverse because no active faults extend into the Alternative 4
21 alignment. Additionally, although the Thornton Arch and West Tracy blind thrusts occur beneath the
22 Alternative 4 alignment, they do not present a hazard of surface rupture based on available
23 information, including the AP Earthquake Fault Zone Map showing faults capable of surface rupture
24 (Figure 9-5).

25 However, because there is limited information regarding the depths of the Thornton Arch and West
26 Tracy blind thrusts, seismic surveys would be performed on the blind thrust during the design phase to
27 determine the depths to the top of the faults. More broadly, design-level geotechnical studies would be
28 prepared by a geotechnical engineer licensed in the state of California during project design. The
29 studies would further assess site-specific conditions at and near all the project facility locations,
30 including seismic activity, soil liquefaction, and other potential geologic and soil-related hazards. This
31 information would be used to verify assumptions and conclusions included in the EIR/EIS. The
32 geotechnical engineer's recommended measures to address adverse conditions would conform to
33 applicable design codes, guidelines, and standards. Potential design strategies or conditions could
34 include avoidance (deliberately positioning structures and lifelines to avoid crossing identified shear
35 rupture zones), geotechnical engineering (using the inherent capability of unconsolidated geomaterials
36 to "locally absorb" and distribute distinct bedrock fault movements) and structural engineering
37 (engineering the facility to undergo some limited amount of ground deformation without collapse or
38 significant damage).

39 As described in Section 9.3.1, *Methods for Analysis*, such design codes, guidelines, and standards are
40 considered environmental commitments by DWR (see also Appendix 3B, *Environmental Commitments*).
41 For construction of the water conveyance facilities, the codes and standards would include the
42 California Building Code and resource agency and professional engineering specifications, such as the
43 Division of Safety of Dams *Guidelines for Use of the Consequence Hazard Matrix and Selection of Ground*
44 *Motion Parameters*, DWR's Division of Flood Management *FloodSAFE Urban Levee Design Criteria*, and
45 USACE's *Engineering and Design—Earthquake Design and Evaluation for Civil Works Projects*. These

1 codes and standards include minimum performance standards for structural design, given site-specific
2 subsurface conditions.

3 DWR would ensure that the geotechnical design recommendations are included in the design of project
4 facilities and construction specifications to minimize the potential effects from seismic events and the
5 presence of adverse soil conditions. DWR would also ensure that the design specifications are properly
6 executed during construction.

7 In particular, conformance with the following codes and standards would reduce the potential risk for
8 increased likelihood of loss of property or personal injury from structural failure resulting from surface
9 rupture resulting from a seismic event during operation:

- 10 • DWR Division of Engineering State Water Project – Seismic Loading Criteria Report, Sept 2012.
- 11 • USACE Engineering and Design – Time-History Dynamic Analysis of Concrete Hydraulic Structure, EM
12 1110-2-6051, 2003.
- 13 • USACE Engineering and Design – Response Spectra and Seismic Analysis for Concrete Hydraulic
14 Structures, EM 1110-2-6050, 1999.
- 15 • American Society of Civil Engineers Minimum Design Loads for Buildings and Other Structures,
16 ASCE-7-05, 2005.
- 17 • California Code of Regulations, Title 8, Section 3203, California Code of Regulations.

18 Generally, the applicable codes require that facilities be built so that they incur minimal damage in the
19 event of a foreseeable seismic event and that they remain functional following such an event and that
20 the facility is able to perform without catastrophic failure in the event of a maximum design earthquake
21 (the greatest earthquake reasonably expected to be generated by a specific source on the basis of
22 seismological and geological evidence).

23 The worker safety codes and standards specify protective measures that must be taken at construction
24 sites to minimize the risk of injury or death from structural or earth failure (e.g., utilizing personal
25 protective equipment). The relevant codes and standards represent performance standards that must
26 be met by contractors and these measures are subject to monitoring by state and local agencies. Cal-
27 OSHA requirements for an IIPP and the terms of the IIPP to protect worker safety are the principal
28 measures that would be enforced at construction sites.

29 Conformance to these and other applicable design specifications and standards would ensure that
30 operation of Alternative 4 would not create an increased likelihood of loss of property, personal injury
31 or death of individuals in the event of ground movement in the vicinity of the Thornton Arch fault zone
32 and West Tracy, blind thrust would not jeopardize the integrity of the surface and subsurface facilities
33 along the Alternative 4 conveyance alignment or the proposed expanded Clifton Court Forebay and
34 associated facilities adjacent to the existing Clifton Court Forebay. Therefore, there would be no
35 adverse effect.

36 **CEQA Conclusion:** There are no active faults capable of surface rupture that extend into the Alternative
37 4 modified pipeline/tunnel alignment. Although the Thornton Arch and West Tracy blind thrusts occur
38 beneath the Alternative 4 modified pipeline/tunnel alignment, based on available information, they do
39 not present a hazard of surface rupture and there would be no increased likelihood of loss of property,
40 personal injury or death due to operation of Alternative 4. There would be no impact. No mitigation is
41 required.

1 **Impact GEO-7: Loss of Property, Personal Injury, or Death from Structural Failure Resulting**
 2 **from Strong Seismic Shaking during Operation of Water Conveyance Features**

3 Earthquake events may occur on the local and regional seismic sources during operation of the
 4 Alternative 4 water conveyance facilities. The ground shaking could damage pipelines, tunnels, intake
 5 facilities, pumping plants, and other facilities disrupting the water supply through the conveyance
 6 system. In an extreme event of strong seismic shaking, uncontrolled release of water from damaged
 7 pipelines, tunnels, intake facilities, pumping plants, and other facilities could cause flooding, disruption
 8 of water supplies to the south, and inundation of structures. These effects are discussed more fully in
 9 Appendix 3E, *Potential Seismicity and Climate Change Risks to SWP/CVP Water Supplies*.

10 Table 9-17 lists the expected PGA and 1.0- S_a values in 2025 at selected facility locations along the
 11 pipeline/tunnel alignment. Alternative 4 would include the same physical/structural components as
 12 Alternative 1A, but would entail two less intakes and two less pumping plants. These differences would
 13 present a slightly lower hazard of seismic shaking but would not substantially change the hazard of loss
 14 of property or personal injury during construction compared to Alternative 1A.

15 For early long-term, earthquake ground motions with return periods of 144 years and 975 years were
 16 estimated from the results presented in the seismic study (California Department of Water Resources
 17 2007a). The 144-year and 975-year ground motions correspond to the OBE (i.e., an earthquake that has
 18 a 50% probability of exceedance in a 100-year period (which is equivalent to a 144-year return period
 19 event) and the MDE (i.e., an earthquake that causes ground motions that have a 10% chance of being
 20 exceeded in 100 years) design ground motions, respectively. Values were estimated for a stiff soil site
 21 (as predicted in the seismic study), and for the anticipated soil conditions at the facility locations. No
 22 seismic study results exist for 2025, so the ground shaking estimated for the 2050 were used for Early
 23 Long-term (2025).

24 Table 9-17 shows that the proposed facilities would be subject to moderate-to-high earthquake ground
 25 shaking through 2025. All facilities would be designed and constructed in accordance with the
 26 requirements of the design guidelines and building codes described in Appendix 3B. Site-specific
 27 geotechnical information would be used to further assess the effects of local soil on the OBE and MDE
 28 ground shaking and to develop design criteria that minimize damage potential.

29 **NEPA Effects:** This potential effect could be substantial because strong ground shaking could damage
 30 pipelines, tunnels, intake facilities, pumping plants, and other facilities and result in loss of property or
 31 personal injury. The damage could disrupt the water supply through the conveyance system. In an
 32 extreme event, an uncontrolled release of water from the conveyance system could cause flooding and
 33 inundation of structures. Please refer to Chapter 6, *Surface Water* and Appendix 3E, *Potential Seismicity*
 34 *and Climate Change Risks to SWP/CVP Water Supplies*, for a detailed discussion of potential flood effects.

35 The structure of the underground conveyance facility would decrease the likelihood of loss of property
 36 or personal injury of individuals from structural shaking of surface and subsurface facilities along the
 37 Alternative 4 conveyance alignment in the event of strong seismic shaking. The conveyance pipeline
 38 will be lined with precast concrete which will be installed continuously following the advancement of a
 39 pressurized tunnel boring machine. The lining consists of precast concrete segments inter-connected to
 40 maintain alignment and structural stability during construction. Reinforced concrete segments are
 41 precast to comply with strict quality control. High performance gasket maintains water tightness at the
 42 concrete joints, while allowing the joint to rotate and accommodate movements during intense ground
 43 shaking. PCTL has been used extensively in seismically active locations such as Japan, Puerto Rico,
 44 Taiwan, Turkey, Italy and Greece. The adoption of PCTL in the United States started about 20 years ago,

1 including many installations in seismically active areas such as Los Angeles, San Diego, Portland and
 2 Seattle. PCTL provides better seismic performance than conventional tunnels for several reasons:

- 3 • higher quality control using precast concrete
- 4 • better ring-build precision with alignment connectors
- 5 • backfill grouting for continuous ground to tunnel support
- 6 • segment joints provide flexibility and accommodate deformation during earthquakes
- 7 • high performance gasket to maintain water tightness during and after seismic movement

8 Reviewing the last 20 years of PCTL seismic performance histories, it can be concluded that little or no
 9 damage to PCTL was observed for major earthquakes around the world. Case studies of the response of
 10 PCTL to large seismic events have shown that PCTL should not experience significant damage for
 11 ground acceleration less than 0.5g (Dean et al. 2006). The design PGA for a 975-year return period is
 12 0.49g (California Department of Water Resources 2010i, Table 4-4). Based on this preliminary data, the
 13 Delta tunnels can be designed to withstand the anticipated seismic loads.

14 Design-level geotechnical studies would be conducted by a licensed civil engineer who practices in
 15 geotechnical engineering. The studies would assess site-specific conditions at and near all the project
 16 facility locations and provide the basis for designing the conveyance features to withstand the peak
 17 ground acceleration caused by fault movement in the region. The California-registered civil engineer or
 18 California-certified engineering geologist's recommended measures to address this hazard would
 19 conform to applicable design codes, guidelines, and standards. As described in Section 9.3.1, *Methods*
 20 *for Analysis*, and in Appendix 3B, *Environmental Commitments*, such design codes, guidelines, and
 21 standards include the California Building Code and resource agency and professional engineering
 22 specifications, such as the Division of Safety of Dams *Guidelines for Use of the Consequence Hazard*
 23 *Matrix and Selection of Ground Motion Parameters*, DWR's Division of Flood Management *FloodSAFE*
 24 *Urban Levee Design Criteria*, and USACE's *Engineering and Design—Earthquake Design and Evaluation*
 25 *for Civil Works Projects*. Conformance with these codes and standards are an environmental
 26 commitment by DWR to ensure that ground shaking risks are minimized as the water conveyance
 27 features are operated.

28 DWR would ensure that the geotechnical design recommendations are included in the design of project
 29 facilities and construction specifications to minimize the potential effects from seismic events and the
 30 presence of adverse soil conditions. DWR would also ensure that the design specifications are properly
 31 executed during construction. See Appendix 3B, *Environmental Commitments*.

32 In particular, conformance with the following codes and standards would reduce the potential risk for
 33 increased likelihood of loss of property or personal injury from structural failure resulting from strong
 34 seismic shaking of water conveyance features during operations:

- 35 • DWR Division of Engineering State Water Project – Seismic Loading Criteria Report, Sept 2012.
- 36 • USACE Engineering and Design – Time-History Dynamic Analysis of Concrete Hydraulic Structure, EM
 37 1110-2-6051, 2003.
- 38 • USACE Engineering and Design – Response Spectra and Seismic Analysis for Concrete Hydraulic
 39 Structures, EM 1110-2-6050, 1999.
- 40 • American Society of Civil Engineers Minimum Design Loads for Buildings and Other Structures,
 41 ASCE-7-05, 2005.

- California Code of Regulations, Title 8, Section 3203, California Code of Regulations.

Generally, the applicable codes require that facilities be built so that they incur minimal damage in the event of a foreseeable seismic event and that they remain functional following such an event and that the facility is able to perform without catastrophic failure in the event of a maximum design earthquake (the greatest earthquake reasonably expected to be generated by a specific source on the basis of seismological and geological evidence).

The worker safety codes and standards specify protective measures that must be taken at construction sites to minimize the risk of injury or death from structural or earth failure (e.g., utilizing personal protective equipment). The relevant codes and standards represent performance standards that must be met by contractors and these measures are subject to monitoring by state and local agencies. Cal-OSHA requirements for an IIPP and the terms of the IIPP to protect worker safety are the principal measures that would be enforced at project sites during operations.

Conformance to these and other applicable design specifications and standards would ensure that operation of Alternative 4 would not create an increased likelihood of loss of property, personal injury or death of individuals from structural shaking of surface and subsurface facilities along the Alternative 4 conveyance alignment in the event of strong seismic shaking. Therefore, there would be no adverse effect.

CEQA Conclusion: Seismically induced strong ground shaking could damage pipelines, tunnels, intake facilities, pumping plants, and other facilities. The damage could disrupt the water supply through the conveyance system. In an extreme event, an uncontrolled release of water from the damaged conveyance system could cause flooding and inundation of structures. (Please refer to Chapter 6, *Surface Water*, for a detailed discussion of potential flood impacts.) However, through the final design process, measures to address this hazard would be required to conform to applicable design codes, guidelines, and standards. As described in Section 9.3.1, *Methods for Analysis*, and in Appendix 3B, *Environmental Commitments*, such design codes, guidelines, and standards include the California Building Code and resource agency and professional engineering specifications, such as the Division of Safety of Dams *Guidelines for Use of the Consequence Hazard Matrix and Selection of Ground Motion Parameters*, DWR's Division of Flood Management *FloodSAFE Urban Levee Design Criteria*, and USACE's *Engineering and Design—Earthquake Design and Evaluation for Civil Works Projects*. Conformance with these codes and standards is an environmental commitment by DWR to ensure that ground shaking risks are minimized as the water conveyance features are operated. The hazard would be controlled to a safe level and there would be no increased likelihood of loss of property, personal injury or death due to operation of Alternative 4. The impact would be less than significant. No mitigation is required.

Impact GEO-8: Loss of Property, Personal Injury, or Death from Structural Failure Resulting from Seismic-Related Ground Failure (Including Liquefaction) during Operation of Water Conveyance Features

Earthquake-induced ground shaking could cause liquefaction, resulting in soil slumping or lateral spreading and subsequent damage to or breaching of water conveyance structures and facilities. The consequences of liquefaction are manifested in terms of compaction or settlement, loss of bearing capacity, lateral spreading (soil movement), increased lateral soil pressure, and buoyancy within zones of liquefaction. Failure of tunnels, pipelines, levees, bridges, and other structures and facilities could result in loss, injury, and disrupt SWP and CVP water supply deliveries. The potential for impacts from flooding as a result of levee or dam failure is also discussed in Chapter 6, *Surface Water*.

1 The native soil underlying Alternative 4 facilities consist of various channel deposits and recent silty
2 and sandy alluvium at shallow depths. The available data along the southern portion of the conveyance
3 (from approximately Potato Slough to Clifton Court Forebay) show that the recent alluvium overlies
4 peaty or organic soils, which in turn is underlain by layers of mostly sandy and silty soil (Real and
5 Knudsen 2009). Soil borings advanced by DWR along the northern portion of the conveyance (from
6 approximately Potato Slough to Intake 1) show the surface soil as being similar to the range reported
7 for the southern portion, but locally containing strata of clayey silt and lean clay. Because the borings
8 were made over water, peat was usually absent from the boring logs (California Department of Water
9 Resources 2011).

10 The silty and sandy soil deposits underlying the peaty and organic soil over parts of the Delta are late-
11 Pleistocene age dune sand, which are liquefiable during major earthquakes. The tops of these materials
12 are exposed in some areas, but generally lie beneath the peaty soil at depths of about 10–40 feet bgs
13 along the modified pipeline/tunnel alignment (Real and Knudsen 2009). Liquefaction hazard mapping
14 by Real and Knudsen (2009), which covers only the southwestern part of the Plan Area, including the
15 part of the alignment from near Isleton to the Palm Tract, indicates that the lateral ground deformation
16 potential would range from <0.1 to 6.0 feet. Liquefaction-induced ground settlement during the 1906
17 San Francisco earthquake was also reported near Alternative 4 facilities at a bridge crossing over
18 Middle River just north of Woodward Island (Youd and Hoose 1978). Local variations in thickness and
19 lateral extent of liquefiable soil may exist, and they may have important influence on liquefaction-
20 induced ground deformations.

21 Figure 9-6 shows that the Alternative 4 alignment has no substantial levee damage potential from
22 liquefaction in its extreme northern part and low to medium-high levee damage potential throughout
23 the remainder.

24 Because the tunnel invert would be at depths of 100–160 feet bgs, the potential effect on these facilities
25 due to liquefaction is judged to be low. However, the surface and near-surface facilities that would
26 be constructed at the access road, intake, pumping plant, and forebay areas would likely be founded on
27 liquefiable soil.

28 **NEPA Effects:** The potential effect could be substantial because seismically induced ground shaking
29 could cause liquefaction, and damage pipelines, tunnels, intake facilities, pumping plants, and other
30 facilities. The damage could disrupt the water supply through the conveyance system. In an extreme
31 event, an uncontrolled release of water from the damaged conveyance system could cause flooding and
32 inundation of structures. Please refer to Appendix 3E, *Potential Seismicity and Climate Change Risks to*
33 *SWP/CVP Water Supplies*, for a detailed discussion of potential flooding effects.

34 In the process of preparing final facility designs, site-specific geotechnical and groundwater
35 investigations would be conducted to identify and characterize the vertical (depth) and horizontal
36 (spatial) extents of liquefiable soil. Engineering soil parameters that could be used to further assess the
37 liquefaction potential, such as SPT blow counts, CPT penetration tip pressure/resistance, and gradation
38 of soil, would also be obtained. SPT blow counts and CPT tip pressure are used to estimate soil
39 resistance to cyclic loadings by using empirical relationships that were developed based on
40 occurrences of liquefaction (or lack of them) during past earthquakes. The resistance then can be
41 compared to cyclic shear stress induced by the design earthquake. If soil resistance is less than induced
42 stress, the potential of having liquefaction during the design earthquakes is high. It is also known that
43 soil with high “fines” (i.e., silt- and clay-sized particles) content are less susceptible to liquefaction.

1 During final design, site-specific potential for liquefaction would be investigated by a geotechnical
 2 engineer. In areas determined to have a potential for liquefaction, a California-registered civil engineer
 3 or California-certified engineering geologist would develop design measures and construction methods
 4 to meet design criteria established by building codes and construction standards to ensure that the
 5 design earthquake does not cause damage to or failure of the facility. Such measures and methods
 6 include removing and replacing potentially liquefiable soil, strengthening foundations (for example,
 7 using post-tensioned slab, reinforced mats, and piles) to resist excessive total and differential
 8 settlements, and using *in situ* ground improvement techniques (such as deep dynamic compaction,
 9 vibro-compaction, vibro-replacement, compaction grouting, and other similar methods). The results of
 10 the site-specific evaluation and California-registered civil engineer or California-certified engineering
 11 geologist's recommendations would be documented in a detailed geotechnical report prepared in
 12 accordance with state guidelines, in particular *Guidelines for Evaluating and Mitigating Seismic Hazards*
 13 *in California* (California Geological Survey 2008). As described in Section 9.3.1, *Methods for Analysis*,
 14 and in Appendix 3B, *Environmental Commitments*, such design codes, guidelines, and standards include
 15 USACE's *Engineering and Design—Stability Analysis of Concrete Structures and Soil Liquefaction during*
 16 *Earthquakes*, by the Earthquake Engineering Research Institute. Conformance with these design
 17 requirements is an environmental commitment by DWR to ensure that liquefaction risks are minimized
 18 as the water conveyance features are operated.

19 DWR would ensure that the geotechnical design recommendations are included in the design of project
 20 facilities and construction specifications to minimize the potential effects from liquefaction and
 21 associated hazards. DWR would also ensure that the design specifications are properly executed during
 22 construction.

23 In particular, conformance with the following codes and standards would reduce the potential risk for
 24 increased likelihood of loss of property or personal injury from structural failure resulting from strong
 25 seismic shaking of water conveyance features during operations:

- 26 ● DWR Division of Engineering State Water Project – Seismic Loading Criteria Report, Sept 2012.
- 27 ● USACE Engineering and Design – Time-History Dynamic Analysis of Concrete Hydraulic Structure, EM
 28 1110-2-6051, 2003
- 29 ● USACE Engineering and Design – Response Spectra and Seismic Analysis for Concrete Hydraulic
 30 Structures, EM 1110-2-6050, 1999.
- 31 ● American Society of Civil Engineers Minimum Design Loads for Buildings and Other Structures,
 32 ASCE-7-05, 2005.
- 33 ● USACE Engineering and Design - Design of Pile Foundations, EM 1110-2-2906, 1991
- 34 ● California Code of Regulations, Title 8, Section 3203, California Code of Regulations.

35 Generally, the applicable codes require that facilities be built so that if soil in the foundation or
 36 surrounding area are subject to liquefaction, the removal or densification of the liquefiable material
 37 should be considered, along with alternative foundation designs. Additionally, any modification to a
 38 federal levee system would require USACE approval under 33 USC 408 (a 408 Permit) and would have
 39 to pass quality assurance review by the Major Subordinate Command prior to being forwarded to
 40 USACE headquarters for final approval by the Chief of Engineers.

41 The worker safety codes and standards specify protective measures that must be taken at construction
 42 sites to minimize the risk of injury or death from structural or earth failure (e.g., utilizing personal
 43 protective equipment). The relevant codes and standards represent performance standards that must

1 be met by contractors and these measures are subject to monitoring by state and local agencies. Cal-
 2 OSHA requirements for an IIPP and the terms of the IIPP to protect worker safety are the principal
 3 measures that would be enforced at project sites during operations.

4 Conformance to these and other applicable design specifications and standards would ensure that the
 5 hazard of liquefaction and associated ground movements would not create an increased likelihood of
 6 loss of property, personal injury or death of individuals from structural failure resulting from seismic-
 7 related ground failure along the Alternative 4 conveyance alignment during operation of the water
 8 conveyance features. Therefore, the effect would not be adverse.

9 **CEQA Conclusion:** Seismically induced ground shaking could cause liquefaction. Liquefaction could
 10 damage pipelines, tunnels, intake facilities, pumping plants, and other facilities, and thereby disrupt the
 11 water supply through the conveyance system. In an extreme event, flooding and inundation of
 12 structures could result from an uncontrolled release of water from the damaged conveyance system.
 13 (Please refer to Chapter 6, *Surface Water*, for a detailed discussion of potential flood impacts.) However,
 14 through the final design process, measures to address the liquefaction hazard would be required to
 15 conform to applicable design codes, guidelines, and standards. As described in Section 9.3.1, *Methods*
 16 *for Analysis*, and in Appendix 3B, *Environmental Commitments*, such design codes, guidelines, and
 17 standards include USACE's *Engineering and Design—Stability Analysis of Concrete Structures and Soil*
 18 *Liquefaction during Earthquakes*, by the Earthquake Engineering Research Institute. Conformance with
 19 these design standards is an environmental commitment by DWR to ensure that liquefaction risks are
 20 minimized as the water conveyance features are operated. The hazard would be controlled to a safe
 21 level and there would be no increased likelihood of loss of property, personal injury or death due to
 22 operation of Alternative 4. The impact would be less than significant. No mitigation is required.

23 **Impact GEO-9: Loss of Property, Personal Injury, or Death from Landslides and Other Slope**
 24 **Instability during Operation of Water Conveyance Features**

25 Alternative 4 would involve excavation that creates new cut-and-fill slopes and construction of new
 26 embankments and levees. As a result of ground shaking and high soil-water content during heavy
 27 rainfall, existing and new slopes that are not properly engineered and natural stream banks could fail
 28 and cause damage to facilities. Levees can fail for several reasons: 1) high velocities of water flow can
 29 result in high rates of erosion and erode and overtop a levee; 2) the higher velocities of water flow can
 30 also lead to higher rates of erosion along the inner parts of levees and lead to undercutting and
 31 clumping of the levee into the river. Heavy rainfall or seepage into the levee from the river can increase
 32 fluid pressure in the levee and lead to slumping on the outer parts of the levee. If the slumps grow to
 33 the top of the levee, large sections of the levee may slump onto the floodplain and lower the elevation of
 34 the top of the levee, leading to overtopping; 3) increasing levels of water in the river will cause the
 35 water table in the levee to rise which will increase fluid pressure and may result in seepage and
 36 eventually lead to internal erosion called piping. Piping will erode the material under the levee,
 37 undermining it and causing its collapse and failure.

38 With the exception of levee slopes and natural stream banks, the topography along the Alternative 4
 39 conveyance alignment is nearly level to very gently sloping. The areas that may be susceptible to slope
 40 failure are along existing levee slopes, and at intakes, pumping plants, forebay, and certain access road
 41 locations. Outside these areas, the land is nearly level and consequently has a negligible potential for
 42 slope failure. Based on review of topographic maps and a landslide map of Alameda County (Roberts et
 43 al. 1999), the conveyance facilities would not be constructed on, nor would it be adjacent to, slopes that
 44 are subject to mudflows/debris flows from natural slopes.

1 **NEPA Effects:** The potential effect could be substantial because levee slopes and stream banks may fail,
 2 either from high pore-water pressure caused by high rainfall and weak soil, or from seismic shaking.
 3 Structures built on these slopes could be damaged or fail entirely as a result of slope instability. As
 4 discussed in Impact SW-2 in Chapter 6, *Surface Water*, operation of the water conveyance features
 5 under Alternative 4 would not result in an increase in potential risk for flood management compared to
 6 existing conditions. Peak monthly flows under Alternative 4 in the locations considered were similar to
 7 or less than those that would occur under existing conditions. Since flows would not be substantially
 8 greater, the potential for increased rates of erosion or seepage are low. For additional discussion on the
 9 possible exposure of people or structures to impacts from flooding due to levee failure, please refer to
 10 Impact SW-6 in Chapter 6, *Surface Water*.

11 During project design, a geotechnical engineer would develop slope stability design criteria (such as
 12 minimum slope safety factors and allowable slope deformation and settlement) for the various
 13 anticipated loading conditions. The design criteria would be documented in a detailed geotechnical
 14 report prepared in accordance with state guidelines, in particular *Guidelines for Evaluating and*
 15 *Mitigating Seismic Hazards in California* (California Geological Survey 2008). As discussed in Chapter 3,
 16 *Description of the Alternatives*, the foundation soil beneath slopes, embankments, or levees could be
 17 improved to increase its strength and to reduce settlement and deformation. Foundation soil
 18 improvement could involve excavation and replacement with engineered fill; preloading; ground
 19 modifications using jet-grouting, compaction grouting, chemical grouting, shallow soil mixing, deep soil
 20 mixing, vibro-compaction, or vibro-replacement; or other methods. Engineered fill also would be used
 21 to construct new slopes, embankments, and levees. Surface and internal drainage systems would be
 22 installed as necessary to reduce erosion and piping (internal erosion) potential.

23 Site-specific geotechnical and hydrological information would be used, and the design would conform
 24 with the current standards and construction practices, as described in Section 9.3.1, *Methods for*
 25 *Analysis*, such as USACE's *Design and Construction of Levees* and USACE's *EM 1110-2-1902, Slope*
 26 *Stability*. The design requirements would be presented in a detailed geotechnical report. Conformance
 27 with these design requirements is an environmental commitment by DWR to ensure that slope stability
 28 hazards would be avoided as the water conveyance features are operated. DWR would ensure that the
 29 geotechnical design recommendations are included in the design of cut and fill slopes, embankments,
 30 and levees to minimize the potential effects from slope failure. DWR would also ensure that the design
 31 specifications are properly executed during construction.

32 In particular, conformance with the following codes and standards would reduce the potential risk for
 33 increased likelihood of loss of property or personal injury from structural failure resulting from seismic
 34 shaking or from high-pore water pressure:

- 35 • DWR Division of Engineering State Water Project – Seismic Loading Criteria Report, Sept 2012.
- 36 • DWR Division of Flood Management FloodSAFE Urban Levee Design Criteria, May 2012.
- 37 • USACE Slope Stability, EM 1110-2-1902, 2003.
- 38 • California Code of Regulations, Title 8, Section 3203, California Code of Regulations.

39 Generally, the applicable codes require that facilities be built to certain factors of safety in order to
 40 ensure that facilities perform as designed for the life of the structure despite various soil parameters.

41 The worker safety codes and standards specify protective measures that must be taken at construction
 42 sites to minimize the risk of injury or death from structural or earth failure (e.g., utilizing personal
 43 protective equipment). The relevant codes and standards represent performance standards that must

1 be met by contractors and these measures are subject to monitoring by state and local agencies. Cal-
 2 OSHA requirements for an IIPP and the terms of the IIPP to protect worker safety are the principal
 3 measures that would be enforced at project sites during operations.

4 Conformance to the above and other applicable design specifications and standards would ensure that
 5 the hazard of slope instability would not create an increased likelihood of loss of property, personal
 6 injury of individuals along the Alternative 4 conveyance alignment during operation of the water
 7 conveyance features. Therefore, the effect would not be adverse.

8 **CEQA Conclusion:** Unstable levee slopes and natural stream banks may fail, either from high pore-
 9 water pressure caused by high rainfall and weak soil, or from seismic shaking. Structures constructed
 10 on these slopes could be damaged or fail entirely as a result of slope instability. However, through the
 11 final design process, measures to address this hazard would be required to conform to applicable
 12 design codes, guidelines, and standards. As described in Section 9.3.1, *Methods for Analysis*, and in
 13 Appendix 3B, *Environmental Commitments*, such design codes, guidelines, and standards include the
 14 California Building Code and resource agency and professional engineering specifications, such as
 15 USACE's *Engineering and Design—Earthquake Design and Evaluation for Civil Works Projects*.
 16 Conformance with these codes and standards is an environmental commitment by DWR to ensure cut
 17 and fill slopes and embankments will be stable as the water conveyance features are operated and
 18 there would be no increased likelihood of loss of property, personal injury or death due to operation of
 19 Alternative 4. The impact would be less than significant. No mitigation is required.

20 **Impact GEO-10: Loss of Property, Personal Injury, or Death from Seiche or Tsunami during**
 21 **Operation of Water Conveyance Features**

22 Based on recorded tsunami wave heights at the Golden Gate (Contra Costa Transportation Agency
 23 2009) and in the interior of the San Francisco Bay and on tsunami inundation maps prepared by the
 24 California Department of Conservation (2009), the height of a tsunami wave reaching the Suisun Marsh
 25 and the Delta would be small because of the distance from the ocean and attenuating effect of the San
 26 Francisco Bay. Therefore, the potential hazard of loss of property or personal injury as a result of a
 27 tsunami on the water conveyance facilities is low.

28 Similarly, with the exception of the expanded Clifton Court Forebay, the potential for a substantial
 29 seiche to take place in the Plan Area is considered low because seismic and water body geometry
 30 conditions for a seiche to occur near conveyance facilities are not favorable. Fugro Consultants, Inc.
 31 (2011) identified the potential for a seiche of an unspecified wave height to occur in the Clifton Court
 32 Forebay, caused by strong ground motions along the underlying West Tracy fault, assuming that this
 33 fault is potentially active. Since the fault also exists in the immediate vicinity of the expanded Clifton
 34 Court Forebay, a seiche could also occur in the expanded Clifton Court Forebay.

35 **NEPA Effects:** The effect of a tsunami generated in the Pacific Ocean would not be adverse because the
 36 distance from the ocean and attenuating effect of the San Francisco Bay would likely allow only a low
 37 (i.e., less than 2 feet) tsunami wave height to reach the Delta (Contra Costa Transportation Agency
 38 2009).

39 In most parts of the Plan Area, the effects of a seiche would not be adverse because the seismic hazard
 40 and the geometry of the water bodies (i.e., wide and shallow) near conveyance facilities are not
 41 favorable for a seiche to occur. However, assuming that the West Tracy fault is potentially active, a
 42 potential exists for a seiche to occur in the expanded Clifton Court Forebay. The effect could be adverse

1 because the waves generated by a seiche could overtop the expanded Clifton Court Forebay
2 embankments, causing erosion of the embankments and subsequent flooding in the vicinity.

3 However, design-level geotechnical studies would be conducted by a licensed civil engineer who
4 practices in geotechnical engineering. The studies would determine the peak ground acceleration
5 caused by movement of the West Tracy fault and the maximum probable seiche wave that could be
6 generated by the ground shaking. The California-registered civil engineer or California-certified
7 engineering geologist's recommended measures to address this hazard, as well as the hazard of a
8 seiche overtopping the expanded Clifton Court Forebay embankment, would conform to applicable
9 design codes, guidelines, and standards. As described in Section 9.3.1, *Methods for Analysis*, and in
10 Appendix 3B, *Environmental Commitments*, such design codes, guidelines, and standards include the
11 Division of Safety of Dams *Guidelines for Use of the Consequence Hazard Matrix and Selection of Ground*
12 *Motion Parameters*, DWR's Division of Flood Management *FloodSAFE Urban Levee Design Criteria*, and
13 USACE's *Engineering and Design—Earthquake Design and Evaluation for Civil Works Projects*.
14 Conformance with these codes and standards is an environmental commitment by DWR to ensure that
15 the adverse effects of a seiche are controlled to an acceptable level while the forebay facility is
16 operated.

17 DWR would ensure that the geotechnical design recommendations are included in the design of project
18 facilities and construction specifications to minimize the potential effects from seismic events and
19 consequent seiche waves. DWR would also ensure that the design specifications are properly executed
20 during construction.

21 In particular, conformance with the following codes and standards would reduce the potential risk for
22 increased likelihood of loss of property or personal injury tsunami or seiche:

- 23 ● U.S. Department of the Interior and USGS Climate Change and Water Resources Management: A
24 Federal Perspective, Circular 1331.
- 25 ● State of California Sea-Level Rise Task Force of the CO-CAT, Sea-Level Rise Interim Guidance
26 Document, 2010
- 27 ● California Code of Regulations, Title 8, Section 3203, California Code of Regulations.

28 Generally, the applicable codes provide guidance on estimating the effects of climate change and sea
29 level rise and associated effects when designing a project and ensuring that a project is able to respond
30 to these effects.

31 The worker safety codes and standards specify protective measures that must be taken at construction
32 sites to minimize the risk of injury or death from structural or earth failure (e.g., utilizing personal
33 protective equipment). The relevant codes and standards represent performance standards that must
34 be met by contractors and these measures are subject to monitoring by state and local agencies. Cal-
35 OSHA requirements for an IIPP and the terms of the IIPP to protect worker safety are the principal
36 measures that would be enforced at project sites during operations.

37 Conformance to these and other applicable design specifications and standards would ensure that the
38 embankment for the expanded portion of the Clifton Court Forebay would be designed and constructed
39 to contain and withstand the anticipated maximum seiche wave height and would not create an
40 increased likelihood of loss of property, personal injury or death of individuals along the Alternative 4
41 conveyance alignment during operation of the water conveyance features. Therefore, the effect would
42 not be adverse.

1 **CEQA Conclusion:** Based on recorded tsunami wave heights at the Golden Gate (Contra Costa
 2 Transportation Agency 2009) and in the interior of the San Francisco Bay and on tsunami inundation
 3 maps prepared by the California Department of Conservation (2009), the height of a tsunami wave
 4 reaching the Suisun Marsh and the Delta would be small because of the distance from the ocean and
 5 attenuating effect of the San Francisco Bay. Similarly, the potential for a significant seiche to occur in
 6 most parts of the Plan Area is considered low because the seismic hazard and the geometry of the
 7 water bodies (i.e., wide and shallow) near conveyance facilities are not favorable for a seiche to occur.
 8 However, assuming the West Tracy fault is potentially active, a potential exists for a seiche to occur in
 9 the expanded Clifton Court Forebay (Fugro Consultants 2011). The effect would not be adverse because
 10 the expanded Clifton Court Forebay embankment would be designed and constructed according to
 11 applicable design codes, guidelines, and standards to contain and withstand the anticipated maximum
 12 seiche wave height. There would be no increased likelihood of loss of property, personal injury or death
 13 due to operation of Alternative 4 from seiche or tsunami. The impact would be less than significant. No
 14 additional mitigation is required.

15 **Impact GEO-11: Ground Failure Caused by Increased Groundwater Surface Elevations from**
 16 **Unlined Canal Seepage as a Result of Operating the Water Conveyance Facilities**

17 **NEPA Effects:** Alternative 4 would not involve construction of unlined canals; therefore, there would be
 18 no increase in groundwater surface elevations and consequently no effect caused by canal seepage.
 19 There would be no adverse effect.

20 **CEQA Conclusion:** Alternative 4 would not involve construction of unlined canals; therefore, there
 21 would be no increase in groundwater surface elevations and consequently no impact caused by canal
 22 seepage. The impact would be less than significant. No mitigation is required.

23 **Impact GEO-12: Loss of Property, Personal Injury, or Death Resulting from Structural Failure**
 24 **Caused by Rupture of a Known Earthquake Fault at Restoration Opportunity Areas**

25 According to the available AP Earthquake Fault Zone Maps, only the Suisun Marsh ROA could be
 26 affected by rupture of an earthquake fault. The active Green Valley fault crosses the southwestern
 27 corner of the ROA. The active Cordelia fault extends approximately 1 mile into the northwestern corner
 28 of the ROA. Rupture of these faults could damage levees and berms constructed as part of the
 29 restoration, which could result in failure of the levees and flooding of otherwise protected areas.

30 Within the Delta, active or potentially active blind thrust faults were identified in the seismic study
 31 (California Department of Water Resources 2007a). The extreme southeastern corner of the Suisun
 32 Marsh is underlain by the Montezuma blind thrust zone. Parts of the Cache Slough and Yolo Bypass
 33 ROAs are underlain by part of the North Midland blind thrust zone. The Cosumnes/Mokelumne River
 34 and East Delta ROAs are underlain by the Thornton Arch zone. Although these blind thrusts are not
 35 expected to rupture to the ground surface during earthquake events, they may produce ground or
 36 near-ground shear zones, bulging, or both. In the seismic study (California Department of Water
 37 Resources 2007a), the Thornton Arch blind thrust was assigned a 20% probability of being active. The
 38 depth to the Thornton Arch blind fault is unknown. Based on limited geologic and seismic survey
 39 information, it appears that the potential of having any shear zones, bulging, or both at the sites of the
 40 habitat levees is low because the depth to the blind thrust faults is generally deep.

41 **NEPA Effects:** The effect of implementing the conservation measures in the ROAs could be substantial
 42 because rupture of the Cordelia and Green Valley faults could occur at the Suisun Marsh ROA and cause

1 damage or failure of ROA facilities, including levees and berms. Damage to these features could result in
2 their failure, causing flooding of otherwise protected areas.

3 Because there is limited information regarding the depths of the blind faults mentioned above, seismic
4 surveys would be performed in the vicinity of the faults as part of final design. These surveys would be
5 used to verify fault depths where levees and other features would be constructed. Collection of this
6 depth information would be part of broader, design-level geotechnical studies prepared by a
7 geotechnical engineer licensed in the state of California to support all aspects of site-specific project
8 design. The studies would assess site-specific conditions at and near all the project facility locations,
9 including the nature and engineering properties of all soil horizons and underlying geologic strata, and
10 groundwater conditions. The geotechnical engineers' information would be used to develop final
11 engineering solutions to any hazardous condition, consistent with the code and standards
12 requirements of federal, state and local oversight agencies. As described in Section 9.3.1, *Methods for*
13 *Analysis*, and in Appendix 3B, *Environmental Commitments*, such design codes, guidelines, and
14 standards include the California Building Code and resource agency and professional engineering
15 specifications, such as the Division of Safety of Dams Guidelines for Use of the Consequence Hazard
16 Matrix and Selection of Ground Motion Parameters, DWR's Division of Flood Management *FloodSAFE*
17 *Urban Levee Design Criteria*, and USACE's *Engineering and Design—Earthquake Design and Evaluation*
18 *for Civil Works Projects*. Conformance with these design standards is an environmental commitment by
19 the BDCP proponents to ensure that risks from a fault rupture are minimized as conservation levees
20 are constructed and maintained. The hazard would be controlled to a safe level by following the proper
21 design standards.

22 The BDCP proponents would ensure that the geotechnical design recommendations are included in the
23 design of project facilities and construction specifications to minimize the potential effects from seismic
24 events and the presence of adverse soil conditions. The BDCP proponents would also ensure that the
25 design specifications are properly executed during implementation.

26 In particular, conformance with the following codes and standards would reduce the potential risk for
27 increased likelihood of loss of property or personal injury from structural failure resulting from surface
28 rupture resulting from a seismic event during operation:

- 29 ● DWR Division of Engineering State Water Project – Seismic Loading Criteria Report, Sept 2012.
- 30 ● DWR DSOD Guidelines for Use of the Consequence-Hazard Matrix and Selection of Ground Motion
31 Parameters, 2002.
- 32 ● USACE Engineering and Design, Earthquake Design and Evaluation for Civil Works Projects, ER 1110-
33 2-1806, 1995.
- 34 ● USACE Design and Construction of Levees, EM 1110-2-1913, 2000.
- 35 ● USACE (Corps, CESP-K-ED-G), Geotechnical Levee Practice, SOP EDG-03, 2004.
- 36 ● DWR Division of Flood Management FloodSAFE Urban Levee Design Criteria, May 2012.
- 37 ● California Code of Regulations, Title 8, Sections 1509 and 3203, California Code of Regulations.

38 Generally, the applicable codes require that facilities be built so that they incur minimal damage in the
39 event of a foreseeable seismic event and that they remain functional following such an event and that
40 the facility is able to perform without catastrophic failure in the event of a maximum design earthquake
41 (the greatest earthquake reasonably expected to be generated by a specific source on the basis of
42 seismological and geological evidence).

1 The worker safety codes and standards specify protective measures that must be taken at construction
 2 sites to minimize the risk of injury or death from structural or earth failure (e.g., utilizing personal
 3 protective equipment, practicing crane and scaffold safety measures). The relevant codes and
 4 standards represent performance standards that must be met by contractors and these measures are
 5 subject to monitoring by state and local agencies. Cal-OSHA requirements for an IIPP and the terms of
 6 the IIPP to protect worker safety are the principal measures that would be enforced at construction
 7 sites.

8 Conformance to these and other applicable design specifications and standards would ensure that the
 9 hazard of ground movement in the vicinity of the blind thrusts underlying the ROAs would not
 10 jeopardize the integrity of the levees and other features constructed in the ROAs and would not create
 11 an increased likelihood of loss of property, personal injury or death of individuals in the ROAs. This
 12 effect would not be adverse.

13 **CEQA Conclusion:** Rupture of the Cordelia and Green Valley faults could occur at the Suisun Marsh ROA
 14 and damage ROA facilities, such as levees and berms. Damage to these features could result in their
 15 failure, causing flooding of otherwise protected areas.

16 However, through the final design process for conservation measures in the ROAs, measures to address
 17 the fault rupture hazard would be required to conform to applicable design codes, guidelines, and
 18 standards. As described in Section 9.3.1, *Methods for Analysis*, and in Appendix 3B, *Environmental*
 19 *Commitments*, such design codes, guidelines, and standards include the Division of Safety of Dams
 20 *Guidelines for Use of the Consequence Hazard Matrix and Selection of Ground Motion Parameters*, DWR's
 21 *Division of Flood Management FloodSAFE Urban Levee Design Criteria*, and USACE's *Engineering and*
 22 *Design—Earthquake Design and Evaluation for Civil Works Projects*. Conformance with these design
 23 standards is an environmental commitment by the BDCP proponents to ensure that fault rupture risks
 24 are minimized as the conservation measures are implemented. The hazard would be controlled to a
 25 safe level and there would be no increased likelihood of loss of property, personal injury or death in the
 26 ROAs. The impact would be less than significant. No mitigation is required.

27 **Impact GEO-13: Loss of Property, Personal Injury, or Death from Structural Failure Resulting**
 28 **from Strong Seismic Shaking at Restoration Opportunity Areas**

29 Earthquake events may occur on the local and regional seismic sources at or near the ROAs. Because of
 30 its proximity to these faults, the Suisun Marsh ROA would be especially subject to ground shaking
 31 caused by the Concord-Green Valley fault. The Cache Slough ROA would be subject to shaking from the
 32 Northern Midland fault zone, which underlies the ROA. Although more distant from these sources, the
 33 other ROAs would be subject to shaking from the San Andreas, Hayward-Rodgers Creek, Calaveras,
 34 Concord-Green Valley, San Gregorio, Greenville, and Mt. Diablo Thrust faults and the more proximate
 35 blind thrusts in the Delta.

36 Among all the ROAs, the Suisun Marsh ROA would be most subject to ground shaking because of its
 37 proximity to active faults. The Suisun Marsh ROA is subject to a PGA of approximately 0.31–0.35 g for
 38 200-year return interval, while the PGA for the other ROAs ranges from approximately 0.11–0.26 g. The
 39 ground shaking could damage levees and other structures, and in an extreme event cause levees to fail
 40 such that protected areas flood.

41 **NEPA Effects:** All temporary facilities would be designed and built to meet the safety and
 42 collapse-prevention requirements for the above-anticipated seismic loads. Therefore, this effect is
 43 considered not adverse. No additional mitigation measures are required. All facilities would be

1 designed and constructed in accordance with the requirements of the design measures described in
 2 Chapter 3, *Description of the Alternatives*. Site-specific geotechnical information would be used to
 3 further assess the effects of local soil on the OBE and MDE ground shaking and to develop design
 4 criteria that minimize the potential of damage. Design-level geotechnical studies would be prepared by
 5 a geotechnical engineer licensed in the state of California during project design. The studies would
 6 assess site-specific conditions at and near all the project facility locations and provide the basis for
 7 designing the levees and other features to withstand the peak ground acceleration caused by fault
 8 movement in the region. The geotechnical engineer's recommended measures to address this hazard
 9 would conform to applicable design codes, guidelines, and standards. Potential design strategies or
 10 conditions could include avoidance (deliberately positioning structures and lifelines to avoid crossing
 11 identified shear rupture zones), geotechnical engineering (using the inherent capability of
 12 unconsolidated geomaterials to "locally absorb" and distribute distinct bedrock fault movements) and
 13 structural engineering (engineering the facility to undergo some limited amount of ground deformation
 14 without collapse or significant damage).

15 As described in Section 9.3.1, *Methods for Analysis*, and in Appendix 3B, *Environmental Commitments*,
 16 such design codes, guidelines, and standards include the California Building Code and resource agency
 17 and professional engineering specifications, such as the Division of Safety of Dams *Guidelines for Use of*
 18 *the Consequence Hazard Matrix and Selection of Ground Motion Parameters*, DWR's Division of Flood
 19 Management *FloodSAFE Urban Levee Design Criteria*, and USACE's *Engineering and Design—Earthquake*
 20 *Design and Evaluation for Civil Works Projects*. Conformance with these design standards is an
 21 environmental commitment by the BDCP proponents to ensure that strong seismic shaking risks are
 22 minimized as the conservation measures are implemented.

23 The BDCP proponents would ensure that the geotechnical design recommendations are included in the
 24 design of project features and construction specifications to minimize the potential effects from seismic
 25 events and the presence of adverse soil conditions. The BDCP proponents would also ensure that the
 26 design specifications are properly executed during implementation.

27 In particular, conformance with the following codes and standards would reduce the potential risk for
 28 increased likelihood of loss of property or personal injury from structural failure resulting from surface
 29 rupture resulting from a seismic event during operation:

- 30 ● DWR Division of Engineering State Water Project – Seismic Loading Criteria Report, Sept 2012.
- 31 ● DWR DSOD Guidelines for Use of the Consequence-Hazard Matrix and Selection of Ground Motion
 32 Parameters, 2002.
- 33 ● USACE Engineering and Design, Earthquake Design and Evaluation for Civil Works Projects, ER 1110-
 34 2-1806, 1995.
- 35 ● USACE Design and Construction of Levees, EM 1110-2-1913, 2000.
- 36 ● USACE (Corps, CESP-K-ED-G), Geotechnical Levee Practice, SOP EDG-03, 2004.
- 37 ● DWR Division of Flood Management FloodSAFE Urban Levee Design Criteria, May 2012.
- 38 ● California Code of Regulations, Title 8, Sections 1509 and 3203, California Code of Regulations.

39 Generally, the applicable codes require that facilities be built so that they incur minimal damage in the
 40 event of a foreseeable seismic event and that they remain functional following such an event and that
 41 the facility is able to perform without catastrophic failure in the event of a maximum design earthquake

1 (the greatest earthquake reasonably expected to be generated by a specific source on the basis of
2 seismological and geological evidence).

3 The worker safety codes and standards specify protective measures that must be taken at construction
4 sites to minimize the risk of injury or death from structural or earth failure (e.g., utilizing personal
5 protective equipment, practicing crane and scaffold safety measures). The relevant codes and
6 standards represent performance standards that must be met by contractors and these measures are
7 subject to monitoring by state and local agencies. Cal-OSHA requirements for an IIPP and the terms of
8 the IIPP to protect worker safety are the principal measures that would be enforced at construction
9 sites.

10 Conformance to these and other applicable design specifications and standards would ensure that the
11 hazard of seismic shaking would not jeopardize the integrity of levees and other features at the ROAs
12 and would not create an increased likelihood of loss of property, personal injury or death of individuals
13 in the ROAs. This effect would not be adverse.

14 **CEQA Conclusion:** Ground shaking could damage levees, berms, and other structures. Among all the
15 ROAs, the Suisun Marsh ROA would be the most subject to ground shaking because of its proximity to
16 active faults. The Suisun Marsh ROA is subject to a PGA of approximately 0.31 to 0.35 g for 200-year
17 return interval, while the PGA for the other ROAs ranges from approximately 0.11 to 0.26 g. Damage to
18 these features could result in their failure, causing flooding of otherwise protected areas. However, as
19 described in Section 9.3.1, *Methods for Analysis*, and in Appendix 3B, *Environmental Commitments*,
20 design codes, guidelines, and standards, including the California Building Code and resource agency
21 and professional engineering specifications, such as DWR's Division of Flood Management *FloodSAFE*
22 *Urban Levee Design Criteria* and USACE's *Engineering and Design—Earthquake Design and Evaluation*
23 *for Civil Works Projects* would be used for final design of conservation features. Conformance with these
24 design standards is an environmental commitment by the BDCP proponents to ensure that strong
25 seismic shaking risks are minimized as the conservation measures are operated and there would be no
26 increased likelihood of loss of property, personal injury or death in the ROAs. The impact would be less
27 than significant. No mitigation is required.

28 **Impact GEO-14: Loss of Property, Personal Injury, or Death from Structural Failure Resulting**
29 **from Seismic-Related Ground Failure (Including Liquefaction) Beneath Restoration Opportunity**
30 **Areas**

31 New structural features are proposed at the ROAs, such as levees as part of CM4, setback levees as part
32 of CM5 and CM6, and experimental ramps and fish ladders at the Fremont Weir as part of CM2.
33 Earthquake-induced ground shaking could cause liquefaction, resulting in damage to or failure of these
34 levees and other features constructed at the restoration areas. The consequences of liquefaction are
35 manifested in terms of compaction or settlement, loss of bearing capacity, lateral spreading (horizontal
36 soil movement), and increased lateral soil pressure. Failure of levees and other structures could result
37 in flooding of otherwise protected areas in Suisun Marsh and behind new setback levees along the
38 Sacramento and San Joaquin Rivers and in the South Delta ROA.

39 The ROAs vary with respect to their liquefaction hazard (Figure 9-6). The Suisun Marsh ROA generally
40 has a moderate or high liquefaction hazard. The liquefaction damage potential among the other ROAs,
41 as well as where setback levees would be constructed along the Old, Middle, and San Joaquin Rivers
42 under CM5 and CM6, is generally low to medium.

1 **NEPA Effects:** The potential effect could be substantial because earthquake-induced liquefaction could
 2 damage ROA facilities, such as levees and berms. Damage to these features could result in their failure,
 3 causing flooding of otherwise protected areas.

4 During final design of conservation facilities, site-specific geotechnical and groundwater investigations
 5 would be conducted to identify and characterize the vertical (depth) and horizontal (spatial) extent of
 6 liquefiable soil. Engineering soil parameters that could be used to assess the liquefaction potential, such
 7 as SPT blow counts, CPT penetration tip pressure/resistance, and gradation of soil, would also be
 8 obtained. SPT blow counts and CPT tip pressure are used to estimate soil resistance to cyclic loadings
 9 by using empirical relationships that were developed based on occurrences of liquefaction (or lack of
 10 them) during past earthquakes. The resistance then can be compared to cyclic shear stress induced by
 11 the design earthquakes. If soil resistance is less than induced stress, the potential of having liquefaction
 12 during the design earthquakes is high. It is also known that soil with high “fines” (i.e., silt- and clay-
 13 sized particles) content is less susceptible to liquefaction.

14 During final design, the facility-specific potential for liquefaction would be investigated by a
 15 geotechnical engineer. In areas determined to have a potential for liquefaction, the engineer would
 16 develop design parameters and construction methods to meet the design criteria established to ensure
 17 that design earthquake does not cause damage to or failure of the facility. Such measures and methods
 18 include removing and replacing potentially liquefiable soil, strengthening foundations (for example,
 19 using post-tensioned slab, reinforced mats, and piles) to resist excessive total and differential
 20 settlements, using *in situ* ground improvement techniques (such as deep dynamic compaction, vibro-
 21 compaction, vibro-replacement, compaction grouting, and other similar methods), and conforming with
 22 current seismic design codes and requirements. As described in Section 9.3.1, *Methods for Analysis*, and
 23 in Appendix 3B, *Environmental Commitments*, such design codes, guidelines, and standards include
 24 USACE’s *Engineering and Design—Stability Analysis of Concrete Structures and Soil Liquefaction during*
 25 *Earthquakes*, by the Earthquake Engineering Research Institute. Conformance with these design
 26 standards is an environmental commitment by the BDCP proponents to ensure that liquefaction risks
 27 are minimized as the conservation measures are implemented. The hazard would be controlled to a
 28 safe level.

29 In particular, conformance with the following codes and standards would reduce the potential risk for
 30 increased likelihood of loss of property or personal injury from structural failure resulting from
 31 seismic-related ground failure:

- 32 ● USACE Engineering and Design - Design of Pile Foundations, EM 1110-2-2906, 1991
- 33 ● USACE Engineering and Design – Stability Analysis of Concrete Structures, EM 1110-2-2100, 2005
- 34 ● USACE Engineering and Design, Earthquake Design and Evaluation for Civil Works Projects, ER 1110-
 35 2-1806, 1995
- 36 ● California Code of Regulations, Title 8, Sections 1509 and 3203, California Code of Regulations.

37 Generally, the applicable codes require that facilities be built so that if soil in the foundation or
 38 surrounding area are subject to liquefaction, the removal or densification of the liquefiable material
 39 should be considered, along with alternative foundation designs.

40 The worker safety codes and standards specify protective measures that must be taken at construction
 41 sites to minimize the risk of injury or death from structural or earth failure (e.g., utilizing personal
 42 protective equipment, practicing crane and scaffold safety measures). The relevant codes and
 43 standards represent performance standards that must be met by contractors and these measures are

1 subject to monitoring by state and local agencies. Cal-OSHA requirements for an IIPP and the terms of
 2 the IIPP to protect worker safety are the principal measures that would be enforced at construction
 3 sites.

4 The BDCP proponents would ensure that the geotechnical design recommendations are included in the
 5 design of levees and construction specifications to minimize the potential effects from liquefaction and
 6 associated hazard. The BDCP proponents would also ensure that the design specifications are properly
 7 executed during implementation and would not create an increased likelihood of loss of property,
 8 personal injury or death of individuals in the ROAs. This effect would not be adverse.

9 **CEQA Conclusion:** Earthquake-induced ground shaking could cause liquefaction, resulting in damage to
 10 or failure of levees, berms, and other features constructed at the restoration areas. Failure of levees and
 11 other structures could result in flooding of otherwise protected areas. However, through the final
 12 design process, measures to address the liquefaction hazard would be required to conform to
 13 applicable design codes, guidelines, and standards. As described in Section 9.3.1, *Methods for Analysis*,
 14 and in Appendix 3B, *Environmental Commitments*, such design codes, guidelines, and standards include
 15 USACE's *Engineering and Design—Stability Analysis of Concrete Structures and Soil Liquefaction during*
 16 *Earthquakes*, by the Earthquake Engineering Research Institute. Conformance with these design
 17 standards is an environmental commitment by the BDCP proponents to ensure that liquefaction risks
 18 are minimized as the water conservation features are implemented and there would be no increased
 19 likelihood of loss of property, personal injury or death in the ROAs. The impact would be less than
 20 significant. No mitigation is required.

21 **Impact GEO-15: Loss of Property, Personal Injury, or Death from Landslides and Other Slope** 22 **Instability at Restoration Opportunity Areas**

23 Implementation of CM2–CM7, would involve breaching, modification or removal of existing levees and
 24 construction of new levees and embankments. CM4 which provides for the restoration of up to 65,000
 25 acres of tidal perennial aquatic, tidal mudflat, tidal freshwater emergent wetland, and tidal brackish
 26 emergent wetland natural communities within the ROAs involves the greatest amount of modifications
 27 to levees. Levee modifications, including levee breaching or lowering, may be performed to reintroduce
 28 tidal exchange, reconnect remnant sloughs, restore natural remnant meandering tidal channels,
 29 encourage development of dendritic channel networks, and improve floodwater conveyance.

30 Levee modifications could involve the removal of vegetation and excavation of levee materials. Excess
 31 earthen materials could be temporarily stockpiled, then re-spread on the surface of the new levee
 32 slopes where applicable or disposed of offsite. Any breaching or other modifications would be required
 33 to be designed and implemented to maintain the integrity of the levee system and to conform with
 34 flood management standards and permitting processes. This would be coordinated with the
 35 appropriate flood management agencies. Those agencies may include USACE, DWR, CVFPB, and other
 36 flood management agencies. For more detail on potential modifications to levees as a part of
 37 conservation measures, please refer to Chapter 3, *Description of Alternatives*.

38 New and existing levee slopes and stream/channel banks could fail and could damage facilities as a
 39 result of seismic shaking and as a result of high soil-water content during heavy rainfall.

40 With the exception of levee slopes, natural stream banks, and part of the Suisun Marsh ROA, the
 41 topography of ROAs is nearly level to gently sloping. The areas that may be susceptible to slope failure
 42 are along existing Sacramento and San Joaquin River and Delta island levees and stream/channel

1 banks, particularly those levees that consist of non-engineered fill and those streambanks that are
2 steep and consist of low strength soil.

3 The structures associated with conservation measures would not be constructed in, nor would they be
4 adjacent to, areas that are subject to mudflows/debris flows from natural slopes.

5 **NEPA Effects:** The potential effect could be substantial because levee slopes and embankments may fail,
6 either from high pore-water pressure caused by high rainfall and weak soil, or from seismic shaking.
7 Failure of these features could result in loss, injury, and death as well as flooding of otherwise
8 protected areas.

9 As outlined in Chapter 3, *Description of Alternatives*, erosion protection measures and protection
10 against related failure of adjacent levees would be taken where levee breaches were developed.
11 Erosion protection could include geotextile fabrics, rock revetments, riprap, or other material selected
12 during future evaluations for each location. Aggregate rock could be placed on the remaining levees to
13 provide an access road to the breach location. Erosion protection measures would also be taken where
14 levee lowering is done for the purposes of allowing seasonal or periodic inundation of lands during
15 high flows or high tides to improve habitat or to reduce velocities and elevations of floodwaters. To
16 reduce erosion potential on the new levee crest, a paved or gravel access road could be constructed
17 with short (approximately 1 foot) retaining walls on each edge of the crest to reduce undercutting of
18 the roadway by high tides. Levee modifications could also include excavation of watersides of the
19 slopes to allow placement of slope protection, such as riprap or geotextile fabric, and to modify slopes
20 to provide levee stability. Erosion and scour protection could be placed on the landside of the levee and
21 continued for several feet onto the land area away from the levee toe. Neighboring levees could require
22 modification to accommodate increased flows or to reduce effects of changes in water elevation or
23 velocities along channels following inundation of tidal marshes. Hydraulic modeling would be used
24 during subsequent analyses to determine the need for such measures.

25 New levees would be constructed to separate lands to be inundated for tidal marsh from non-
26 inundated lands, including lands with substantial subsidence. Levees could be constructed as described
27 for the new levees at intake locations. Any new levees would be required to be designed and
28 implemented to conform with applicable flood management standards and permitting processes. This
29 would be coordinated with the appropriate flood management agencies, which may include USACE,
30 DWR, CVFPB, and local flood management agencies.

31 Additionally, during project design, a geotechnical engineer would develop slope stability design
32 criteria (such as minimum slope safety factors and allowable slope deformation and settlement) for the
33 various anticipated loading conditions. As discussed in Chapter 3, *Description of the Alternatives*,
34 foundation soil beneath embankments and levees could be improved to increase its strength and to
35 reduce settlement and deformation. Foundation soil improvement could involve excavation and
36 replacement with engineered fill; preloading; ground modifications using jet-grouting, compaction
37 grouting, chemical grouting, shallow soil mixing, deep soil mixing, vibro-compaction, or
38 vibro-replacement; or other methods. Engineered fill could also be used to construct new
39 embankments and levees.

40 Site-specific geotechnical and hydrological information would be used, and the design would conform
41 with the current standards and construction practices, as described in Chapter 3, *Description of the*
42 *Alternatives*, such as USACE's *Design and Construction of Levees* and USACE's *EM 1110-2-1902, Slope*
43 *Stability*.

1 The BDCP proponents would ensure that the geotechnical design recommendations are included in the
 2 design of embankments and levees to minimize the potential effects from slope failure. The BDCP
 3 proponents would also ensure that the design specifications are properly executed during
 4 implementation.

5 In particular, conformance with the following codes and standards would reduce the potential risk for
 6 increased likelihood of loss of property or personal injury from structural failure resulting from
 7 landslides or other slope instability:

- 8 • DWR Division of Engineering State Water Project – Seismic Loading Criteria Report, Sept 2012.
- 9 • DWR Division of Flood Management FloodSAFE Urban Levee Design Criteria, May 2012.
- 10 • USACE Slope Stability, EM 1110-2-1902, 2003.
- 11 • California Code of Regulations, Title 8, Section 3203, California Code of Regulations.

12 Generally, the applicable codes require that facilities be built to certain factors of safety in order to
 13 ensure that facilities perform as designed for the life of the structure despite various soil parameters.

14 The worker safety codes and standards specify protective measures that must be taken at construction
 15 sites to minimize the risk of injury or death from structural or earth failure (e.g., utilizing personal
 16 protective equipment). The relevant codes and standards represent performance standards that must
 17 be met by contractors and these measures are subject to monitoring by state and local agencies. Cal-
 18 OSHA requirements for an IIPP and the terms of the IIPP to protect worker safety are the principal
 19 measures that would be enforced at project sites during operations.

20 Conformance to the above and other applicable design specifications and standards would ensure that
 21 the hazard of slope instability would not jeopardize the integrity of levees and other features at the
 22 ROAs and would not create an increased likelihood of loss of property, personal injury or death of
 23 individuals in the ROAs. This effect would not be adverse.

24 **CEQA Conclusion:** Unstable new and existing levee and embankment slopes could fail as a result of
 25 seismic shaking and as a result of high soil-water content during heavy rainfall and cause flooding of
 26 otherwise protected areas. However, because the BDCP proponents would conform with applicable
 27 design guidelines and standards, such as USACE design measures, the hazard would be controlled to a
 28 safe level and there would be no increased likelihood of loss of property, personal injury or death in the
 29 ROAs. The impact would be less than significant. Therefore, no mitigation is required.

30 **Impact GEO-16: Loss of Property, Personal Injury, or Death from Seiche or Tsunami at** 31 **Restoration Opportunity Areas as a Result of Implementing the Conservation Actions**

32 **NEPA Effects:** The distance from the ocean and attenuating effect of the San Francisco Bay would likely
 33 allow only a low tsunami wave height to reach the Suisun Marsh and the Delta. Conditions for a seiche
 34 to occur at the ROAs are not favorable. Therefore, the effect would not be adverse.

35 **CEQA Conclusion:** Based on recorded tsunami heights at the Golden Gate, the height of a tsunami wave
 36 reaching the ROAs would be small because of the distance from the ocean and attenuating effect of the
 37 San Francisco Bay. Similarly, the potential for a significant seiche to occur in the Plan Area that would
 38 cause loss of property, personal injury, or death at the ROAs is considered low because conditions for a
 39 seiche to occur at the ROAs are not favorable. The impact would be less than significant. No mitigation
 40 is required.

9.3.3.10 Alternative 5—Dual Conveyance with Pipeline/Tunnel and Intake 1 (3,000 cfs; Operational Scenario C)

Impact GEO-1: Loss of Property, Personal Injury, or Death from Structural Failure Resulting from Strong Seismic Shaking of Water Conveyance Features during Construction

NEPA Effects: Alternative 5 would include the same physical/structural components as Alternative 1A, except that it would entail four less intakes and four less pumping plants. These differences would present a lower hazard of structural failure from seismic shaking but would not substantially change the hazard of loss of property, personal injury, or death during construction compared to Alternative 1A. The effects of Alternative 5 would, therefore, be the same as 1A. See the description and findings under Alternative 1A. There would be no adverse effect.

CEQA Conclusion: Seismically induced ground shaking could cause collapse or other failure of project facilities while under construction. However, DWR would conform with Cal-OSHA and other state code requirements, such as shoring, bracing, lighting, excavation depth restrictions, required slope angles, and other measures, to protect worker safety. Conformance with these standards and codes is an environmental commitment of the project (see Appendix 3B, *Environmental Commitments*). Conformance with these health and safety requirements and the application of accepted, proven construction engineering practices would reduce this risk and there would be no increased likelihood of loss of property, personal injury or death due to construction of Alternative 5. This impact would be less than significant. No mitigation is required.

Impact GEO-2: Loss of Property, Personal Injury, or Death from Settlement or Collapse Caused by Dewatering during Construction of Water Conveyance Features

NEPA Effects: Alternative 5 would include the same physical/structural components as Alternative 1A, except that it would entail four less intakes and four less pumping plants. These differences would present a lower hazard of settlement or collapse caused by dewatering but would not substantially change the hazard of loss of property, personal injury, or death during construction compared to Alternative 1A. The effects of Alternative 5 would, therefore, be the same as 1A. See the description and findings under Alternative 1A. There would be no adverse effect.

CEQA Conclusion: Settlement or failure of excavations during construction could result in loss of property or personal injury. However, DWR would conform with Cal-OSHA and other state code requirements, such as using seepage cutoff walls, shoring, and other measures, to protect worker safety. DWR would also ensure that the design specifications are properly executed during construction. DWR has made an environmental commitment to use the appropriate code and standard requirements to minimize potential risks (Appendix 3B, *Environmental Commitments*) and there would be no increased likelihood of loss of property, personal injury or death due to construction of Alternative 5. The impact would be less than significant. No mitigation is required.

Impact GEO-3: Loss of Property, Personal Injury, or Death from Ground Settlement during Construction of Water Conveyance Features

NEPA Effects: Alternative 5 would include the same physical/structural components as Alternative 1A, except that it would entail four less intakes and four less pumping plants. These differences would not create a lower hazard of ground settlement on the tunnels and would not substantially change the hazard of loss of property, personal injury, or death during construction compared to Alternative 1A.

1 The effects of Alternative 5 would, therefore, be the same as 1A. See the description and findings under
2 Alternative 1A. There would be no adverse effect.

3 **CEQA Conclusion:** Ground settlement above the tunneling operation could result in loss of property or
4 personal injury during construction. However, DWR would conform with Cal-OSHA, USACE, and other
5 design requirements to protect worker safety. DWR would also ensure that the design specifications
6 are properly executed during construction. DWR has made an environmental commitment to use the
7 appropriate code and standard requirements to minimize potential risks (Appendix 3B, *Environmental*
8 *Commitments*) and there would be no increased likelihood of loss of property, personal injury or death
9 due to construction of Alternative 5. Hazards to workers and project structures would be controlled at
10 safe levels and the impact would be less than significant. No mitigation is required.

11 **Impact GEO-4: Loss of Property, Personal Injury, or Death from Slope Failure during** 12 **Construction of Water Conveyance Features**

13 **NEPA Effects:** Alternative 5 would include the same physical/structural components as Alternative 1A,
14 except that it would entail four less intakes and four less pumping plants. These differences would
15 present a lower hazard of slope failure at borrow and spoils storage sites but would not substantially
16 change the hazard of loss of property, personal injury, or death during construction compared to
17 Alternative 1A. The effects of Alternative 5 would, therefore, be the same as 1A. See the description and
18 findings under Alternative 1A. There would be no adverse effect.

19 **CEQA Conclusion:** Settlement/failure of cutslopes of borrow sites and failure of soil/RTM fill slopes
20 could result in loss of property or personal injury during construction. However, because DWR would
21 conform with Cal-OSHA and other state code requirements and conform to applicable geotechnical
22 design guidelines and standards, such as USACE design measures, the hazard would be controlled to a
23 safe level and there would be no increased likelihood of loss of property, personal injury or death due
24 to construction of Alternative 5. The impact would be less than significant. No mitigation is required.

25 **Impact GEO-5: Loss of Property, Personal Injury, or Death from Structural Failure Resulting** 26 **from Construction-Related Ground Motions during Construction of Water Conveyance Features**

27 **NEPA Effects:** Alternative 5 would include the same physical/structural components as Alternative 1A,
28 except that it would entail four less intakes and four less pumping plants. These differences would
29 present a lower hazard of structural failure from construction-related ground motions but would not
30 substantially change the hazard of loss of property, personal injury, or death during construction
31 compared to Alternative 1A. The effects of Alternative 5 would, therefore, be the same as 1A. See the
32 description and findings under Alternative 1A. There would be no adverse effect.

33 **CEQA Conclusion:** Construction-related ground motions could initiate liquefaction, which could cause
34 failure of structures during construction, which could result in injury of workers at the construction
35 sites. However, because DWR would conform with Cal-OSHA and other state code requirements and
36 conform to applicable design guidelines and standards, such as USACE design measures, the hazard
37 would be controlled to a level that would protect worker safety (see Appendix 3B, *Environmental*
38 *Commitments*) and there would be no increased likelihood of loss of property, personal injury or death
39 due to construction of Alternative 5. The impact would be less than significant. No mitigation is
40 required.

1 **Impact GEO-6: Loss of Property, Personal Injury, or Death from Structural Failure Resulting**
 2 **from Rupture of a Known Earthquake Fault during Operation of Water Conveyance Features**

3 *NEPA Effects:* Alternative 5 would include the same physical/structural components as Alternative 1A,
 4 except that it would entail four less intakes and four less pumping plants. These differences would
 5 present a lower hazard from an earthquake fault rupture but would not substantially change the
 6 hazard of loss of property, personal injury, or death during construction compared to Alternative 1A.
 7 The effects of Alternative 5 would, therefore, be the same as 1A. See the description and findings under
 8 Alternative 1A. The impact would be less than significant.

9 *CEQA Conclusion:* There are no active faults capable of surface rupture that extend into the
 10 pipeline/tunnel alignment. Although the Thornton Arch and West Tracy blind thrusts occur beneath
 11 the pipeline/tunnel alignment, based on available information, they do not present a hazard of surface
 12 rupture and there would be no increased likelihood of loss of property, personal injury or death due to
 13 operation of Alternative 5. There would be no impact. Therefore, no mitigation is required.

14 **Impact GEO-7: Loss of Property, Personal Injury, or Death from Structural Failure Resulting**
 15 **from Strong Seismic Shaking during Operation of Water Conveyance Features**

16 *NEPA Effects:* Alternative 5 would include the same physical/structural components as Alternative 1A,
 17 except that it would entail four less intakes and four less pumping plants. These differences would
 18 present a lower hazard from seismic shaking but would not substantially change the hazard of loss of
 19 property, personal injury, or death during construction compared to Alternative 1A. The effects of
 20 Alternative 5 would, therefore, be the same as 1A. See the description and findings under Alternative
 21 1A. The impact would be less than significant.

22 *CEQA Conclusion:* Seismically induced strong ground shaking could damage pipelines, tunnels, intake
 23 facilities, pumping plants, and other facilities. The damage could disrupt the water supply through the
 24 conveyance system. In an extreme event, flooding and inundation of structures could result from an
 25 uncontrolled release of water from the damaged conveyance system. (Please refer to Chapter 6, *Surface*
 26 *Water*, for a detailed discussion of potential flood impacts.) However, through the final design process,
 27 measures to address this hazard would be required to conform to applicable design codes, guidelines,
 28 and standards. As described in Section 9.3.1, *Methods for Analysis*, and in Appendix 3B, *Environmental*
 29 *Commitments*, such design codes, guidelines, and standards include the California Building Code and
 30 resource agency and professional engineering specifications, such as the Division of Safety of Dams
 31 *Guidelines for Use of the Consequence Hazard Matrix and Selection of Ground Motion Parameters*, DWR's
 32 Division of Flood Management *FloodSAFE Urban Levee Design Criteria*, and USACE's *Engineering and*
 33 *Design—Earthquake Design and Evaluation for Civil Works Projects*. Conformance with these codes and
 34 standards is an environmental commitment by DWR to ensure that ground shaking risks are minimized
 35 as the water conveyance features are operated and there would be no increased likelihood of loss of
 36 property, personal injury or death due to operation of Alternative 5. The hazard would be controlled to
 37 a safe level. The impact would be less than significant. No mitigation is required.

38 **Impact GEO-8: Loss of Property, Personal Injury, or Death from Structural Failure Resulting**
 39 **from Seismic-Related Ground Failure (Including Liquefaction) during Operation of Water**
 40 **Conveyance Features**

41 *NEPA Effects:* Alternative 5 would include the same physical/structural components as Alternative 1A,
 42 except that it would entail four less intakes and four less pumping plants. These differences would
 43 present a lower hazard of structural failure from ground failure but would not substantially change the

1 hazard of loss of property, personal injury, or death during construction compared to Alternative 1A.
 2 The effects of Alternative 5 would, therefore, be the same as 1A. See the description and findings under
 3 Alternative 1A. There would be no adverse effect.

4 **CEQA Conclusion:** Seismically induced ground shaking could cause liquefaction. Liquefaction could
 5 damage pipelines, tunnels, intake facilities, pumping plants, and other facilities, and thereby disrupt the
 6 water supply through the conveyance system. In an extreme event, an uncontrolled release of water
 7 from the damaged conveyance system could result in flooding and inundation of structures. (Please
 8 refer to Chapter 6, *Surface Water*, for a detailed discussion of potential flood impacts.) However,
 9 through the final design process, measures to address the liquefaction hazard would be required to
 10 conform to applicable design codes, guidelines, and standards. As described in Section 9.3.1, *Methods*
 11 *for Analysis*, and in Appendix 3B, *Environmental Commitments*, such design codes, guidelines, and
 12 standards include USACE's *Engineering and Design—Stability Analysis of Concrete Structures and Soil*
 13 *Liquefaction during Earthquakes*, by the Earthquake Engineering Research Institute. Conformance with
 14 these design standards is an environmental commitment by DWR to ensure that liquefaction risks are
 15 minimized as the water conveyance features are operated. The hazard would be controlled to a safe
 16 level and there would be no increased likelihood of loss of property, personal injury or death due to
 17 operation of Alternative 5. The impact would be less than significant. No mitigation is required.

18 **Impact GEO-9: Loss of Property, Personal Injury, or Death from Landslides and Other Slope**
 19 **Instability during Operation of Water Conveyance Features**

20 **NEPA Effects:** Alternative 5 would include the same physical/structural components as Alternative 1A,
 21 except that it would entail four less intakes and four less pumping plants. These differences would
 22 present a lower hazard from landslides and other slope instability but would not substantially change
 23 the hazard of loss of property, personal injury, or death during construction compared to Alternative
 24 1A. The effects of Alternative 5 would, therefore, be the same as 1A. See the description and findings
 25 under Alternative 1A. There would be no adverse effect.

26 **CEQA Conclusion:** Unstable levee slopes and natural stream banks may fail, either from high pore-
 27 water pressure caused by high rainfall and weak soil, or from seismic shaking. Structures constructed
 28 on these slopes could be damaged or fail entirely as a result of slope instability. However, through the
 29 final design process, measures to address this hazard would be required to conform to applicable
 30 design codes, guidelines, and standards. As described in Section 9.3.1, *Methods for Analysis*, and in
 31 Appendix 3B, *Environmental Commitments*, such design codes, guidelines, and standards include the
 32 California Building Code and resource agency and professional engineering specifications, such as
 33 USACE's *Engineering and Design—Earthquake Design and Evaluation for Civil Works Projects*.
 34 Conformance with these codes and standards is an environmental commitment by DWR to ensure cut
 35 and fill slopes and embankments will be stable as the water conveyance features are operated and
 36 there would be no increased likelihood of loss of property, personal injury or death due to operation of
 37 Alternative 5. The impact would be less than significant. No mitigation is required.

38 **Impact GEO-10: Loss of Property, Personal Injury, or Death from Seiche or Tsunami during**
 39 **Operation of Water Conveyance Features**

40 **NEPA Effects:** Alternative 5 would include the same physical/structural components as Alternative 1A,
 41 except that it would entail four less intakes and four less pumping plants. These differences would not
 42 present a lower hazard of a seiche or tsunami and would not substantially change the hazard of loss of
 43 property, personal injury, or death during construction compared to Alternative 1A. The effects of

1 Alternative 5 would, therefore, be the same as 1A. See the description and findings under Alternative
2 1A. There would be no adverse effect.

3 **CEQA Conclusion:** Based on recorded tsunami wave heights at the Golden Gate (Contra Costa
4 Transportation Agency 2009) and in the interior of the San Francisco Bay and on tsunami inundation
5 maps prepared by the California Department of Conservation (2009), the height of a tsunami wave
6 reaching the Suisun Marsh and the Delta would be small because of the distance from the ocean and
7 attenuating effect of the San Francisco Bay. Similarly, the potential for a significant seiche to occur in
8 most parts of the Plan Area is considered low because the seismic hazard and the geometry of the
9 water bodies (i.e., wide and shallow) near conveyance facilities are not favorable for a seiche to occur.
10 However, assuming the West Tracy fault is potentially active, a potential exists for a seiche to occur in
11 the Clifton Court Forebay and the Byron Tract Forebay (Fugro Consultants 2011). The impact would
12 not be significant because the Byron Tract Forebay embankment would be designed and constructed
13 according to applicable design codes, guidelines, and standards to contain and withstand the
14 anticipated maximum seiche wave height. There would be no increased likelihood of loss of property,
15 personal injury or death due to operation of Alternative 5 from seiche or tsunami. The impact would be
16 less than significant. No mitigation is required.

17 **Impact GEO-11: Ground Failure Caused by Increased Groundwater Surface Elevations from**
18 **Unlined Canal Seepage as a Result of Operating the Water Conveyance Facilities**

19 **NEPA Effects:** Alternative 5 would not involve construction of unlined canals; therefore, there would be
20 no increase in groundwater surface elevations and consequently no effect caused by canal seepage.
21 There would be no adverse effect.

22 **CEQA Conclusion:** Alternative 5 would not involve construction of unlined canals; therefore, there
23 would be no increase in groundwater surface elevations and consequently no effect caused by canal
24 seepage. The impact would be less than significant. No mitigation is required.

25 **Impact GEO-12: Loss of Property, Personal Injury, or Death Resulting from Structural Failure**
26 **Caused by Rupture of a Known Earthquake Fault at Restoration Opportunity Areas**

27 **NEPA Effects:** Conservation measures would be the same under Alternative 5 as under 1A, except that
28 only up to 25,000 acres of tidal habitat would be restored. The effects of Alternative 5 relating to the
29 hazard of loss of property, personal injury, or death from rupture of an earthquake fault would,
30 therefore, be similar to that of Alternative 1A, but of a lower magnitude (fewer new levees and berms in
31 restoration areas). See description and findings under Alternative 1A. There would be no adverse
32 effect.

33 **CEQA Conclusion:** Rupture of the Cordelia and Green Valley faults could occur at the Suisun Marsh ROA
34 and damage ROA facilities, such as levees and berms. Damage to these features could result in their
35 failure, causing flooding of otherwise protected areas. However, through the final design process for
36 conservation measures in the ROAs, measures to address the fault rupture hazard would be required to
37 conform to applicable design codes, guidelines, and standards. As described in Section 9.3.1, *Methods*
38 *for Analysis*, and in Appendix 3B, *Environmental Commitments*, such design codes, guidelines, and
39 standards include the Division of Safety of Dams *Guidelines for Use of the Consequence Hazard Matrix*
40 *and Selection of Ground Motion Parameters*, DWR's Division of Flood Management *FloodSAFE Urban*
41 *Levee Design Criteria*, and USACE's *Engineering and Design—Earthquake Design and Evaluation for Civil*
42 *Works Projects*. Conformance with these design standards is an environmental commitment by the
43 BDPC proponents to ensure that fault rupture risks are minimized as the conservation measures are

1 implemented. The hazard would be controlled to a safe level and there would be no increased
 2 likelihood of loss of property, personal injury or death in the ROAs. The impact would be less than
 3 significant. No mitigation is required.

4 **Impact GEO-13: Loss of Property, Personal Injury, or Death from Structural Failure Resulting**
 5 **from Strong Seismic Shaking at Restoration Opportunity Areas**

6 **NEPA Effects:** Conservation measures would be the same under Alternative 5 as under 1A, except that
 7 only up to 25,000 acres of tidal habitat would be restored. The effects of Alternative 5 relating to the
 8 hazard of loss of property, personal injury, or death from a structural failure from seismic shaking
 9 would, therefore, be similar to that of Alternative 1A, but of a lower magnitude (fewer new levees and
 10 berms in restoration areas). See description and findings under Alternative 1A. There would be no
 11 adverse effect.

12 **CEQA Conclusion:** Ground shaking could damage levees, berms, and other structures. Among all the
 13 ROAs, the Suisun Marsh ROA would be the most subject to ground shaking because of its proximity to
 14 active faults. The Suisun Marsh ROA is subject to a PGA of approximately 0.31 to 0.35 g for 200-year
 15 return interval, while the PGA for the other ROAs ranges from approximately 0.11 to 0.26 g. Damage to
 16 these features could result in their failure, causing flooding of otherwise protected areas. However, as
 17 described in Section 9.3.1, *Methods for Analysis*, and in Appendix 3B, *Environmental Commitments*,
 18 design codes, guidelines, and standards, including the California Building Code and resource agency
 19 and professional engineering specifications, such as DWR's Division of Flood Management *FloodSAFE*
 20 *Urban Levee Design Criteria* and USACE's *Engineering and Design—Earthquake Design and Evaluation*
 21 *for Civil Works Projects* would be used for final design of conservation features. Conformance with these
 22 design standards is an environmental commitment by the BDCP proponents to ensure that strong
 23 seismic shaking risks are minimized as the conservation measures are operated and there would be no
 24 increased likelihood of loss of property, personal injury or death in the ROAs. The impact would be less
 25 than significant. No mitigation is required.

26 **Impact GEO-14: Loss of Property, Personal Injury, or Death from Structural Failure Resulting**
 27 **from Seismic-Related Ground Failure (Including Liquefaction) Beneath Restoration Opportunity**
 28 **Areas**

29 **NEPA Effects:** Conservation measures would be the same under Alternative 5 as under 1A, except that
 30 only up to 25,000 acres of tidal habitat would be restored. The effects of Alternative 5 relating to the
 31 hazard of loss of property, personal injury, or death from ground failure would, therefore, be similar to
 32 that of Alternative 1A, but of a lower magnitude (because of fewer new levees and berms in restoration
 33 areas). See description and findings under Alternative 1A. There would be no adverse effect.

34 **CEQA Conclusion:** Earthquake-induced ground shaking could cause liquefaction, resulting in damage to
 35 or failure of levees, berms, and other features constructed at the restoration areas. Failure of levees and
 36 other structures could result in flooding of otherwise protected areas.

37 However, through the final design process, measures to address the liquefaction hazard would be
 38 required to conform to applicable design codes, guidelines, and standards. As described in Section
 39 9.3.1, *Methods for Analysis*, and in Appendix 3B, *Environmental Commitments*, such design codes,
 40 guidelines, and standards include USACE's *Engineering and Design—Stability Analysis of Concrete*
 41 *Structures and Soil Liquefaction during Earthquakes*, by the Earthquake Engineering Research Institute.
 42 Conformance with these design standards is an environmental commitment by the BDCP proponents to
 43 ensure that liquefaction risks are minimized as the water conservation features are implemented and

1 there would be no increased likelihood of loss of property, personal injury or death in the ROAs. The
2 impact would be less than significant. No mitigation is required.

3 **Impact GEO-15: Loss of Property, Personal Injury, or Death from Landslides and Other Slope**
4 **Instability at Restoration Opportunity Areas**

5 *NEPA Effects:* Conservation measures would be the same under Alternative 5 as under 1A, except that
6 only up to 25,000 acres of tidal habitat would be restored. The effects of Alternative 5 relating to the
7 hazard of loss of property, personal injury, or death from a landslide or other slope failure would,
8 therefore, be similar to that of Alternative 1A, but of a lower magnitude. See description and findings
9 under Alternative 1A. There would be no adverse effect.

10 *CEQA Conclusion:* Unstable new and existing levee and embankment slopes could fail as a result of
11 seismic shaking and as a result of high soil-water content during heavy rainfall and cause flooding of
12 otherwise protected areas. However, because the BDCP proponents would conform with applicable
13 design guidelines and standards, such as USACE design measures, the hazard would be controlled to a
14 safe level and there would be no increased likelihood of loss of property, personal injury or death in the
15 ROAs. The impact would be less than significant. Therefore, no mitigation is required.

16 **Impact GEO-16: Loss of Property, Personal Injury, or Death from Seiche or Tsunami at**
17 **Restoration Opportunity Areas as a Result of Implementing the Conservation Actions**

18 *NEPA Effects:* Conservation measures under Alternative 5 would be similar to that as under Alternative
19 1A. See description and findings under Alternative 1A. There would be no adverse effect.

20 *CEQA Conclusion:* Based recorded tsunami heights at the Golden Gate, the height of a tsunami wave
21 reaching the ROAs would be small because of the distance from the ocean and attenuating effect of the
22 San Francisco Bay. Similarly, the potential for a significant seiche to occur in the Plan Area that would
23 cause loss of property, personal injury, or death at the ROAs is considered low because conditions for a
24 seiche to occur near conveyance facilities are not favorable. The impact would be less than significant.
25 No mitigation is required.

26 **9.3.3.11 Alternative 6A—Isolated Conveyance with Pipeline/Tunnel and**
27 **Intakes 1–5 (15,000 cfs; Operational Scenario D)**

28 **Impact GEO-1: Loss of Property, Personal Injury, or Death from Structural Failure Resulting**
29 **from Strong Seismic Shaking of Water Conveyance Features during Construction**

30 *NEPA Effects:* Alternative 6A would include the same physical/structural components as Alternative
31 1A, but existing connections between the SWP and CVP south Delta export facilities would be severed.
32 These differences would not have a bearing on the hazard of loss of property, personal injury, or death
33 from seismic shaking during construction compared to Alternative 1A. The effects of Alternative 6A
34 would, therefore, be the same as 1A. See the description and findings under Alternative 1A. There
35 would be no adverse effect.

36 *CEQA Conclusion:* Seismically induced ground shaking could cause collapse or other failure of project
37 facilities while under construction. However, DWR would conform with Cal-OSHA and other state code
38 requirements, such as shoring, bracing, lighting, excavation depth restrictions, required slope angles,
39 and other measures, to protect worker safety. Conformance with these standards and codes is an
40 environmental commitment of the project (see Appendix 3B, *Environmental Commitments*).

1 Conformance with these health and safety requirements and the application of accepted, proven
 2 construction engineering practices would reduce this risk and there would be no increased likelihood
 3 of loss of property, personal injury or death due to construction of Alternative 6A. This impact would be
 4 less than significant. No mitigation is required.

5 **Impact GEO-2: Loss of Property, Personal Injury, or Death from Settlement or Collapse Caused**
 6 **by Dewatering during Construction of Water Conveyance Features**

7 *NEPA Effects:* Alternative 6A would include the same physical/structural components as Alternative
 8 1A, but existing connections between the SWP and CVP south Delta export facilities would be severed.
 9 These differences would not have a bearing on the hazard of loss of property, personal injury, or death
 10 from settlement or collapse caused by dewatering during construction compared to Alternative 1A. The
 11 effects of Alternative 6A would, therefore, be the same as 1A. See the description and findings under
 12 Alternative 1A. There would be no adverse effect.

13 *CEQA Conclusion:* Settlement or failure of excavations during construction could result in loss of
 14 property or personal injury. However, DWR would conform with Cal-OSHA and other state code
 15 requirements, such as using seepage cutoff walls, shoring, and other measures, to protect worker
 16 safety. DWR would also ensure that the design specifications are properly executed during
 17 construction. DWR has made an environmental commitment to use the appropriate code and standard
 18 requirements to minimize potential risks (Appendix 3B, *Environmental Commitments*) and there would
 19 be no increased likelihood of loss of property, personal injury or death due to construction of
 20 Alternative 6A. The impact would be less than significant. No mitigation is required.

21 **Impact GEO-3: Loss of Property, Personal Injury, or Death from Ground Settlement during**
 22 **Construction of Water Conveyance Features**

23 *NEPA Effects:* Alternative 6A would include the same physical/structural components as Alternative
 24 1A, but existing connections between the SWP and CVP south Delta export facilities would be severed.
 25 These differences would not have a bearing on the hazard of loss of property, personal injury, or death
 26 from ground settlement of tunnels during construction compared to Alternative 1A. The effects of
 27 Alternative 6A would, therefore, be the same as 1A. See the description and findings under Alternative
 28 1A. There would be no adverse effect.

29 *CEQA Conclusion:* Ground settlement above the tunneling operation could result in loss of property or
 30 personal injury during construction. However, DWR would conform with Cal-OSHA, USACE, and other
 31 design requirements to protect worker safety. DWR would also ensure that the design specifications
 32 are properly executed during construction. DWR has made an environmental commitment to use the
 33 appropriate code and standard requirements to minimize potential risks (Appendix 3B, *Environmental*
 34 *Commitments*) and there would be no increased likelihood of loss of property, personal injury or death
 35 due to construction of Alternative 6A. Hazards to workers and project structures would be controlled at
 36 safe levels and the impact would be less than significant. No mitigation is required.

37 **Impact GEO-4: Loss of Property, Personal Injury, or Death from Slope Failure during**
 38 **Construction of Water Conveyance Features**

39 *NEPA Effects:* Alternative 6A would include the same physical/structural components as Alternative
 40 1A, but existing connections between the SWP and CVP south Delta export facilities would be severed.
 41 These differences would not have a bearing on the hazard of loss of property, personal injury, or death
 42 from slope failure at borrow and spoils storage sites during construction compared to Alternative 1A.

1 The effects of Alternative 6A would, therefore, be the same as 1A. See the description and findings
2 under Alternative 1A. There would be no adverse effect.

3 **CEQA Conclusion:** Settlement/failure of cutslopes of borrow sites and failure of soil/RTM fill slopes
4 could result in loss of property or personal injury during construction. However, because DWR would
5 conform with Cal-OSHA and other state code requirements and conform to applicable geotechnical
6 design guidelines and standards, such as USACE design measures, the hazard would be controlled to a
7 safe level and there would be no increased likelihood of loss of property, personal injury or death due
8 to construction of Alternative 6A. The impact would be less than significant. No mitigation is required.

9 **Impact GEO-5: Loss of Property, Personal Injury, or Death from Structural Failure Resulting**
10 **from Construction-Related Ground Motions during Construction of Water Conveyance Features**

11 **NEPA Effects:** Alternative 6A would include the same physical/structural components as Alternative
12 1A, but existing connections between the SWP and CVP south Delta export facilities would be severed.
13 These differences would not have a bearing on the hazard of loss of property, personal injury, or death
14 from structural failure from construction-related motions compared to Alternative 1A. The effects of
15 Alternative 6A would, therefore, be the same as 1A. See the description and findings under Alternative
16 1A. There would be no adverse effect.

17 **CEQA Conclusion:** Construction-related ground motions could initiate liquefaction, which could cause
18 failure of structures during construction, which could result in injury of workers at the construction
19 sites. However, because DWR would conform with Cal-OSHA and other state code requirements and
20 conform to applicable design guidelines and standards, such as USACE design measures, the hazard
21 would be controlled to a level that would protect worker safety (see Appendix 3B, *Environmental*
22 *Commitments*) and there would be no increased likelihood of loss of property, personal injury or death
23 due to construction of Alternative 6A. The impact would be less than significant. No mitigation is
24 required.

25 **Impact GEO-6: Loss of Property, Personal Injury, or Death from Structural Failure Resulting**
26 **from Rupture of a Known Earthquake Fault during Operation of Water Conveyance Features**

27 **NEPA Effects:** Alternative 6A would include the same physical/structural components as Alternative
28 1A, but existing connections between the SWP and CVP south Delta export facilities would be severed.
29 These differences would not have a bearing on the hazard of loss of property, personal injury, or death
30 from rupture of an earthquake fault compared to Alternative 1A. The effects of Alternative 6A would,
31 therefore, be the same as 1A. See the description and findings under Alternative 1A. There would be no
32 adverse effect.

33 **CEQA Conclusion:** There are no active faults capable of surface rupture that extend into the
34 pipeline/tunnel alignment. Although the Thornton Arch and West Tracy blind thrusts occur beneath
35 the Alternative pipeline/tunnel, based on available information, they do not present a hazard of surface
36 rupture and there would be no increased likelihood of loss of property, personal injury or death due to
37 operation of Alternative 6A. There would be no impact. Therefore, no mitigation is required.

38 **Impact GEO-7: Loss of Property, Personal Injury, or Death from Structural Failure Resulting**
39 **from Strong Seismic Shaking during Operation of Water Conveyance Features**

40 **NEPA Effects:** Alternative 6A would include the same physical/structural components as Alternative
41 1A, but existing connections between the SWP and CVP south Delta export facilities would be severed.

1 These differences would not have a bearing on the hazard of loss of property, personal injury, or death
 2 from seismic shaking during operation compared to Alternative 1A. The effects of Alternative 6A
 3 would, therefore, be the same as 1A. See the description and findings under Alternative 1A. There
 4 would be no adverse effect.

5 **CEQA Conclusion:** Seismically induced strong ground shaking could damage pipelines, tunnels, intake
 6 facilities, pumping plants, and other facilities. The damage could disrupt the water supply through the
 7 conveyance system.

8 In an extreme event, an uncontrolled release of water from the damaged conveyance system could
 9 cause flooding and inundation of structures. (Please refer to Chapter 6, *Surface Water*, for a detailed
 10 discussion of potential flood impacts.) However, through the final design process, measures to address
 11 this hazard would be required to conform to applicable design codes, guidelines, and standards. As
 12 described in Section 9.3.1, *Methods for Analysis*, and in Appendix 3B, *Environmental Commitments*, such
 13 design codes, guidelines, and standards include the California Building Code and resource agency and
 14 professional engineering specifications, such as the Division of Safety of Dams *Guidelines for Use of the*
 15 *Consequence Hazard Matrix and Selection of Ground Motion Parameters*, DWR's Division of Flood
 16 Management *FloodSAFE Urban Levee Design Criteria*, and USACE's *Engineering and Design—Earthquake*
 17 *Design and Evaluation for Civil Works Projects*. Conformance with these codes and standards is an
 18 environmental commitment by DWR to ensure that ground shaking risks are minimized as the water
 19 conveyance features are operated. The hazard would be controlled to a safe level and there would be
 20 no increased likelihood of loss of property, personal injury or death due to operation of Alternative 6A.
 21 The impact would be less than significant. No mitigation is required.

22 **Impact GEO-8: Loss of Property, Personal Injury, or Death from Structural Failure Resulting**
 23 **from Seismic-Related Ground Failure (Including Liquefaction) during Operation of Water**
 24 **Conveyance Features**

25 **NEPA Effects:** Alternative 6A would include the same physical/structural components as Alternative
 26 1A, but existing connections between the SWP and CVP south Delta export facilities would be severed.
 27 These differences would not have a bearing on the hazard of loss of property, personal injury, or death
 28 from ground failure compared to Alternative 1A. The effects of Alternative 6A would, therefore, be the
 29 same as 1A. See the description and findings under Alternative 1A. There would be no adverse effect.

30 **CEQA Conclusion:** Seismically induced ground shaking could cause liquefaction. Liquefaction could
 31 damage pipelines, tunnels, intake facilities, pumping plants, and other facilities, and thereby disrupt the
 32 water supply through the conveyance system. In an extreme event, flooding and inundation of
 33 structures could result from an uncontrolled release of water from the damaged conveyance system.
 34 (Please refer to Chapter 6, *Surface Water*, for a detailed discussion of potential flood impacts.)

35 However, through the final design process, measures to address the liquefaction hazard would be
 36 required to conform to applicable design codes, guidelines, and standards. As described in Section
 37 9.3.1, *Methods for Analysis*, and in Appendix 3B, *Environmental Commitments*, such design codes,
 38 guidelines, and standards include USACE's *Engineering and Design—Stability Analysis of Concrete*
 39 *Structures and Soil Liquefaction during Earthquakes*, by the Earthquake Engineering Research Institute.
 40 Conformance with these design standards is an environmental commitment by DWR to ensure that
 41 liquefaction risks are minimized as the water conveyance features are operated. The hazard would be
 42 controlled to a safe level and there would be no increased likelihood of loss of property, personal injury
 43 or death due to operation of Alternative 6A. The impact would be less than significant. No mitigation is
 44 required.

1 **Impact GEO-9: Loss of Property, Personal Injury, or Death from Landslides and Other Slope**
2 **Instability during Operation of Water Conveyance Features**

3 **NEPA Effects:** Alternative 6A would include the same physical/structural components as Alternative
4 1A, but existing connections between the SWP and CVP south Delta export facilities would be severed.
5 These differences would not have a bearing on the hazard of loss of property, personal injury, or death
6 from landslides and other slope instability compared to Alternative 1A. The effects of Alternative 6A
7 would, therefore, be the same as 1A. See the description and findings under Alternative 1A. There
8 would be no adverse effect.

9 **CEQA Conclusion:** Unstable levee slopes and natural stream banks may fail, either from high pore-
10 water pressure caused by high rainfall and weak soil, or from seismic shaking. Structures constructed
11 on these slopes could be damaged or fail entirely as a result of slope instability. However, through the
12 final design process, measures to address this hazard would be required to conform to applicable
13 design codes, guidelines, and standards. As described in Section 9.3.1, *Methods for Analysis*, and in
14 Appendix 3B, *Environmental Commitments*, such design codes, guidelines, and standards include the
15 California Building Code and resource agency and professional engineering specifications, such as
16 USACE's *Engineering and Design—Earthquake Design and Evaluation for Civil Works Projects*.
17 Conformance with these codes and standards is an environmental commitment by DWR to ensure cut
18 and fill slopes and embankments will be stable as the water conveyance features are operated and
19 there would be no increased likelihood of loss of property, personal injury or death due to operation of
20 Alternative 6A. The impact would be less than significant. No mitigation is required.

21 **Impact GEO-10: Loss of Property, Personal Injury, or Death from Seiche or Tsunami during**
22 **Operation of Water Conveyance Features**

23 **NEPA Effects:** Alternative 6A would include the same physical/structural components as Alternative
24 1A, but existing connections between the SWP and CVP south Delta export facilities would be severed.
25 These differences would not have a bearing on the hazard of loss of property, personal injury, or death
26 from seiche or tsunami compared to Alternative 1A. The effects of Alternative 6A would, therefore, be
27 the same as 1A. See the description and findings under Alternative 1A. There would be no adverse
28 effect.

29 **CEQA Conclusion:** Based on recorded tsunami wave heights at the Golden Gate (Contra Costa
30 Transportation Agency 2009) and in the interior of the San Francisco Bay and on tsunami inundation
31 maps prepared by the California Department of Conservation (2009), the height of a tsunami wave
32 reaching the Suisun Marsh and the Delta would be small because of the distance from the ocean and
33 attenuating effect of the San Francisco Bay. Similarly, the potential for a significant seiche to occur in
34 most parts of the Plan Area is considered low because the seismic hazard and the geometry of the
35 water bodies (i.e., wide and shallow) near conveyance facilities are not favorable for a seiche to occur.
36 However, assuming the West Tracy fault is potentially active, a potential exists for a seiche to occur in
37 the Clifton Court Forebay and the Byron Tract Forebay (Fugro Consultants 2011). The impact would
38 not be significant because the Byron Tract Forebay embankment would be designed and constructed
39 according to applicable design codes, guidelines, and standards to contain and withstand the
40 anticipated maximum seiche wave height. There would be no increased likelihood of loss of property,
41 personal injury or death due to operation of Alternative 6A from seiche or tsunami. The impact would
42 be less than significant. No mitigation is required.

1 **Impact GEO-11: Ground Failure Caused by Increased Groundwater Surface Elevations from**
 2 **Unlined Canal Seepage as a Result of Operating the Water Conveyance Facilities**

3 **NEPA Effects:** Alternative 6A would not involve construction of unlined canals; therefore, there would
 4 be no increase in groundwater surface elevations and consequently no effect caused by canal seepage.
 5 There would be no adverse effect.

6 **CEQA Conclusion:** Alternative 6A would not involve construction of unlined canals; therefore, there
 7 would be no increase in groundwater surface elevations and consequently no impact caused by canal
 8 seepage. The impact would be less than significant. No mitigation is required.

9 **Impact GEO-12: Loss of Property, Personal Injury, or Death Resulting from Structural Failure**
 10 **Caused by Rupture of a Known Earthquake Fault at Restoration Opportunity Areas**

11 **NEPA Effects:** Conservation measures would be the same under Alternative 6A as under 1A. See
 12 description and findings under Alternative 1A. There would be no adverse effect.

13 **CEQA Conclusion:** Rupture of the Cordelia and Green Valley faults could occur at the Suisun Marsh ROA
 14 and damage ROA facilities, such as levees and berms. Damage to these features could result in their
 15 failure, causing flooding of otherwise protected areas. However, through the final design process for
 16 conservation measures in the ROAs, measures to address the fault rupture hazard would be required to
 17 conform to applicable design codes, guidelines, and standards. As described in Section 9.3.1, *Methods*
 18 *for Analysis*, and in Appendix 3B, *Environmental Commitments*, such design codes, guidelines, and
 19 standards include the Division of Safety of Dams *Guidelines for Use of the Consequence Hazard Matrix*
 20 *and Selection of Ground Motion Parameters*, DWR's Division of Flood Management *FloodSAFE Urban*
 21 *Levee Design Criteria*, and USACE's *Engineering and Design—Earthquake Design and Evaluation for Civil*
 22 *Works Projects*. Conformance with these design standards is an environmental commitment by the
 23 BDCP proponents to ensure that fault rupture risks are minimized as the conservation measures are
 24 implemented. The hazard would be controlled to a safe level and there would be no increased
 25 likelihood of loss of property, personal injury or death in the ROAs. The impact would be less than
 26 significant. No mitigation is required.

27 **Impact GEO-13: Loss of Property, Personal Injury, or Death from Structural Failure Resulting**
 28 **from Strong Seismic Shaking at Restoration Opportunity Areas**

29 **NEPA Effects:** Conservation measures would be the same under Alternative 6A as under 1A. See
 30 description and findings under Alternative 1A. There would be no adverse effect.

31 **CEQA Conclusion:** Ground shaking could damage levees, berms, and other structures. Among all the
 32 ROAs, the Suisun Marsh ROA would be the most subject to ground shaking because of its proximity to
 33 active faults. The Suisun Marsh ROA is subject to a PGA of approximately 0.31 to 0.35 g for 200-year
 34 return interval, while the PGA for the other ROAs ranges from approximately 0.11 to 0.26 g. Damage to
 35 these features could result in their failure, causing flooding of otherwise protected areas.

36 However, as described in Section 9.3.1, *Methods for Analysis*, and in Appendix 3B, *Environmental*
 37 *Commitments*, design codes, guidelines, and standards, including the California Building Code and
 38 resource agency and professional engineering specifications, such as DWR's Division of Flood
 39 Management *FloodSAFE Urban Levee Design Criteria* and USACE's *Engineering and Design—Earthquake*
 40 *Design and Evaluation for Civil Works Projects* would be used for final design of conservation features.
 41 Conformance with these design standards is an environmental commitment by the BDCP proponents to
 42 ensure that strong seismic shaking risks are minimized as the conservation measures are operated and

1 there would be no increased likelihood of loss of property, personal injury or death in the ROAs. The
2 impact would be less than significant. No mitigation is required.

3 **Impact GEO-14: Loss of Property, Personal Injury, or Death from Structural Failure Resulting**
4 **from Seismic-Related Ground Failure (Including Liquefaction) Beneath Restoration Opportunity**
5 **Areas**

6 *NEPA Effects:* Conservation measures would be the same under Alternative 6A as under 1A. See
7 description and findings under Alternative 1A. There would be no adverse effect.

8 *CEQA Conclusion:* Earthquake-induced ground shaking could cause liquefaction, resulting in damage to
9 or failure of levees, berms, and other features constructed at the restoration areas. Failure of levees and
10 other structures could result in flooding of otherwise protected areas.

11 However, through the final design process, measures to address the liquefaction hazard would be
12 required to conform to applicable design codes, guidelines, and standards. As described in Section
13 9.3.1, *Methods for Analysis*, and in Appendix 3B, *Environmental Commitments*, such design codes,
14 guidelines, and standards include USACE's *Engineering and Design—Stability Analysis of Concrete*
15 *Structures* and *Soil Liquefaction during Earthquakes*, by the Earthquake Engineering Research Institute.
16 Conformance with these design standards is an environmental commitment by the BDCP proponents to
17 ensure that liquefaction risks are minimized as the water conservation features are implemented and
18 there would be no increased likelihood of loss of property, personal injury or death in the ROAs. The
19 impact would be less than significant. No mitigation is required.

20 **Impact GEO-15: Loss of Property, Personal Injury, or Death from Landslides and Other Slope**
21 **Instability at Restoration Opportunity Areas**

22 *NEPA Effects:* Conservation measures would be the same under Alternative 6A as under 1A. See
23 description and findings under Alternative 1A. There would be no adverse effect.

24 *CEQA Conclusion:* Unstable new and existing levee and embankment slopes could fail as a result of
25 seismic shaking and as a result of high soil-water content during heavy rainfall and cause flooding of
26 otherwise protected areas. However, because the BDCP proponents would conform with applicable
27 design guidelines and standards, such as USACE design measures, the hazard would be controlled to a
28 safe level and there would be no increased likelihood of loss of property, personal injury or death in the
29 ROAs. The impact would be less than significant. Therefore, no mitigation is required.

30 **Impact GEO-16: Loss of Property, Personal Injury, or Death from Seiche or Tsunami at**
31 **Restoration Opportunity Areas as a Result of Implementing the Conservation Actions**

32 *NEPA Effects:* Conservation measures under Alternative 6A would be similar to that as under
33 Alternative 1A. See description and findings under Alternative 1A. There would be no adverse effect.

34 *CEQA Conclusion:* Based on recorded tsunami heights at the Golden Gate, the height of a tsunami wave
35 reaching the Suisun Marsh and the Delta would be small because of the distance from the ocean and
36 attenuating effect of the San Francisco Bay. The impact would be less than significant. No mitigation is
37 required. Similarly, the potential for a significant seiche to occur in the Plan Area is considered low
38 because conditions for a seiche to occur near conveyance facilities are not favorable and there would be
39 no increased likelihood of loss of property, personal injury or death in the ROAs. The impact would be
40 less than significant. No mitigation is required.

9.3.3.12 Alternative 6B—Isolated Conveyance with East Alignment and Intakes 1–5 (15,000 cfs; Operational Scenario D)

Impact GEO-1: Loss of Property, Personal Injury, or Death from Structural Failure Resulting from Strong Seismic Shaking of Water Conveyance Features during Construction

NEPA Effects: Alternative 6B would include the same physical/structural components as Alternative 1B, but existing connections between the SWP and CVP south Delta export facilities would be severed. These differences would not have a bearing on the hazard of loss of property, personal injury, or death from seismic shaking during construction compared to Alternative 1B. The effects of Alternative 6B would, therefore, be the same as 1B. See the description and findings under Alternative 1B. There would be no adverse effect.

CEQA Conclusion: Seismically induced ground shaking could cause collapse or other failure of project facilities while under construction. However, DWR would conform with Cal-OSHA and other state code requirements, such as shoring, bracing, lighting, excavation depth restrictions, required slope angles, and other measures, to protect worker safety. Conformance with these standards and codes is an environmental commitment of the project (see Appendix 3B, *Environmental Commitments*). Conformance with these health and safety requirements and the application of accepted, proven construction engineering practices would reduce this risk and there would be no increased likelihood of loss of property, personal injury or death due to construction of Alternative 6B. This impact would be less than significant. No mitigation is required.

Impact GEO-2: Loss of Property, Personal Injury, or Death from Settlement or Collapse Caused by Dewatering during Construction of Water Conveyance Features

NEPA Effects: Alternative 6B would include the same physical/structural components as Alternative 1B, but existing connections between the SWP and CVP south Delta export facilities would be severed. These differences would not have a bearing on the hazard of loss of property, personal injury, or death from settlement or collapse caused by dewatering during construction compared to Alternative 1B. The effects of Alternative 6B would, therefore, be the same as 1B. See the description and findings under Alternative 1B. There would be no adverse effect.

CEQA Conclusion: Settlement or failure of excavations during construction could result in loss of property or personal injury. However, DWR would conform with Cal-OSHA and other state code requirements, such as using seepage cutoff walls, shoring, and other measures, to protect worker safety. DWR would also ensure that the design specifications are properly executed during construction. DWR has made an environmental commitment to use the appropriate code and standard requirements to minimize potential risks (Appendix 3B, *Environmental Commitments*) and there would be no increased likelihood of loss of property, personal injury or death due to construction of Alternative 6B. The impact would be less than significant. No mitigation is required.

Impact GEO-3: Loss of Property, Personal Injury, or Death from Ground Settlement during Construction of Water Conveyance Features

NEPA Effects: Alternative 6B would include the same physical/structural components as Alternative 1B, but existing connections between the SWP and CVP south Delta export facilities would be severed. These differences would not have a bearing on the hazard of loss of property, personal injury, or death from ground settlement during construction of tunnel siphons, compared to Alternative 1B. The effects

1 of Alternative 6B would, therefore, be the same as 1B. See the description and findings under
2 Alternative 1B. There would be no adverse effect.

3 **CEQA Conclusion:** Ground settlement above the tunneling operation could result in loss of property or
4 personal injury during construction. However, DWR would conform with Cal-OSHA, USACE and other
5 design requirements to protect worker safety. DWR would also ensure that the design specifications
6 are properly executed during construction. DWR has made an environmental commitment to use the
7 appropriate code and standard requirements to minimize potential risks (Appendix 3B, *Environmental*
8 *Commitments*). Hazards to workers and project structures would be controlled at safe levels and there
9 would be no increased likelihood of loss of property, personal injury or death due to construction of
10 Alternative 6B. The impact would be less than significant. No mitigation is required.

11 **Impact GEO-4: Loss of Property, Personal Injury, or Death from Slope Failure during** 12 **Construction of Water Conveyance Features**

13 **NEPA Effects:** Alternative 6B would include the same physical/structural components as Alternative
14 1B, but existing connections between the SWP and CVP south Delta export facilities would be severed.
15 These differences would not have a bearing on the hazard of loss of property, personal injury, or death
16 from slope failure at borrow and spoils storage sites during construction compared to Alternative 1B.
17 The effects of Alternative 6B would, therefore, be the same as 1B. See the description and findings
18 under Alternative 1B. There would be no adverse effect.

19 **CEQA Conclusion:** Settlement/failure of cutslopes of borrow sites and failure of soil/RTM fill slopes
20 could result in loss of property or personal injury during construction. However, because DWR would
21 conform with Cal-OSHA and other state code requirements and conform to applicable geotechnical
22 design guidelines and standards, such as USACE design measures, the hazard would be controlled to a
23 safe level and there would be no increased likelihood of loss of property, personal injury or death due
24 to construction of Alternative 6B. The impact would be less than significant. No mitigation is required.

25 **Impact GEO-5: Loss of Property, Personal Injury, or Death from Structural Failure Resulting** 26 **from Construction-Related Ground Motions during Construction of Water Conveyance Features**

27 **NEPA Effects:** Alternative 6B would include the same physical/structural components as Alternative
28 1B, but existing connections between the SWP and CVP south Delta export facilities would be severed.
29 These differences would not have a bearing on the hazard of loss of property, personal injury, or death
30 from structural failure from construction-related motions compared to Alternative 1B. The effects of
31 Alternative 6B would, therefore, be the same as 1B. See the description and findings under Alternative
32 1B. There would be no adverse effect.

33 **CEQA Conclusion:** Construction-related ground motions could initiate liquefaction, which could cause
34 failure of structures during construction, which could result in injury of workers at the construction
35 sites. However, because DWR has committed to conform with Cal-OSHA and other state code
36 requirements and conform to applicable design guidelines and standards, such as USACE design
37 measures, the hazard would be controlled to a level that would protect worker safety (see Appendix 3B,
38 *Environmental Commitments*) and there would be no increased likelihood of loss of property, personal
39 injury or death due to construction of Alternative 6B. The impact would be less than significant. No
40 mitigation is required.

1 **Impact GEO-6: Loss of Property, Personal Injury, or Death from Structural Failure Resulting**
 2 **from Rupture of a Known Earthquake Fault during Operation of Water Conveyance Features**

3 **NEPA Effects:** Alternative 6B would include the same physical/structural components as Alternative
 4 1B, but existing connections between the SWP and CVP south Delta export facilities would be severed.
 5 These differences would not have a bearing on the hazard of loss of property, personal injury, or death
 6 from rupture of an earthquake fault compared to Alternative 1B. The effects of Alternative 6B would,
 7 therefore, be the same as 1B. See the description and findings under Alternative 1B. There would be no
 8 adverse effect.

9 **CEQA Conclusion:** There are no active faults capable of surface rupture that extend into the East
 10 alignment. Although the Thornton Arch and West Tracy blind thrusts occur beneath the East alignment,
 11 based on available information, they do not present a hazard of surface rupture and there would be no
 12 increased likelihood of direct loss, injury or death due to operation of Alternative 6B. There would be
 13 no impact. Therefore, no mitigation is required.

14 **Impact GEO-7: Loss of Property, Personal Injury, or Death from Structural Failure Resulting**
 15 **from Strong Seismic Shaking during Operation of Water Conveyance Features**

16 **NEPA Effects:** Alternative 6B would include the same physical/structural components as Alternative
 17 1B, but existing connections between the SWP and CVP south Delta export facilities would be severed.
 18 These differences would not have a bearing on the hazard of loss of property, personal injury, or death
 19 from seismic shaking during operation compared to Alternative 1B. The effects of Alternative 6B would,
 20 therefore, be the same as 1B. See the description and findings under Alternative 1B. There would be no
 21 adverse effect.

22 **CEQA Conclusion:** Seismically induced strong ground shaking could damage the canals, pipelines,
 23 tunnel and culvert siphons, intake facilities, pumping plants, and other facilities. The damage could
 24 disrupt the water supply through the conveyance system. In an extreme event, an uncontrolled release
 25 of water from the damaged conveyance system could cause flooding and inundation of structures.
 26 (Please refer to Chapter 6, *Surface Water*, for a detailed discussion of potential flood impacts.) However,
 27 through the final design process, measures to address this hazard would be required to conform to
 28 applicable design codes, guidelines, and standards. As described in Section 9.3.1, *Methods for Analysis*,
 29 and in Appendix 3B, *Environmental Commitments*, such design codes, guidelines, and standards include
 30 the California Building Code and resource agency and professional engineering specifications, such as
 31 the Division of Safety of Dams *Guidelines for Use of the Consequence Hazard Matrix and Selection of*
 32 *Ground Motion Parameters*, DWR's Division of Flood Management *FloodSAFE Urban Levee Design*
 33 *Criteria*, and USACE's *Engineering and Design—Earthquake Design and Evaluation for Civil Works*
 34 *Projects*. Conformance with these codes and standards is an environmental commitment by DWR to
 35 ensure that ground shaking risks are minimized as the water conveyance features are operated and
 36 there would be no increased likelihood of loss of property, personal injury or death due to operation of
 37 Alternative 6B. The hazard would be controlled to a safe level. The impact would be less than
 38 significant. No mitigation is required.

39 **Impact GEO-8: Loss of Property, Personal Injury, or Death from Structural Failure Resulting**
 40 **from Seismic-Related Ground Failure (Including Liquefaction) during Operation of Water**
 41 **Conveyance Features**

42 **NEPA Effects:** Alternative 6B would include the same physical/structural components as Alternative
 43 1B, but existing connections between the SWP and CVP south Delta export facilities would be severed.

1 These differences would not have a bearing on the hazard of loss of property, personal injury, or death
 2 from ground failure compared to Alternative 1B. The effects of Alternative 6B would, therefore, be the
 3 same as 1B. See the description and findings under Alternative 1B. There would be no adverse effect.

4 **CEQA Conclusion:** Seismically induced ground shaking could cause liquefaction. Liquefaction could
 5 damage the canals, pipelines, tunnel and culvert siphons, intake facilities, pumping plants, and other
 6 facilities, and thereby disrupt the water supply through the conveyance system. In an extreme event,
 7 flooding and inundation of structures could result from an uncontrolled release of water from the
 8 damaged conveyance system. (Please refer to Chapter 6, *Surface Water*, for a detailed discussion of
 9 potential flood impacts.) However, through the final design process, measures to address the
 10 liquefaction hazard would be required to conform to applicable design codes, guidelines, and
 11 standards. As described in Section 9.3.1, *Methods for Analysis*, and in Appendix 3B, *Environmental*
 12 *Commitments*, such design codes, guidelines, and standards include USACE's *Engineering and Design—*
 13 *Stability Analysis of Concrete Structures* and *Soil Liquefaction during Earthquakes*, by the Earthquake
 14 Engineering Research Institute. Conformance with these design standards is an environmental
 15 commitment by DWR to ensure that liquefaction risks are minimized as the water conveyance features
 16 are operated. The hazard would be controlled to a safe level and there would be no increased likelihood
 17 of loss of property, personal injury or death due to operation of Alternative 6B. The impact would be
 18 less than significant. No mitigation is required.

19 **Impact GEO-9: Loss of Property, Personal Injury, or Death from Landslides and Other Slope**
 20 **Instability during Operation of Water Conveyance Features**

21 **NEPA Effects:** Alternative 6B would include the same physical/structural components as Alternative
 22 1B, but existing connections between the SWP and CVP south Delta export facilities would be severed.
 23 These differences would not have a bearing on the hazard of loss of property, personal injury, or death
 24 from landslides and other slope instability compared to Alternative 1B. The effects of Alternative 6B
 25 would, therefore, be the same as 1B. See the description and findings under Alternative 1B. There
 26 would be no adverse effect.

27 **CEQA Conclusion:** Unstable levee slopes and natural stream banks may fail, either from high pore-
 28 water pressure caused by high rainfall and weak soil, or from seismic shaking. Structures constructed
 29 on these slopes could be damaged or fail entirely as a result of slope instability. However, through the
 30 final design process, measures to address this hazard would be required to conform to applicable
 31 design codes, guidelines, and standards. As described in Section 9.3.1, *Methods for Analysis*, and in
 32 Appendix 3B, *Environmental Commitments*, such design codes, guidelines, and standards include the
 33 California Building Code and resource agency and professional engineering specifications, such as
 34 USACE's *Engineering and Design—Earthquake Design and Evaluation for Civil Works Projects*.
 35 Conformance with these codes and standards is an environmental commitment by DWR to ensure cut
 36 and fill slopes and embankments will be stable as the water conveyance features are operated and
 37 there would be no increased likelihood of loss of property, personal injury or death due to operation of
 38 Alternative 6B. The impact would be less than significant. No mitigation is required.

39 **Impact GEO-10: Loss of Property, Personal Injury, or Death from Seiche or Tsunami during**
 40 **Operation of Water Conveyance Features**

41 **NEPA Effects:** Alternative 6B would include the same physical/structural components as Alternative
 42 1B, but existing connections between the SWP and CVP south Delta export facilities would be severed.
 43 These differences would not have a bearing on the hazard of loss of property, personal injury, or death

1 from seiche or tsunami compared to Alternative 1B. The effects of Alternative 6B would, therefore, be
 2 the same as 1B. See the description and findings under Alternative 1B. There would be no adverse
 3 effect.

4 **CEQA Conclusion:** Based on recorded tsunami wave heights at the Golden Gate (Contra Costa
 5 Transportation Agency 2009) and in the interior of the San Francisco Bay and on tsunami inundation
 6 maps prepared by the California Department of Conservation (2009), the height of a tsunami wave
 7 reaching the Suisun Marsh and the Delta would be small because of the distance from the ocean and
 8 attenuating effect of the San Francisco Bay. Similarly, the potential for a significant seiche to occur in
 9 most parts of the Plan Area is considered low because the seismic hazard and the geometry of the
 10 water bodies (i.e., wide and shallow) near conveyance facilities are not favorable for a seiche to occur.
 11 However, assuming that the West Tracy fault is potentially active, a potential exists for a seiche to occur
 12 in the Clifton Court Forebay and the Byron Tract Forebay (Fugro Consultants 2011). The impact would
 13 not be significant because the Byron Tract Forebay embankment would be designed and constructed
 14 according to applicable design codes, guidelines, and standards to contain and withstand the
 15 anticipated maximum seiche wave height. There would be no increased likelihood of loss of property,
 16 personal injury or death due to operation of Alternative 6B from seiche or tsunami. The impact would
 17 be less than significant. No mitigation is required.

18 **Impact GEO-11: Ground Failure Caused by Increased Groundwater Surface Elevations from**
 19 **Unlined Canal Seepage as a Result of Operating the Water Conveyance Facilities**

20 **NEPA Effects:** Alternative 6B would include the same physical/structural components as Alternative
 21 1B, but existing connections between the SWP and CVP south Delta export facilities would be severed.
 22 These differences would not have a bearing on the hazard of loss of property, personal injury, or death
 23 from seismic shaking during operation compared to Alternative 1B. The effects of Alternative 6B would,
 24 therefore, be the same as 1B. See the description and findings under Alternative 1B. There would be no
 25 adverse effect.

26 **CEQA Conclusion:** Seepage from an unlined canal could raise the water table level along the canal,
 27 thereby increasing the hazard of liquefaction where the water table is not already close to the surface.
 28 The increased hazard of liquefaction could threaten the integrity of the canal in the event that
 29 liquefaction occurs. However, because DWR would conform with applicable design guidelines and
 30 standards, such as USACE design measures, the hazard would be controlled to a safe level and there
 31 would be no increased likelihood of loss of property, personal injury or death due to operation of
 32 Alternative 6B. The impact would be less than significant. No mitigation is required.

33 **Impact GEO-12: Loss of Property, Personal Injury, or Death Resulting from Structural Failure**
 34 **Caused by Rupture of a Known Earthquake Fault at Restoration Opportunity Areas**

35 **NEPA Effects:** Conservation measures would be the same under Alternative 6B as under 1A. See
 36 description and findings under Alternative 1A. There would be no adverse effect.

37 **CEQA Conclusion:** Rupture of the Cordelia and Green Valley faults could occur at the Suisun Marsh ROA
 38 and damage ROA facilities, such as levees and berms. Damage to these features could result in their
 39 failure, causing flooding of otherwise protected areas. However, through the final design process for
 40 conservation measures in the ROAs, measures to address the fault rupture hazard would be required to
 41 conform to applicable design codes, guidelines, and standards. As described in Section 9.3.1, *Methods*
 42 *for Analysis*, and in Appendix 3B, *Environmental Commitments*, such design codes, guidelines, and
 43 standards include the Division of Safety of Dams *Guidelines for Use of the Consequence Hazard Matrix*

1 *and Selection of Ground Motion Parameters, DWR's Division of Flood Management FloodSAFE Urban*
 2 *Levee Design Criteria, and USACE's Engineering and Design—Earthquake Design and Evaluation for Civil*
 3 *Works Projects. Conformance with these design standards is an environmental commitment by the*
 4 *BDCP proponents to ensure that fault rupture risks are minimized as the conservation measures are*
 5 *implemented. The hazard would be controlled to a safe level and there would be no increased*
 6 *likelihood of loss of property, personal injury or death in the ROAs. The impact would be less than*
 7 *significant. No mitigation is required.*

8 **Impact GEO-13: Loss of Property, Personal Injury, or Death from Structural Failure Resulting**
 9 **from Strong Seismic Shaking at Restoration Opportunity Areas**

10 **NEPA Effects:** Conservation measures would be the same under Alternative 6B as under 1A. See
 11 description and findings under Alternative 1A. There would be no adverse effect.

12 **CEQA Conclusion:** Ground shaking could damage levees, berms, and other structures. Among all the
 13 ROAs, the Suisun Marsh ROA would be the most subject to ground shaking because of its proximity to
 14 active faults. The Suisun Marsh ROA is subject to a PGA of approximately 0.31 to 0.35 g for 200-year
 15 return interval, while the PGA for the other ROAs ranges from approximately 0.11 to 0.26 g. Damage to
 16 these features could result in their failure, causing flooding of otherwise protected areas.

17 However, as described in Section 9.3.1, *Methods for Analysis*, and in Appendix 3B, *Environmental*
 18 *Commitments*, design codes, guidelines, and standards, including the California Building Code and
 19 resource agency and professional engineering specifications, such as DWR's Division of Flood
 20 Management *FloodSAFE Urban Levee Design Criteria* and USACE's *Engineering and Design—Earthquake*
 21 *Design and Evaluation for Civil Works Projects* would be used for final design of conservation features.
 22 Conformance with these design standards is an environmental commitment by the BDCP proponents to
 23 ensure that strong seismic shaking risks are minimized as the conservation measures are operated and
 24 there would be no increased likelihood of loss of property, personal injury or death in the ROAs. The
 25 impact would be less than significant. No mitigation is required.

26 **Impact GEO-14: Loss of Property, Personal Injury, or Death from Structural Failure Resulting**
 27 **from Seismic-Related Ground Failure (Including Liquefaction) Beneath Restoration Opportunity**
 28 **Areas**

29 **NEPA Effects:** Conservation measures would be the same under Alternative 6B as under 1A. See
 30 description and findings under Alternative 1A. There would be no adverse effect.

31 **CEQA Conclusion:** Earthquake-induced ground shaking could cause liquefaction, resulting in damage to
 32 or failure of levees, berms, and other features constructed at the restoration areas. Failure of levees and
 33 other structures could result in flooding of otherwise protected areas.

34 However, through the final design process, measures to address the liquefaction hazard would be
 35 required to conform to applicable design codes, guidelines, and standards. As described in Section
 36 9.3.1, *Methods for Analysis*, and in Appendix 3B, *Environmental Commitments*, such design codes,
 37 guidelines, and standards include USACE's *Engineering and Design—Stability Analysis of Concrete*
 38 *Structures and Soil Liquefaction during Earthquakes*, by the Earthquake Engineering Research Institute.
 39 Conformance with these design standards is an environmental commitment by the BDCP proponents to
 40 ensure that liquefaction risks are minimized as the water conservation features are implemented. The
 41 hazard would be controlled to a safe level and there would be no increased likelihood of loss of

1 property, personal injury or death in the ROAs. The impact would be less than significant. No mitigation
2 is required.

3 **Impact GEO-15: Loss of Property, Personal Injury, or Death from Landslides and Other Slope** 4 **Instability at Restoration Opportunity Areas**

5 *NEPA Effects:* Conservation measures would be the same under Alternative 6B as under 1A. See
6 description and findings under Alternative 1A. There would be no adverse effect.

7 *CEQA Conclusion:* Unstable levee slopes and natural stream banks may fail, either from high pore-
8 water pressure caused by high rainfall and weak soil, or from seismic shaking. Structures constructed
9 on these slopes could be damaged or fail entirely as a result of slope instability. However, because the
10 BDCP proponents would conform with applicable design guidelines and standards, such as USACE
11 design measures, the hazard would be controlled to a safe level and there would be no increased
12 likelihood of loss of property, personal injury or death in the ROAs. The impact would be less than
13 significant. Therefore, no mitigation is required.

14 **Impact GEO-16: Loss of Property, Personal Injury, or Death from Seiche or Tsunami at** 15 **Restoration Opportunity Areas as a Result of Implementing the Conservation Actions**

16 *NEPA Effects:* Conservation measures under Alternative 6B would be similar to that as under
17 Alternative 1A. See description and findings under Alternative 1A. There would be no adverse effect.

18 *CEQA Conclusion:* Based on recorded tsunami wave heights at the Golden Gate, the height of a tsunami
19 wave reaching the Suisun Marsh and the Delta would be small because of the distance from the ocean
20 and attenuating effect of the San Francisco Bay. The impact would be less than significant. No
21 mitigation is required. Similarly, the potential for a significant seiche to occur at the ROAs is considered
22 low because conditions for a seiche to occur near conveyance facilities are not favorable and there
23 would be no increased likelihood of loss of property, personal injury or death in the ROAs. The impact
24 would be less than significant. No mitigation is required.

25 **9.3.3.13 Alternative 6C—Isolated Conveyance with West Alignment and** 26 **Intakes W1–W5 (15,000 cfs; Operational Scenario D)**

27 **Impact GEO-1: Loss of Property, Personal Injury, or Death from Structural Failure Resulting** 28 **from Strong Seismic Shaking of Water Conveyance Features during Construction**

29 *NEPA Effects:* Alternative 6C would include the same physical/structural components as Alternative
30 1C, but existing connections between the SWP and CVP south Delta export facilities would be severed.
31 These differences would not have a bearing on the hazard of loss of property, personal injury, or death
32 from seismic shaking during construction compared to Alternative 1C. The effects of Alternative 6C
33 would, therefore, be the same as 1C. See the description and findings under Alternative 1C. There
34 would be no adverse effect.

35 *CEQA Conclusion:* Seismically induced ground shaking could cause collapse or other failure of project
36 facilities while under construction, resulting in loss of property or personal injury. However, DWR
37 would conform with Cal-OSHA and other state code requirements, such as shoring, bracing, lighting,
38 excavation depth restrictions, required slope angles, and other measures, to protect worker safety.
39 Conformance with these standards and codes is an environmental commitment of the project (see
40 Appendix 3B, *Environmental Commitments*). Conformance with these health and safety requirements

1 and the application of accepted, proven construction engineering practices would reduce this risk and
 2 there would be no increased likelihood of loss of property, personal injury or death due to construction
 3 of Alternative 6C. This impact would be less than significant. No mitigation is required.

4 **Impact GEO-2: Loss of Property, Personal Injury, or Death from Settlement or Collapse Caused**
 5 **by Dewatering during Construction of Water Conveyance Features**

6 *NEPA Effects:* Alternative 6C would include the same physical/structural components as Alternative
 7 1C, but existing connections between the SWP and CVP south Delta export facilities would be severed.
 8 These differences would not have a bearing on the hazard of loss of property, personal injury, or death
 9 from settlement or collapse caused by dewatering during construction compared to Alternative 1C. The
 10 effects of Alternative 6C would, therefore, be the same as 1C. See the description and findings under
 11 Alternative 1C. There would be no adverse effect.

12 *CEQA Conclusion:* Settlement or failure of excavations during construction could result in loss of
 13 property or personal injury. However, DWR would conform with Cal-OSHA and other state code
 14 requirements, such as using seepage cutoff walls, shoring, and other measures, to protect worker
 15 safety. DWR would also ensure that the design specifications are properly executed during
 16 construction. DWR has made an environmental commitment to use the appropriate code and standard
 17 requirements to minimize potential risks (Appendix 3B, *Environmental Commitments*) and there would
 18 be no increased likelihood of loss of property, personal injury or death due to construction of
 19 Alternative 6C. The impact would be less than significant. No mitigation is required.

20 **Impact GEO-3: Loss of Property, Personal Injury, or Death from Ground Settlement during**
 21 **Construction of Water Conveyance Features**

22 *NEPA Effects:* Alternative 6C would include the same physical/structural components as Alternative
 23 1C, but existing connections between the SWP and CVP south Delta export facilities would be severed.
 24 These differences would not have a bearing on the hazard of loss of property, personal injury, or death
 25 from ground settlement of tunnels and culvert siphons during construction compared to Alternative 1C.
 26 The effects of Alternative 6C would, therefore, be the same as 1C. See the description and findings
 27 under Alternative 1C. There would be no adverse effect.

28 *CEQA Conclusion:* Ground settlement above the tunneling operation could result in loss of property or
 29 personal injury during construction. However, DWR would conform with Cal-OSHA, USACE and other
 30 design requirements to protect worker safety. DWR would also ensure that the design specifications
 31 are properly executed during construction. DWR has made an environmental commitment to use the
 32 appropriate code and standard requirements to minimize potential risks (Appendix 3B, *Environmental*
 33 *Commitments*). Hazards to workers and project structures would be controlled at safe levels and there
 34 would be no increased likelihood of loss of property, personal injury or death due to construction of
 35 Alternative 6C. The impact would be less than significant. No mitigation is required.

36 **Impact GEO-4: Loss of Property, Personal Injury, or Death from Slope Failure during**
 37 **Construction of Water Conveyance Features**

38 *NEPA Effects:* Alternative 6C would include the same physical/structural components as Alternative
 39 1C, but existing connections between the SWP and CVP south Delta export facilities would be severed.
 40 These differences would not have a bearing on the hazard of loss of property, personal injury, or death
 41 from slope failure at borrow and spoils storage sites during construction compared to Alternative 1C.

1 The effects of Alternative 6A would, therefore, be the same as 1C. See the description and findings
2 under Alternative 1C. There would be no adverse effect.

3 **CEQA Conclusion:** Settlement/failure of cutslopes of borrow sites and failure of soil/RTM fill slopes
4 could result in loss of property or personal injury during construction. However, because DWR would
5 conform with Cal-OSHA and other state code requirements and conform to applicable geotechnical
6 design guidelines and standards, such as USACE design measures, the hazard would be controlled to a
7 safe level and there would be no increased likelihood of loss of property, personal injury or death due
8 to construction of Alternative 6C. The impact would be less than significant. No mitigation is required.

9 **Impact GEO-5: Loss of Property, Personal Injury, or Death from Structural Failure Resulting**
10 **from Construction-Related Ground Motions during Construction of Water Conveyance Features**

11 **NEPA Effects:** Alternative 6C would include the same physical/structural components as Alternative
12 1C, but existing connections between the SWP and CVP south Delta export facilities would be severed.
13 These differences would not have a bearing on the hazard of loss of property, personal injury, or death
14 from structural failure from construction-related motions compared to Alternative 1C. The effects of
15 Alternative 6C would, therefore, be the same as 1C. See the description and findings under Alternative
16 1C. There would be no adverse effect.

17 **CEQA Conclusion:** Construction-related ground motions could initiate liquefaction, which could cause
18 failure of structures during construction, which could result in injury of workers at the construction
19 sites. However, because DWR has committed to conform with Cal-OSHA and other state code
20 requirements and conform to applicable design guidelines and standards, such as USACE design
21 measures, the hazard would be controlled to a level that would protect worker safety (see Appendix 3B,
22 *Environmental Commitments*) and there would be no increased likelihood of loss of property, personal
23 injury or death due to construction of Alternative 6C. The impact would be less than significant. No
24 mitigation is required.

25 **Impact GEO-6: Loss of Property, Personal Injury, or Death from Structural Failure Resulting**
26 **from Rupture of a Known Earthquake Fault during Operation of Water Conveyance Features**

27 **NEPA Effects:** Alternative 6C would include the same physical/structural components as Alternative
28 1C, but existing connections between the SWP and CVP south Delta export facilities would be severed.
29 These differences would not have a bearing on the hazard of loss of property, personal injury, or death
30 from rupture of an earthquake fault compared to Alternative 1C. The effects of Alternative 6C would,
31 therefore, be the same as 1C. See the description and findings under Alternative 1C. There would be no
32 adverse effect.

33 **CEQA Conclusion:** There are no active faults capable of surface rupture that extend into the West
34 alignment. Although the Thornton Arch and West Tracy blind thrusts occur beneath the West
35 alignment, based on available information, they do not present a hazard of surface rupture and there
36 would be no increased likelihood of loss of property, personal injury or death due to operation of
37 Alternative 6C. There would be no impact. No mitigation is required.

38 **Impact GEO-7: Loss of Property, Personal Injury, or Death from Structural Failure Resulting**
39 **from Strong Seismic Shaking during Operation of Water Conveyance Features**

40 **NEPA Effects:** Alternative 6C would include the same physical/structural components as Alternative
41 1C, but existing connections between the SWP and CVP south Delta export facilities would be severed.

1 These differences would not have a bearing on the hazard of loss of property, personal injury, or death
 2 from seismic shaking during operation compared to Alternative 1C. The effects of Alternative 6C would,
 3 therefore, be the same as 1C. See the description and findings under Alternative 1C. There would be no
 4 adverse effect.

5 **CEQA Conclusion:** Seismically induced strong ground shaking could damage the canals, pipelines,
 6 tunnel, culvert siphons, intake facilities, pumping plants, and other facilities. The damage could disrupt
 7 the water supply through the conveyance system. In an extreme event, an uncontrolled release of water
 8 from the damaged conveyance system could cause flooding and inundation of structures. (Please refer
 9 to Chapter 6, *Surface Water*, for a detailed discussion of potential flood impacts.) However, through the
 10 final design process, measures to address this hazard would be required to conform to applicable
 11 design codes, guidelines, and standards. As described in Section 9.3.1, *Methods for Analysis*, and in
 12 Appendix 3B, *Environmental Commitments*, such design codes, guidelines, and standards include the
 13 California Building Code and resource agency and professional engineering specifications, such as the
 14 Division of Safety of Dams *Guidelines for Use of the Consequence Hazard Matrix and Selection of Ground*
 15 *Motion Parameters*, DWR's Division of Flood Management *FloodSAFE Urban Levee Design Criteria*, and
 16 USACE's *Engineering and Design—Earthquake Design and Evaluation for Civil Works Projects*.
 17 Conformance with these codes and standards is an environmental commitment by DWR to ensure that
 18 ground shaking risks are minimized as the water conveyance features are operated. The hazard would
 19 be controlled to a safe level and there would be no increased likelihood of loss of property, personal
 20 injury or death due to operation of Alternative 6C. The impact would be less than significant. No
 21 mitigation is required.

22 **Impact GEO-8: Loss of Property, Personal Injury, or Death from Structural Failure Resulting**
 23 **from Seismic-Related Ground Failure (Including Liquefaction) during Operation of Water**
 24 **Conveyance Features**

25 **NEPA Effects:** Alternative 6C would include the same physical/structural components as Alternative
 26 1C, but existing connections between the SWP and CVP south Delta export facilities would be severed.
 27 These differences would not have a bearing on the hazard of loss of property, personal injury, or death
 28 from ground failure compared to Alternative 1C. The effects of Alternative 6C would, therefore, be the
 29 same as 1C. See the description and findings under Alternative 1C. There would be no adverse effect.

30 **CEQA Conclusion:** Seismically induced ground shaking could cause liquefaction. Liquefaction could
 31 damage pipelines, tunnels, culvert siphons, intake facilities, pumping plants, and other facilities, and
 32 thereby disrupt the water supply through the conveyance system. In an extreme event, flooding and
 33 inundation of structures could result from an uncontrolled release of water from the damaged
 34 conveyance system. (Please refer to Chapter 6, *Surface Water*, for a detailed discussion of potential
 35 flood impacts.) However, through the final design process, measures to address the liquefaction hazard
 36 would be required to conform to applicable design codes, guidelines, and standards. As described in
 37 Section 9.3.1, *Methods for Analysis*, and in Appendix 3B, *Environmental Commitments*, such design
 38 codes, guidelines, and standards include USACE's *Engineering and Design—Stability Analysis of Concrete*
 39 *Structures and Soil Liquefaction during Earthquakes*, by the Earthquake Engineering Research Institute.
 40 Conformance with these design standards is an environmental commitment by DWR to ensure that
 41 liquefaction risks are minimized as the water conveyance features are operated. The hazard would be
 42 controlled to a safe level and there would be no increased likelihood of loss of property, personal injury
 43 or death due to operation of Alternative 6C. The impact would be less than significant. No mitigation is
 44 required.

1 **Impact GEO-9: Loss of Property, Personal Injury, or Death from Landslides and Other Slope**
2 **Instability during Operation of Water Conveyance Features**

3 **NEPA Effects:** Alternative 6C would include the same physical/structural components as Alternative
4 1C, but existing connections between the SWP and CVP south Delta export facilities would be severed.
5 These differences would not have a bearing on the hazard of loss of property, personal injury, or death
6 from landslides and other slope instability compared to Alternative 1C. The effects of Alternative 6C
7 would, therefore, be the same as 1C. See the description and findings under Alternative 1C. There
8 would be no adverse effect.

9 **CEQA Conclusion:** Unstable levee slopes and natural stream banks may fail, either from high pore-
10 water pressure caused by high rainfall and weak soil, or from seismic shaking. Structures constructed
11 on these slopes could be damaged or fail entirely as a result of slope instability. However, through the
12 final design process, measures to address this hazard would be required to conform to applicable
13 design codes, guidelines, and standards. As described in Section 9.3.1, *Methods for Analysis*, and in
14 Appendix 3B, *Environmental Commitments*, such design codes, guidelines, and standards include the
15 California Building Code and resource agency and professional engineering specifications, such as
16 USACE's *Engineering and Design—Earthquake Design and Evaluation for Civil Works Projects*.
17 Conformance with these codes and standards is an environmental commitment by DWR to ensure cut
18 and fill slopes and embankments will be stable as the water conveyance features are operated and
19 there would be no increased likelihood of loss of property, personal injury or death due to operation of
20 Alternative 6C. The impact would be less than significant. No mitigation is required.

21 **Impact GEO-10: Loss of Property, Personal Injury, or Death from Seiche or Tsunami during**
22 **Operation of Water Conveyance Features**

23 **NEPA Effects:** Alternative 6C would include the same physical/structural components as Alternative
24 1C, but existing connections between the SWP and CVP south Delta export facilities would be severed.
25 These differences would not have a bearing on the hazard of loss of property, personal injury, or death
26 from seiche or tsunami compared to Alternative 1C. The effects of Alternative 6C would, therefore, be
27 the same as 1C. See the description and findings under Alternative 1C. There would be no adverse
28 effect.

29 **CEQA Conclusion:** Based on recorded tsunami wave heights at the Golden Gate (Contra Costa
30 Transportation Agency 2009) and in the interior of the San Francisco Bay and on tsunami inundation
31 maps prepared by the California Department of Conservation (2009), the height of a tsunami wave
32 reaching the Suisun Marsh and the Delta would be small because of the distance from the ocean and
33 attenuating effect of the San Francisco Bay. Similarly, the potential for a significant seiche to occur in
34 most parts of the Plan Area is considered low because the seismic hazard and the geometry of the
35 water bodies (i.e., wide and shallow) near conveyance facilities are not favorable for a seiche to occur.
36 However, assuming that the West Tracy fault is potentially active, a potential exists for a seiche to occur
37 in the Clifton Court Forebay and the Byron Tract Forebay (Fugro Consultants 2011). The impact would
38 not be significant because the Byron Tract Forebay embankment would be designed and constructed
39 according to applicable design codes, guidelines, and standards to contain and withstand the
40 anticipated maximum seiche wave height. There would be no increased likelihood of loss of property,
41 personal injury or death due to operation of Alternative 6C from seiche or tsunami. The impact would
42 be less than significant. No mitigation is required.

1 **Impact GEO-11: Ground Failure Caused by Increased Groundwater Surface Elevations from**
 2 **Unlined Canal Seepage as a Result of Operating the Water Conveyance Facilities**

3 **NEPA Effects:** Alternative 6C would include the same physical/structural components as Alternative
 4 1C, but existing connections between the SWP and CVP south Delta export facilities would be severed.
 5 These differences would not have a bearing on the hazard of loss of property, personal injury, or death
 6 from seismic shaking during operation compared to Alternative 1C. The effects of Alternative 6C would,
 7 therefore, be the same as 1C. See the description and findings under Alternative 1C. There would be no
 8 adverse effect.

9 **CEQA Conclusion:** Seepage from an unlined canal could raise the water table level along the canal,
 10 thereby increasing the hazard of liquefaction where the water table is not already close to the surface.
 11 The increased hazard of liquefaction could threaten the integrity of the canal in the event that
 12 liquefaction occurs. However, because DWR would conform with applicable design guidelines and
 13 standards, such as USACE design measures, the hazard would be controlled to a safe level and there
 14 would be no increased likelihood of loss of property, personal injury or death due to operation of
 15 Alternative 6C. The impact would be less than significant. No mitigation is required.

16 **Impact GEO-12: Loss of Property, Personal Injury, or Death Resulting from Structural Failure**
 17 **Caused by Rupture of a Known Earthquake Fault at Restoration Opportunity Areas**

18 **NEPA Effects:** Conservation measures would be the same under Alternative 6C as under 1A. See
 19 description and findings under Alternative 1A. There would be no adverse effect.

20 **CEQA Conclusion:** Rupture of the Cordelia and Green Valley faults could occur at the Suisun Marsh ROA
 21 and damage ROA facilities, such as levees and berms. Damage to these features could result in their
 22 failure, causing flooding of otherwise protected areas. However, through the final design process for
 23 conservation measures in the ROAs, measures to address the fault rupture hazard would be required to
 24 conform to applicable design codes, guidelines, and standards. As described in Section 9.3.1, *Methods*
 25 *for Analysis*, and in Appendix 3B, *Environmental Commitments*, such design codes, guidelines, and
 26 standards include the Division of Safety of Dams *Guidelines for Use of the Consequence Hazard Matrix*
 27 *and Selection of Ground Motion Parameters*, DWR's Division of Flood Management *FloodSAFE Urban*
 28 *Levee Design Criteria*, and USACE's *Engineering and Design—Earthquake Design and Evaluation for Civil*
 29 *Works Projects*. Conformance with these design standards is an environmental commitment by the
 30 BDCP proponents to ensure that fault rupture risks are minimized as the conservation measures are
 31 implemented. The hazard would be controlled to a safe level and there would be no increased
 32 likelihood of loss of property, personal injury or death in the ROAs. The impact would be less than
 33 significant. No mitigation is required.

34 **Impact GEO-13: Loss of Property, Personal Injury, or Death from Structural Failure Resulting**
 35 **from Strong Seismic Shaking at Restoration Opportunity Areas**

36 **NEPA Effects:** Conservation measures would be the same under Alternative 6C as under 1A. See
 37 description and findings under Alternative 1A. There would be no adverse effect.

38 **CEQA Conclusion:** Ground shaking could damage levees, berms, and other structures. Among all the
 39 ROAs, the Suisun Marsh ROA would be the most subject to ground shaking because of its proximity to
 40 active faults. The Suisun Marsh ROA is subject to a PGA of approximately 0.31 to 0.35 g for 200-year
 41 return interval, while the PGA for the other ROAs ranges from approximately 0.11 to 0.26 g. Damage to
 42 these features could result in their failure, causing flooding of otherwise protected areas. However, as

1 described in Section 9.3.1, *Methods for Analysis*, and in Appendix 3B, *Environmental Commitments*,
 2 design codes, guidelines, and standards, including the California Building Code and resource agency
 3 and professional engineering specifications, such as DWR's Division of Flood Management *FloodSAFE*
 4 *Urban Levee Design Criteria* and USACE's *Engineering and Design—Earthquake Design and Evaluation*
 5 *for Civil Works Projects* would be used for final design of conservation features. Conformance with these
 6 design standards is an environmental commitment by the BDCP proponents to ensure that strong
 7 seismic shaking risks are minimized as the conservation measures are operated and there would be no
 8 increased likelihood of loss of property, personal injury or death in the ROAs. The impact would be less
 9 than significant. No mitigation is required.

10 **Impact GEO-14: Loss of Property, Personal Injury, or Death from Structural Failure Resulting**
 11 **from Seismic-Related Ground Failure (Including Liquefaction) Beneath Restoration Opportunity**
 12 **Areas**

13 **NEPA Effects:** Conservation measures would be the same under Alternative 6C as under 1A. See
 14 description and findings under Alternative 1A. There would be no adverse effect.

15 **CEQA Conclusion:** Earthquake-induced ground shaking could cause liquefaction, resulting in damage to
 16 or failure of levees, berms, and other features constructed at the restoration areas. Failure of levees and
 17 other structures could result in flooding of otherwise protected areas. However, through the final
 18 design process, measures to address the liquefaction hazard would be required to conform to
 19 applicable design codes, guidelines, and standards. As described in Section 9.3.1, *Methods for Analysis*,
 20 and in Appendix 3B, *Environmental Commitments*, such design codes, guidelines, and standards include
 21 USACE's *Engineering and Design—Stability Analysis of Concrete Structures and Soil Liquefaction during*
 22 *Earthquakes*, by the Earthquake Engineering Research Institute. Conformance with these design
 23 standards is an environmental commitment by the BDCP proponents to ensure that liquefaction risks
 24 are minimized as the water conservation features are implemented. The hazard would be controlled to
 25 a safe level and there would be no increased likelihood of loss of property, personal injury or death in
 26 the ROAs. The impact would be less than significant. No mitigation is required

27 **Impact GEO-15: Loss of Property, Personal Injury, or Death from Landslides and Other Slope**
 28 **Instability at Restoration Opportunity Areas**

29 **NEPA Effects:** Conservation measures would be the same under Alternative 6C as under 1A. See
 30 description and findings under Alternative 1A. There would be no adverse effect.

31 **CEQA Conclusion:** Unstable new and existing levee and embankment slopes could fail as a result of
 32 seismic shaking and as a result of high soil-water content during heavy rainfall and cause flooding of
 33 otherwise protected areas. However, because the BDCP proponents would conform with applicable
 34 design guidelines and standards, such as USACE design measures, the hazard would be controlled to a
 35 safe level and there would be no increased likelihood of loss of property, personal injury or death in the
 36 ROAs. The impact would be less than significant. Therefore, no mitigation is required.

37 **Impact GEO-16: Loss of Property, Personal Injury, or Death from Seiche or Tsunami at**
 38 **Restoration Opportunity Areas as a Result of Implementing the Conservation Actions**

39 **NEPA Effects:** Conservation measures under Alternative 6C would be similar to that as under
 40 Alternative 1A. See description and findings under Alternative 1A. There would be no adverse effect.

1 **CEQA Conclusion:** Based on recorded tsunami wave heights at the Golden Gate, the height of a tsunami
 2 wave reaching the ROAs would be small because of the distance from the ocean and attenuating effect
 3 of the San Francisco Bay. The impact would be less than significant. No mitigation is required. Similarly,
 4 the potential for a significant seiche to occur in the Plan Area that would cause loss of property,
 5 personal injury, or death at the ROAs is considered low because conditions for a seiche to occur near
 6 conveyance facilities are not favorable. The impact would be less than significant. No mitigation is
 7 required.

8 **9.3.3.14 Alternative 7—Dual Conveyance with Pipeline/Tunnel, Intakes 2, 3, 9 and 5, and Enhanced Aquatic Conservation (9,000 cfs; Operational 10 Scenario E)**

11 **Impact GEO-1: Loss of Property, Personal Injury, or Death from Structural Failure Resulting 12 from Strong Seismic Shaking of Water Conveyance Features during Construction**

13 **NEPA Effects:** Alternative 7 would include the same physical/structural components as Alternative 1A,
 14 but would entail two less intakes and two less pumping plants. These differences would present a
 15 slightly lower hazard of structural failure from seismic shaking but would not substantially change the
 16 hazard of loss of property, personal injury, or death during construction compared to Alternative 1A.
 17 The effects of Alternative 7 would, therefore, be the same as 1A. See the description and findings under
 18 Alternative 1A. There would be no adverse effect.

19 **CEQA Conclusion:** Seismically induced ground shaking could cause collapse or other failure of project
 20 facilities while under construction. However, DWR would conform with Cal-OSHA and other state code
 21 requirements, such as shoring, bracing, lighting, excavation depth restrictions, required slope angles,
 22 and other measures, to protect worker safety. Conformance with these standards and codes is an
 23 environmental commitment of the project (see Appendix 3B, *Environmental Commitments*).
 24 Conformance with these health and safety requirements and the application of accepted, proven
 25 construction engineering practices would reduce this risk and there would be no increased likelihood
 26 of loss of property, personal injury or death due to construction of Alternative 7. This impact would be
 27 less than significant. No mitigation is required.

28 **Impact GEO-2: Loss of Property, Personal Injury, or Death from Settlement or Collapse Caused 29 by Dewatering during Construction of Water Conveyance Features**

30 **NEPA Effects:** Alternative 7 would include the same physical/structural components as Alternative 1A,
 31 but would entail two less intakes and two less pumping plants. These differences would present a
 32 slightly lower hazard of settlement or collapse caused by dewatering but would not substantially
 33 change the hazard of loss of property, personal injury, or death during construction compared to
 34 Alternative 1A. The effects of Alternative 7 would, therefore, be the same as 1A. See the description and
 35 findings under Alternative 1A. There would be no adverse effect.

36 **CEQA Conclusion:** Settlement or failure of excavations during construction could result in loss of
 37 property or personal injury. However, DWR would conform with Cal-OSHA and other state code
 38 requirements, such as using seepage cutoff walls, shoring, and other measures, to protect worker
 39 safety. DWR would also ensure that the design specifications are properly executed during
 40 construction. DWR has made an environmental commitment to use the appropriate code and standard
 41 requirements to minimize potential risks (Appendix 3B, *Environmental Commitments*) and there would

1 be no increased likelihood of loss of property, personal injury or death due to construction of
2 Alternative 7. The impact would be less than significant. No mitigation is required.

3 **Impact GEO-3: Loss of Property, Personal Injury, or Death from Ground Settlement during**
4 **Construction of Water Conveyance Features**

5 *NEPA Effects:* Alternative 7 would include the same physical/structural components as Alternative 1A,
6 but would entail two less intakes and two less pumping plants. These differences would present a
7 slightly lower hazard of ground settlement hazard on the tunnel but would not substantially change the
8 hazard of loss of property, personal injury, or death during construction compared to Alternative 1A.
9 The effects of Alternative 7 would, therefore, be the same as 1A. See the description and findings under
10 Alternative 1A. There would be no adverse effect.

11 *CEQA Conclusion:* Settlement/failure of cutslopes of borrow sites and failure of soil/RTM fill slopes
12 could result in loss of property or personal injury during construction. However, DWR would conform
13 with Cal-OSHA, USACE, and other design requirements to protect worker safety. DWR would also
14 ensure that the design specifications are properly executed during construction. DWR has made an
15 environmental commitment to use the appropriate code and standard requirements to minimize
16 potential risks (Appendix 3B, *Environmental Commitments*) and there would be no increased likelihood
17 of loss of property, personal injury or death due to construction of Alternative 7. Hazards to workers
18 and project structures would be controlled at safe levels and the impact would be less than significant.
19 No mitigation is required.

20 **Impact GEO-4: Loss of Property, Personal Injury, or Death from Slope Failure during**
21 **Construction of Water Conveyance Features**

22 *NEPA Effects:* Alternative 7 would include the same physical/structural components as Alternative 1A,
23 but would entail two less intakes and two less pumping plants. These differences would present a
24 slightly lower hazard of slope failure at borrow and spoils storage sites but would not substantially
25 change the hazard of loss of property, personal injury, or death during construction compared to
26 Alternative 1A. The effects of Alternative 7 would, therefore, be the same as 1A. See the description and
27 findings under Alternative 1A. There would be no adverse effect.

28 *CEQA Conclusion:* Settlement/failure of cutslopes of borrow sites and failure of soil/RTM fill slopes
29 could result in loss of property or personal injury during construction. However, because DWR would
30 conform with Cal-OSHA and other state code requirements and conform to applicable geotechnical
31 design guidelines and standards, such as USACE design measures, the hazard would be controlled to a
32 safe level and there would be no increased likelihood of loss of property, personal injury or death due
33 to construction of Alternative 7. The impact would be less than significant. No mitigation is required.

34 **Impact GEO-5: Loss of Property, Personal Injury, or Death from Structural Failure Resulting**
35 **from Construction-Related Ground Motions during Construction of Water Conveyance Features**

36 *NEPA Effects:* Alternative 7 would include the same physical/structural components as Alternative 1A,
37 but would entail two less intakes and two less pumping plants. These differences would present a
38 slightly lower hazard of structural failure from construction-related ground motions but would not
39 substantially change the hazard of loss of property, personal injury, or death during construction
40 compared to Alternative 1A. The effects of Alternative 7 would, therefore, be the same as 1A. See the
41 description and findings under Alternative 1A. There would be no adverse effect.

1 **CEQA Conclusion:** Construction-related ground motions could initiate liquefaction, which could cause
 2 failure of structures during construction, which could result in injury of workers at the construction
 3 sites. However, because DWR would conform with Cal-OSHA and other state code requirements and
 4 conform to applicable design guidelines and standards, such as USACE design measures, the hazard
 5 would be controlled to a level that would protect worker safety (see Appendix 3B, *Environmental*
 6 *Commitments*) and there would be no increased likelihood of loss of property, personal injury or death
 7 due to construction of Alternative 7. The impact would be less than significant. No mitigation is
 8 required.

9 **Impact GEO-6: Loss of Property, Personal Injury, or Death from Structural Failure Resulting**
 10 **from Rupture of a Known Earthquake Fault during Operation of Water Conveyance Features**

11 **NEPA Effects:** Alternative 7 would include the same physical/structural components as Alternative 1A,
 12 but would entail two less intakes and two less pumping plants. These differences would not reduce the
 13 hazard structural damage from rupture of an earthquake fault and would not substantially change the
 14 hazard of loss of property, personal injury, or death during construction compared to Alternative 1A.
 15 The effects of Alternative 7 would, therefore, be the same as 1A. See the description and findings under
 16 Alternative 1A. There would be no adverse effect.

17 **CEQA Conclusion:** There are no active faults capable of surface rupture that extend into the
 18 pipeline/tunnel alignment. Although the Thornton Arch and West Tracy blind thrusts occur beneath
 19 the pipeline/tunnel alignment, based on available information, they do not present a hazard of surface
 20 rupture and there would be no increased likelihood of loss of property, personal injury or death due to
 21 operation of Alternative 7. There would be no impact. No mitigation is required.

22 **Impact GEO-7: Loss of Property, Personal Injury, or Death from Structural Failure Resulting**
 23 **from Strong Seismic Shaking during Operation of Water Conveyance Features**

24 **NEPA Effects:** Alternative 7 would include the same physical/structural components as Alternative 1A,
 25 but would entail two less intakes and two less pumping plants. These differences would present a
 26 slightly lower hazard of seismic shaking but would not substantially change the hazard of loss of
 27 property, personal injury, or death during construction compared to Alternative 1A. The effects of
 28 Alternative 7 would, therefore, be the same as 1A. See the description and findings under Alternative
 29 1A. There would be no adverse effect.

30 **CEQA Conclusion:** Seismically induced strong ground shaking could damage pipelines, tunnels, intake
 31 facilities, pumping plants, and other facilities. The damage could disrupt the water supply through the
 32 conveyance system. In an extreme event, an uncontrolled release of water from the damaged
 33 conveyance system could cause flooding and inundation of structures. (Please refer to Chapter 6,
 34 *Surface Water*, for a detailed discussion of potential flood impacts.) However, through the final design
 35 process, measures to address this hazard would be required to conform to applicable design codes,
 36 guidelines, and standards. As described in Section 9.3.1, *Methods for Analysis*, and in Appendix 3B,
 37 *Environmental Commitments*, such design codes, guidelines, and standards include the California
 38 Building Code and resource agency and professional engineering specifications, such as the Division of
 39 Safety of Dams *Guidelines for Use of the Consequence Hazard Matrix and Selection of Ground Motion*
 40 *Parameters*, DWR's Division of Flood Management *FloodSAFE Urban Levee Design Criteria*, and USACE's
 41 *Engineering and Design—Earthquake Design and Evaluation for Civil Works Projects*. Conformance with
 42 these codes and standards is an environmental commitment by DWR to ensure that ground shaking
 43 risks are minimized as the water conveyance features are operated. The hazard would be controlled to

1 a safe level and there would be no increased likelihood of loss of property, personal injury or death due
2 to operation of Alternative 7. The impact would be less than significant. No mitigation is required.

3 **Impact GEO-8: Loss of Property, Personal Injury, or Death from Structural Failure Resulting**
4 **from Seismic-Related Ground Failure (Including Liquefaction) during Operation of Water**
5 **Conveyance Features**

6 **NEPA Effects:** Alternative 7 would include the same physical/structural components as Alternative 1A,
7 but would entail two less intakes and two less pumping plants. These differences would present a
8 slightly lower hazard of structural failure from ground failure but would not substantially change the
9 hazard of loss of property, personal injury, or death during construction compared to Alternative 1A.
10 The effects of Alternative 7 would, therefore, be the same as 1A. See the description and findings under
11 Alternative 1A. There would be no adverse effect.

12 **CEQA Conclusion:** Seismically induced ground shaking could cause liquefaction. Liquefaction could
13 damage pipelines, tunnels, intake facilities, pumping plants, and other facilities, and thereby disrupt the
14 water supply through the conveyance system. In an extreme event, flooding and inundation of
15 structures could result from an uncontrolled release of water from the damaged conveyance system.
16 (Please refer to Chapter 6, *Surface Water*, for a detailed discussion of potential flood impacts.) However,
17 through the final design process, measures to address the liquefaction hazard would be required to
18 conform to applicable design codes, guidelines, and standards. As described in Section 9.3.1, *Methods*
19 *for Analysis*, and in Appendix 3B, *Environmental Commitments*, such design codes, guidelines, and
20 standards include USACE's *Engineering and Design—Stability Analysis of Concrete Structures and Soil*
21 *Liquefaction during Earthquakes*, by the Earthquake Engineering Research Institute. Conformance with
22 these design standards is an environmental commitment by DWR to ensure that liquefaction risks are
23 minimized as the water conveyance features are operated. The hazard would be controlled to a safe
24 level and there would be no increased likelihood of loss of property, personal injury or death due to
25 operation of Alternative 7. The impact would be less than significant. No mitigation is required.

26 **Impact GEO-9: Loss of Property, Personal Injury, or Death from Landslides and Other Slope**
27 **Instability during Operation of Water Conveyance Features**

28 **NEPA Effects:** Alternative 7 would include the same physical/structural components as Alternative 1A,
29 but would entail two less intakes and two less pumping plants. These differences would present a
30 slightly lower hazard from landslides and other slope instability but would not substantially change the
31 hazard of loss of property, personal injury, or death during construction compared to Alternative 1A.
32 The effects of Alternative 7 would, therefore, be the same as 1A. See the description and findings under
33 Alternative 1A. There would be no adverse effect.

34 **CEQA Conclusion:** Unstable levee slopes and natural stream banks may fail, either from high pore-
35 water pressure caused by high rainfall and weak soil, or from seismic shaking. Structures constructed
36 on these slopes could be damaged or fail entirely as a result of slope instability. However, through the
37 final design process, measures to address this hazard would be required to conform to applicable
38 design codes, guidelines, and standards. As described in Section 9.3.1, *Methods for Analysis*, and in
39 Appendix 3B, *Environmental Commitments*, such design codes, guidelines, and standards include the
40 California Building Code and resource agency and professional engineering specifications, such as
41 USACE's *Engineering and Design—Earthquake Design and Evaluation for Civil Works Projects*.
42 Conformance with these codes and standards is an environmental commitment by DWR to ensure cut
43 and fill slopes and embankments will be stable as the water conveyance features are operated and

1 there would be no increased likelihood of loss of property, personal injury or death due to operation of
 2 Alternative 7. The impact would be less than significant. No mitigation is required.

3 **Impact GEO-10: Loss of Property, Personal Injury, or Death from Seiche or Tsunami during**
 4 **Operation of Water Conveyance Features**

5 *NEPA Effects:* Alternative 7 would include the same physical/structural components as Alternative 1A,
 6 but would entail two less intakes and two less pumping plants. These differences would present a
 7 slightly lower hazard from a seiche or tsunami but would not substantially change the hazard of loss of
 8 property, personal injury, or death during construction compared to Alternative 1A. The effects of
 9 Alternative 7 would, therefore, be the same as 1A. See the description and findings under Alternative
 10 1A. There would be no adverse effect.

11 *CEQA Conclusion:* Based on recorded tsunami wave heights at the Golden Gate (Contra Costa
 12 Transportation Agency 2009) and in the interior of the San Francisco Bay and on tsunami inundation
 13 maps prepared by the California Department of Conservation (2009), the height of a tsunami wave
 14 reaching the Suisun Marsh and the Delta would be small because of the distance from the ocean and
 15 attenuating effect of the San Francisco Bay. Similarly, the potential for a significant seiche to occur in
 16 most parts of the Plan Area is considered low because the seismic hazard and the geometry of the
 17 water bodies (i.e., wide and shallow) near conveyance facilities are not favorable for a seiche to occur.
 18 However, assuming the West Tracy fault is potentially active, a potential exists for a seiche to occur in
 19 the Clifton Court Forebay and the Byron Tract Forebay (Fugro Consultants 2011). The impact would
 20 not be significant because the Byron Tract Forebay embankment would be designed and constructed
 21 according to applicable design codes, guidelines, and standards to contain and withstand the
 22 anticipated maximum seiche wave height. There would be no increased likelihood of loss of property,
 23 personal injury or death due to operation of Alternative 7 from seiche or tsunami. The impact would be
 24 less than significant. No mitigation is required.

25 **Impact GEO-11: Ground Failure Caused by Increased Groundwater Surface Elevations from**
 26 **Unlined Canal Seepage as a Result of Operating the Water Conveyance Facilities**

27 *NEPA Effects:* Alternative 7 would not involve construction of unlined canals; therefore, there would be
 28 no increase in groundwater surface elevations and consequently no effect caused by canal seepage.
 29 There would be no adverse effect.

30 *CEQA Conclusion:* Alternative 7 would not involve construction of unlined canals; therefore, there
 31 would be no increase in groundwater surface elevations and consequently no impact caused by canal
 32 seepage. The impact would be less than significant. No mitigation is required.

33 **Impact GEO-12: Loss of Property, Personal Injury, or Death Resulting from Structural Failure**
 34 **Caused by Rupture of a Known Earthquake Fault at Restoration Opportunity Areas**

35 *NEPA Effects:* Conservation measures under Alternative 7 would be the same that as under Alternative
 36 1A, except up to an additional 20 linear miles of channel margin habitat would be created and up to an
 37 additional 10,000 acres of seasonally inundated floodplain habitat would be restored. The potential
 38 effects of a structural failure from rupture of an earthquake fault would pertain only to the Suisun
 39 Marsh ROA, which is the only ROA in which AP faults are found. However, the same engineering design
 40 and construction requirements that apply to all the ROAs would ensure that levees and other
 41 structures would withstand the effect of a fault rupture. The effect of Alternative 7 would, therefore, be

1 the similar to that of Alternative 1A. See description and findings under Alternative 1A. There would be
2 no adverse effect.

3 **CEQA Conclusion:** Rupture of the Cordelia and Green Valley faults could occur at the Suisun Marsh ROA
4 and damage ROA facilities, such as levees and berms. Damage to these features could result in their
5 failure, causing flooding of otherwise protected areas.

6 However, through the final design process for conservation measures in the ROAs, measures to address
7 the fault rupture hazard would be required to conform to applicable design codes, guidelines, and
8 standards. As described in Section 9.3.1, *Methods for Analysis*, and in Appendix 3B, *Environmental*
9 *Commitments*, such design codes, guidelines, and standards include the Division of Safety of Dams
10 *Guidelines for Use of the Consequence Hazard Matrix and Selection of Ground Motion Parameters*, DWR's
11 Division of Flood Management *FloodSAFE Urban Levee Design Criteria*, and USACE's *Engineering and*
12 *Design—Earthquake Design and Evaluation for Civil Works Projects*. Conformance with these design
13 standards is an environmental commitment by the BDCP proponents to ensure that fault rupture risks
14 are minimized as the conservation measures are implemented. The hazard would be controlled to a
15 safe level and there would be no increased likelihood of loss of property, personal injury or death in the
16 ROAs. The impact would be less than significant. No mitigation is required.

17 **Impact GEO-13: Loss of Property, Personal Injury, or Death from Structural Failure Resulting** 18 **from Strong Seismic Shaking at Restoration Opportunity Areas**

19 **NEPA Effects:** Conservation measures under Alternative 7 would be the same that as under Alternative
20 1A, except that up to an additional 20 linear miles of channel margin habitat would be created and up to
21 an additional 10,000 acres of seasonally inundated floodplain habitat would be restored. The potential
22 effects of a structural failure from seismic shaking would also be of a greater magnitude than that of
23 Alternative 1A. However, the same engineering design and construction requirements that apply to all
24 the ROAs would ensure that levees and other structures would withstand the effects of seismic shaking.
25 The effect of Alternative 7 would, therefore, be the similar to that of Alternative 1A but of a greater
26 magnitude. See description and findings under Alternative 1A. There would be no adverse effect.

27 **CEQA Conclusion:** Ground shaking could damage levees, berms, and other structures. Among all the
28 ROAs, the Suisun Marsh ROA would be the most subject to ground shaking because of its proximity to
29 active faults. The Suisun Marsh ROA is subject to a PGA of approximately 0.31 to 0.35 g for 200-year
30 return interval, while the PGA for the other ROAs ranges from approximately 0.11 to 0.26 g. Damage to
31 these features could result in their failure, causing flooding of otherwise protected areas. However, as
32 described in Section 9.3.1, *Methods for Analysis*, and in Appendix 3B, *Environmental Commitments*,
33 design codes, guidelines, and standards, including the California Building Code and resource agency
34 and professional engineering specifications, such as DWR's Division of Flood Management *FloodSAFE*
35 *Urban Levee Design Criteria* and USACE's *Engineering and Design—Earthquake Design and Evaluation*
36 *for Civil Works Projects* would be used for final design of conservation features. Conformance with these
37 design standards is an environmental commitment by the BDCP proponents to ensure that strong
38 seismic shaking risks are minimized as the conservation measures are operated and there would be no
39 increased likelihood of loss of property, personal injury or death in the ROAs. This impact would be less
40 than significant. No mitigation is required.

1 **Impact GEO-14: Loss of Property, Personal Injury, or Death from Structural Failure Resulting**
 2 **from Seismic-Related Ground Failure (Including Liquefaction) Beneath Restoration Opportunity**
 3 **Areas**

4 **NEPA Effects:** Conservation measures under Alternative 7 would be the same that as under Alternative
 5 1A, except that up to an additional 20 linear miles of channel margin habitat would be created and up to
 6 an additional 10,000 acres of seasonally inundated floodplain habitat would be restored. The potential
 7 effects of a structural failure from ground failure would also be of a greater magnitude than that of
 8 Alternative 1A. However, the same engineering design and construction requirements that apply to all
 9 the ROAs would ensure that levees and other structures would withstand the effects of liquefaction.
 10 The effect of Alternative 7 would, therefore, be the similar to that of Alternative 1A but of a greater
 11 magnitude. See description and findings under Alternative 1A. There would be no adverse effect.

12 **CEQA Conclusion:** Earthquake-induced ground shaking could cause liquefaction, resulting in damage to
 13 or failure of levees, berms, and other features constructed at the restoration areas. Failure of levees and
 14 other structures could result in flooding of otherwise protected areas.

15 However, through the final design process, measures to address the liquefaction hazard would be
 16 required to conform to applicable design codes, guidelines, and standards. As described in Section
 17 9.3.1, *Methods for Analysis*, and in Appendix 3B, *Environmental Commitments*, such design codes,
 18 guidelines, and standards include USACE's *Engineering and Design—Stability Analysis of Concrete*
 19 *Structures* and *Soil Liquefaction during Earthquakes*, by the Earthquake Engineering Research Institute.
 20 Conformance with these design standards is an environmental commitment by the BDCP proponents to
 21 ensure that liquefaction risks are minimized as the water conservation features are implemented. The
 22 hazard would be controlled to a safe level and there would be no increased likelihood of loss of
 23 property, personal injury or death in the ROAs. The impact would be less than significant. No mitigation
 24 is required.

25 **Impact GEO-15: Loss of Property, Personal Injury, or Death from Landslides and Other Slope**
 26 **Instability at Restoration Opportunity Areas**

27 Conservation measures under Alternative 7 would be the same that as under Alternative 1A, except
 28 that up to an additional 20 linear miles of channel margin habitat would be created and up to an
 29 additional 10,000 acres of seasonally inundated floodplain habitat would be restored. The potential
 30 effects of a landslide or other slope instability would also be of a greater magnitude than that of
 31 Alternative 1A. However, the same engineering design and construction requirements that apply to all
 32 the ROAs would ensure that levees and other structures would withstand the effects of landslides and
 33 other slope instability. The effect of Alternative 7 would, therefore, be the similar to that of Alternative
 34 1A but of a greater magnitude. See description and findings under Alternative 1A.

35 **NEPA Effects:** The potential effect could be substantial because levee slopes and embankments may fail,
 36 either from high pore-water pressure caused by high rainfall and weak soil, or from seismic shaking.
 37 Failure of these features could result in flooding of otherwise protected areas.

38 As outlined in Chapter 3, *Description of Alternatives*, erosion protection measures and protection
 39 against related failure of adjacent levees would be taken where levee breaches were developed.
 40 Erosion protection could include geotextile fabrics, rock revetments, riprap, or other material selected
 41 during future evaluations for each location. Aggregate rock could be placed on the remaining levees to
 42 provide an access road to the breach location. Erosion protection measures would also be taken where
 43 levee lowering is done for the purposes of allowing seasonal or periodic inundation of lands during

1 high flows or high tides to improve habitat or to reduce velocities and elevations of floodwaters. To
2 reduce erosion potential on the new levee crest, a paved or gravel access road could be constructed
3 with short (approximately 1 foot) retaining walls on each edge of the crest to reduce undercutting of
4 the roadway by high tides. Levee modifications could also include excavation of watersides of the
5 slopes to allow placement of slope protection, such as riprap or geotextile fabric, and to modify slopes
6 to provide levee stability. Erosion and scour protection could be placed on the landside of the levee and
7 continued for several feet onto the land area away from the levee toe. Neighboring levees could require
8 modification to accommodate increased flows or to reduce effects of changes in water elevation or
9 velocities along channels following inundation of tidal marshes. Hydraulic modeling would be used
10 during subsequent analyses to determine the need for such measures.

11 New levees would be constructed to separate lands to be inundated for tidal marsh from non-
12 inundated lands, including lands with substantial subsidence. Levees could be constructed as described
13 for the new levees at intake locations. Any new levees would be required to be designed and
14 implemented to conform with applicable flood management standards and permitting processes. This
15 would be coordinated with the appropriate flood management agencies, which may include USACE,
16 DWR, CVFPB, and local flood management agencies.

17 Additionally, during project design, a geotechnical engineer would develop slope stability design
18 criteria (such as minimum slope safety factors and allowable slope deformation and settlement) for the
19 various anticipated loading conditions. As discussed in Chapter 3, foundation soil beneath
20 embankments and levees could be improved to increase its strength and to reduce settlement and
21 deformation. Foundation soil improvement could involve excavation and replacement with engineered
22 fill; preloading; ground modifications using jet-grouting, compaction grouting, chemical grouting,
23 shallow soil mixing, deep soil mixing, vibro-compaction, or vibro-replacement; or other methods.
24 Engineered fill could also be used to construct new embankments and levees.

25 Site-specific geotechnical and hydrological information would be used, and the design would conform
26 with the current standards and construction practices, as described in Chapter 3, such as USACE's
27 *Design and Construction of Levees* and USACE's *EM 1110-2-1902, Slope Stability*.

28 The BDCP proponents would ensure that the geotechnical design recommendations are included in the
29 design of embankments and levees to minimize the potential effects from slope failure. The BDCP
30 proponents would also ensure that the design specifications are properly executed during
31 implementation.

32 Conformance to the above and other applicable design specifications and standards would ensure that
33 the hazard of slope instability would not jeopardize the integrity of levee and other features thereby
34 creating an increased likelihood of loss of property, personal injury or death of individuals in the ROAs.
35 Therefore, there would be no adverse effect.

36 **CEQA Conclusion:** Unstable new and existing levee and embankment slopes could fail as a result of
37 seismic shaking and as a result of high soil-water content during heavy rainfall and cause flooding of
38 otherwise protected areas. However, because BDCP proponents would conform with applicable design
39 guidelines and standards, such as USACE design measures, the hazard would be controlled to a safe
40 level and there would be no increased likelihood of loss of property, personal injury or death in the
41 ROAs. The impact would be less than significant. Therefore, no mitigation is required.

1 **Impact GEO-16: Loss of Property, Personal Injury, or Death from Seiche or Tsunami at**
 2 **Restoration Opportunity Areas as a Result of Implementing the Conservation Actions**

3 **NEPA Effects:** Conservation measures under Alternative 7 would be similar to that as under Alternative
 4 1A. See description and findings under Alternative 1A. There would be no adverse effect.

5 **CEQA Conclusion:** Based recorded tsunami heights at the Golden Gate, the height of a tsunami wave
 6 reaching the ROAs would be small because of the distance from the ocean and attenuating effect of the
 7 San Francisco Bay. Similarly, the potential for a significant seiche to occur in the Plan Area that would
 8 cause loss of property, personal injury, or death at the ROAs is considered low because conditions for a
 9 seiche to occur near conveyance facilities are not favorable. The impact would be less than significant.
 10 No mitigation is required.

11 **9.3.3.15 Alternative 8—Dual Conveyance with Pipeline/Tunnel, Intakes 2, 3,**
 12 **and 5, and Increased Delta Outflow (9,000 cfs; Operational**
 13 **Scenario F)**

14 **Impact GEO-1: Loss of Property, Personal Injury, or Death from Structural Failure Resulting**
 15 **from Strong Seismic Shaking of Water Conveyance Features during Construction**

16 **NEPA Effects:** Alternative 8 would include the same physical/structural components as Alternative 1A,
 17 but would entail two less intakes and two less pumping plants. These differences would present a
 18 slightly lower hazard of structural failure from seismic shaking but would not substantially change the
 19 hazard of loss of property, personal injury, or death during construction compared to Alternative 1A.
 20 The effects of Alternative 8 would, therefore, be the same as 1A. See the description and findings under
 21 Alternative 1A. There would be no adverse effect.

22 **CEQA Conclusion:** Seismically induced ground shaking could cause collapse or other failure of project
 23 facilities while under construction. However, DWR would conform with Cal-OSHA and other state code
 24 requirements, such as shoring, bracing, lighting, excavation depth restrictions, required slope angles,
 25 and other measures, to protect worker safety. Conformance with these standards and codes is an
 26 environmental commitment of the project (see Appendix 3B, *Environmental Commitments*).
 27 Conformance with these health and safety requirements and the application of accepted, proven
 28 construction engineering practices would reduce this risk and there would be no increased likelihood
 29 of loss of property, personal injury or death due to the construction of Alternative 8. This impact would
 30 be less than significant. No mitigation is required.

31 **Impact GEO-2: Loss of Property, Personal Injury, or Death from Settlement or Collapse Caused**
 32 **by Dewatering during Construction of Water Conveyance Features**

33 **NEPA Effects:** Alternative 8 would include the same physical/structural components as Alternative 1A,
 34 but would entail two less intakes and two less pumping plants. These differences would present a
 35 slightly lower hazard of settlement or collapse caused by dewatering but would not substantially
 36 change the hazard of loss of property, personal injury, or death during construction compared to
 37 Alternative 1A. The effects of Alternative 8 would, therefore, be the same as 1A. See the description and
 38 findings under Alternative 1A. There would be no adverse effect.

39 **CEQA Conclusion:** Settlement or failure of excavations during construction could result in loss of
 40 property or personal injury. However, DWR would conform with Cal-OSHA and other state code
 41 requirements, such as using seepage cutoff walls, shoring, and other measures, to protect worker

1 safety. DWR would also ensure that the design specifications are properly executed during
2 construction. DWR has made an environmental commitment to use the appropriate code and standard
3 requirements to minimize potential risks (Appendix 3B, *Environmental Commitments*) and there would
4 be no increased likelihood of loss of property, personal injury or death due to the construction of
5 Alternative 8. The impact would be less than significant. No mitigation is required.

6 **Impact GEO-3: Loss of Property, Personal Injury, or Death from Ground Settlement during**
7 **Construction of Water Conveyance Features**

8 **NEPA Effects:** Alternative 8 would include the same physical/structural components as Alternative 1A,
9 but would entail two less intakes and two less pumping plants. These differences would present a
10 slightly lower hazard of ground settlement on the tunnel but would not substantially change the hazard
11 of loss of property, personal injury, or death during construction compared to Alternative 1A. The
12 effects of Alternative 8 would, therefore, be the same as 1A. See the description and findings under
13 Alternative 1A. There would be no adverse effect.

14 **CEQA Conclusion:** Ground settlement above the tunneling operation could result in loss of property or
15 personal injury during construction. However, DWR would conform with Cal-OSHA, USACE, and other
16 design requirements to protect worker safety. DWR would also ensure that the design specifications
17 are properly executed during construction. DWR has made an environmental commitment to use the
18 appropriate code and standard requirements to minimize potential risks (Appendix 3B, *Environmental*
19 *Commitments*) and there would be no increased likelihood of loss of property, personal injury or death
20 due to the construction of Alternative 8. Hazards to workers and project structures would be controlled
21 at safe levels and the impact would be less than significant. No mitigation is required.

22 **Impact GEO-4: Loss of Property, Personal Injury, or Death from Slope Failure during**
23 **Construction of Water Conveyance Features**

24 **NEPA Effects:** Alternative 8 would include the same physical/structural components as Alternative 1A,
25 but would entail two less intakes and two less pumping plants. These differences would present a
26 slightly lower hazard of slope failure at borrow and spoils storage sites but would not substantially
27 change the hazard of loss of property, personal injury, or death during construction compared to
28 Alternative 1A. The effects of Alternative 8 would, therefore, be the same as 1A. See the description and
29 findings under Alternative 1A. There would be no adverse effect.

30 **CEQA Conclusion:** Settlement/failure of cutslopes of borrow sites and failure of soil/RTM fill slopes
31 could result in loss of property or personal injury during construction. However, because DWR would
32 conform with Cal-OSHA and other state code requirements and conform to applicable geotechnical
33 design guidelines and standards, such as USACE design measures, the hazard would be controlled to a
34 safe level and there would be no increased likelihood of loss of property, personal injury or death due
35 to the construction of Alternative 8. The impact would be less than significant. No mitigation is
36 required.

37 **Impact GEO-5: Loss of Property, Personal Injury, or Death from Structural Failure Resulting**
38 **from Construction-Related Ground Motions during Construction of Water Conveyance Features**

39 **NEPA Effects:** Alternative 8 would include the same physical/structural components as Alternative 1A,
40 but would entail two less intakes and two less pumping plants. These differences would present a
41 slightly lower hazard of structural failure from construction-related ground motions but would not
42 substantially change the hazard of loss of property, personal injury, or death during construction

1 compared to Alternative 1A. The effects of Alternative 8 would, therefore, be the same as 1A. See the
2 description and findings under Alternative 1A. There would be no adverse effect.

3 **CEQA Conclusion:** Construction-related ground motions could initiate liquefaction, which could cause
4 failure of structures during construction, which could result in injury of workers at the construction
5 sites. However, because DWR would conform with Cal-OSHA and other state code requirements and
6 conform to applicable design guidelines and standards, such as USACE design measures, the hazard
7 would be controlled to a level that would protect worker safety (see Appendix 3B, *Environmental*
8 *Commitments*) and there would be no increased likelihood of loss of property, personal injury or death
9 due to the construction of Alternative 8. The impact would be less than significant. No mitigation is
10 required.

11 **Impact GEO-6: Loss of Property, Personal Injury, or Death from Structural Failure Resulting**
12 **from Rupture of a Known Earthquake Fault during Operation of Water Conveyance Features**

13 **NEPA Effects:** Alternative 8 would include the same physical/structural components as Alternative 1A,
14 but would entail two less intakes and two less pumping plants. These differences would not create a
15 change in the hazard of structural damage from rupture of an earthquake fault and would not
16 substantially change the hazard of loss of property, personal injury, or death during construction
17 compared to Alternative 1A. The effects of Alternative 8 would, therefore, be the same as 1A. See the
18 description and findings under Alternative 1A. There would be no adverse effect.

19 **CEQA Conclusion:** There are no active faults capable of surface rupture that extend into the
20 pipeline/tunnel alignment. Although the Thornton Arch and West Tracy blind thrusts occur beneath
21 the pipeline/tunnel alignment, based on available information, they do not present a hazard of surface
22 rupture and there would be no increased likelihood of loss of property, personal injury or death due to
23 the operation of Alternative 8. There would be no impact. Therefore, no mitigation is required.

24 **Impact GEO-7: Loss of Property, Personal Injury, or Death from Structural Failure Resulting**
25 **from Strong Seismic Shaking during Operation of Water Conveyance Features**

26 **NEPA Effects:** Alternative 8 would include the same physical/structural components as Alternative 1A,
27 but would entail two less intakes and two less pumping plants. These differences would present a
28 slightly lower hazard of seismic shaking but would not substantially change the hazard of loss of
29 property, personal injury, or death during construction compared to Alternative 1A. The effects of
30 Alternative 8 would, therefore, be the same as 1A. See the description and findings under Alternative
31 1A. There would be no adverse effect.

32 **CEQA Conclusion:** Seismically induced strong ground shaking could damage pipelines, tunnels, intake
33 facilities, pumping plants, and other facilities. The damage could disrupt the water supply through the
34 conveyance system. In an extreme event, an uncontrolled release of water from the damaged
35 conveyance system could cause flooding and inundation of structures. (Please refer to Chapter 6,
36 *Surface Water*, for a detailed discussion of potential flood impacts.) However, through the final design
37 process, measures to address this hazard would be required to conform to applicable design codes,
38 guidelines, and standards. As described in Section 9.3.1, *Methods for Analysis*, and in Appendix 3B,
39 *Environmental Commitments*, such design codes, guidelines, and standards include the California
40 Building Code and resource agency and professional engineering specifications, such as the Division of
41 Safety of Dams *Guidelines for Use of the Consequence Hazard Matrix and Selection of Ground Motion*
42 *Parameters*, DWR's Division of Flood Management *FloodSAFE Urban Levee Design Criteria*, and USACE's
43 *Engineering and Design—Earthquake Design and Evaluation for Civil Works Projects*. Conformance with

1 these codes and standards is an environmental commitment by DWR to ensure that ground shaking
 2 risks are minimized as the water conveyance features are operated. The hazard would be controlled to
 3 a safe level and there would be no increased likelihood of loss of property, personal injury or death due
 4 to the operation of Alternative 8. The impact would be less than significant. No mitigation is required.

5 **Impact GEO-8: Loss of Property, Personal Injury, or Death from Structural Failure Resulting**
 6 **from Seismic-Related Ground Failure (Including Liquefaction) during Operation of Water**
 7 **Conveyance Features**

8 **NEPA Effects:** Alternative 8 would include the same physical/structural components as Alternative 1A,
 9 but would entail two less intakes and two less pumping plants. These differences would present a
 10 slightly lower hazard of structural failure from ground failure but would not substantially change the
 11 hazard of loss of property, personal injury, or death during construction compared to Alternative 1A.
 12 The effects of Alternative 8 would, therefore, be the same as 1A. See the description and findings under
 13 Alternative 1A. There would be no adverse effect.

14 **CEQA Conclusion:** Seismically induced ground shaking could cause liquefaction. Liquefaction could
 15 damage pipelines, tunnels, intake facilities, pumping plants, and other facilities, and thereby disrupt the
 16 water supply through the conveyance system.

17 In an extreme event, an uncontrolled release of water from the damaged conveyance system could
 18 cause flooding and inundation of structures. (Please refer to Chapter 6, *Surface Water*, for a detailed
 19 discussion of potential flood impacts.) However, through the final design process, measures to address
 20 the liquefaction hazard would be required to conform to applicable design codes, guidelines, and
 21 standards. As described in Section 9.3.1, *Methods for Analysis*, and in Appendix 3B, *Environmental*
 22 *Commitments*, such design codes, guidelines, and standards include USACE's *Engineering and Design—*
 23 *Stability Analysis of Concrete Structures* and *Soil Liquefaction during Earthquakes*, by the Earthquake
 24 Engineering Research Institute. Conformance with these design standards is an environmental
 25 commitment by DWR to ensure that liquefaction risks are minimized as the water conveyance features
 26 are operated. The hazard would be controlled to a safe level and there would be no increased likelihood
 27 of loss of property, personal injury or death due to the operation of Alternative 8. The impact would be
 28 less than significant. No mitigation is required.

29 **Impact GEO-9: Loss of Property, Personal Injury, or Death from Landslides and Other Slope**
 30 **Instability during Operation of Water Conveyance Features**

31 **NEPA Effects:** Alternative 8 would include the same physical/structural components as Alternative 1A,
 32 but would entail two less intakes and two less pumping plants. These differences would present a
 33 slightly lower hazard from landslides and other slope instability but would not substantially change the
 34 hazard of loss of property, personal injury, or death during construction compared to Alternative 1A.
 35 The effects of Alternative 8 would, therefore, be the same as 1A. See the description and findings under
 36 Alternative 1A. There would be no adverse effect.

37 **CEQA Conclusion:** Unstable levee slopes and natural stream banks may fail, either from high pore-
 38 water pressure caused by high rainfall and weak soil, or from seismic shaking. Structures constructed
 39 on these slopes could be damaged or fail entirely as a result of slope instability. However, through the
 40 final design process, measures to address this hazard would be required to conform to applicable
 41 design codes, guidelines, and standards. As described in Section 9.3.1, *Methods for Analysis*, and in
 42 Appendix 3B, *Environmental Commitments*, such design codes, guidelines, and standards include the
 43 California Building Code and resource agency and professional engineering specifications, such as

1 USACE's *Engineering and Design—Earthquake Design and Evaluation for Civil Works Projects*.
 2 Conformance with these codes and standards is an environmental commitment by DWR to ensure cut
 3 and fill slopes and embankments will be stable as the water conveyance features are operated and
 4 there would be no increased likelihood of loss of property, personal injury or death due to the
 5 operation of Alternative 8. The impact would be less than significant. No mitigation is required.

6 **Impact GEO-10: Loss of Property, Personal Injury, or Death from Seiche or Tsunami during**
 7 **Operation of Water Conveyance Features**

8 **NEPA Effects:** Alternative 8 would include the same physical/structural components as Alternative 1A,
 9 but would entail two less intakes and two less pumping plants. These differences would present a
 10 slightly lower hazard from a seiche or tsunami but would not substantially change the hazard of loss of
 11 property, personal injury, or death during construction compared to Alternative 1A. The effects of
 12 Alternative 8 would, therefore, be the same as 1A. See the description and findings under Alternative
 13 1A. There would be no adverse effect.

14 **CEQA Conclusion:** Based on recorded tsunami wave heights at the Golden Gate (Contra Costa
 15 Transportation Agency 2009) and in the interior of the San Francisco Bay and on tsunami inundation
 16 maps prepared by the California Department of Conservation (2009), the height of a tsunami wave
 17 reaching the Suisun Marsh and the Delta would be small because of the distance from the ocean and
 18 attenuating effect of the San Francisco Bay. Similarly, the potential for a significant seiche to occur in
 19 most parts of the Plan Area is considered low because the seismic hazard and the geometry of the
 20 water bodies (i.e., wide and shallow) near conveyance facilities are not favorable for a seiche to occur.
 21 However, assuming the West Tracy fault is potentially active, a potential exists for a seiche to occur in
 22 the Clifton Court Forebay and the Byron Tract Forebay (Fugro Consultants 2011). The impact would
 23 not be significant because the Byron Tract Forebay embankment would be designed and constructed
 24 according to applicable design codes, guidelines, and standards to contain and withstand the
 25 anticipated maximum seiche wave height. There would be no increased likelihood of loss of property,
 26 personal injury or death due to the operation of Alternative 8 from seiche or tsunami. The impact
 27 would be less than significant. No mitigation is required.

28 **Impact GEO-11: Ground Failure Caused by Increased Groundwater Surface Elevations from**
 29 **Unlined Canal Seepage as a Result of Operating the Water Conveyance Facilities**

30 **NEPA Effects:** Alternative 8 would not involve construction of unlined canals; therefore, there would be
 31 no increase in groundwater surface elevations and consequently no effect caused by canal seepage.
 32 There would be no adverse effect.

33 **CEQA Conclusion:** Alternative 8 would not involve construction of unlined canals; therefore, there
 34 would be no increase in groundwater surface elevations and consequently no impact caused by canal
 35 seepage. The impact would be less than significant. No mitigation is required.

36 **Impact GEO-12: Loss of Property, Personal Injury, or Death Resulting from Structural Failure**
 37 **Caused by Rupture of a Known Earthquake Fault at Restoration Opportunity Areas**

38 **NEPA Effects:** Conservation measures under Alternative 8 would be the same as those under
 39 Alternative 1A. See description and findings under Alternative 1A. There would be no adverse effect.

40 **CEQA Conclusion:** Rupture of the Cordelia and Green Valley faults could occur at the Suisun Marsh ROA
 41 and damage ROA facilities, such as levees and berms. Damage to these features could result in their

1 failure, causing flooding of otherwise protected areas. However, through the final design process for
 2 conservation measures in the ROAs, measures to address the fault rupture hazard would be required to
 3 conform to applicable design codes, guidelines, and standards. As described in Section 9.3.1, *Methods*
 4 *for Analysis*, and in Appendix 3B, *Environmental Commitments*, such design codes, guidelines, and
 5 standards include the Division of Safety of Dams *Guidelines for Use of the Consequence Hazard Matrix*
 6 *and Selection of Ground Motion Parameters*, DWR's Division of Flood Management *FloodSAFE Urban*
 7 *Levee Design Criteria*, and USACE's *Engineering and Design—Earthquake Design and Evaluation for Civil*
 8 *Works Projects*. Conformance with these design standards is an environmental commitment by the
 9 BDCP proponents to ensure that fault rupture risks are minimized as the conservation measures are
 10 implemented. The hazard would be controlled to a safe level and there would be no increased
 11 likelihood of loss of property, personal injury or death in the ROAs. The impact would be less than
 12 significant. No mitigation is required.

13 **Impact GEO-13: Loss of Property, Personal Injury, or Death from Structural Failure Resulting** 14 **from Strong Seismic Shaking at Restoration Opportunity Areas**

15 **NEPA Effects:** Conservation measures under Alternative 8 would be the same as those under
 16 Alternative 1A. See description and findings under Alternative 1A. There would be no adverse effect.

17 **CEQA Conclusion:** Ground shaking could damage levees, berms, and other structures. Among all the
 18 ROAs, the Suisun Marsh ROA would be the most subject to ground shaking because of its proximity to
 19 active faults. The Suisun Marsh ROA is subject to a PGA of approximately 0.31 to 0.35 g for 200-year
 20 return interval, while the PGA for the other ROAs ranges from approximately 0.11 to 0.26 g. Damage to
 21 these features could result in their failure, causing flooding of otherwise protected areas. However, as
 22 described in Section 9.3.1, *Methods for Analysis*, and in Appendix 3B, *Environmental Commitments*,
 23 design codes, guidelines, and standards, including the California Building Code and resource agency
 24 and professional engineering specifications, such as DWR's Division of Flood Management *FloodSAFE*
 25 *Urban Levee Design Criteria* and USACE's *Engineering and Design—Earthquake Design and Evaluation*
 26 *for Civil Works Projects* would be used for final design of conservation features. Conformance with these
 27 design standards is an environmental commitment by the BDCP proponents to ensure that strong
 28 seismic shaking risks are minimized as the conservation measures are operated and there would be no
 29 increased likelihood of loss of property, personal injury or death in the ROAs. The impact would be less
 30 than significant. No mitigation is required.

31 **Impact GEO-14: Loss of Property, Personal Injury, or Death from Structural Failure Resulting** 32 **from Seismic-Related Ground Failure (Including Liquefaction) Beneath Restoration Opportunity** 33 **Areas**

34 **NEPA Effects:** Conservation measures under Alternative 8 would be the same as those under
 35 Alternative 1A. See description and findings under Alternative 1A. There would be no adverse effect.

36 **CEQA Conclusion:** Earthquake-induced ground shaking could cause liquefaction, resulting in damage to
 37 or failure of levees, berms, and other features constructed at the restoration areas. Failure of levees and
 38 other structures could result in flooding of otherwise protected areas.

39 However, through the final design process, measures to address the liquefaction hazard would be
 40 required to conform to applicable design codes, guidelines, and standards. As described in Section
 41 9.3.1, *Methods for Analysis*, and in Appendix 3B, *Environmental Commitments*, such design codes,
 42 guidelines, and standards include USACE's *Engineering and Design—Stability Analysis of Concrete*
 43 *Structures and Soil Liquefaction during Earthquakes*, by the Earthquake Engineering Research Institute.

1 Conformance with these design standards is an environmental commitment by the BDCP proponents to
 2 ensure that liquefaction risks are minimized as the water conservation features are implemented and
 3 there would be no increased likelihood of loss of property, personal injury or death in the ROAs. The
 4 impact would be less than significant. No mitigation is required.

5 **Impact GEO-15: Loss of Property, Personal Injury, or Death from Landslides and Other Slope**
 6 **Instability at Restoration Opportunity Areas**

7 *NEPA Effects:* Conservation measures under Alternative 8 would be the same as those under
 8 Alternative 1A. See description and findings under Alternative 1A. There would be no adverse effect.

9 *CEQA Conclusion:* Unstable new and existing levee and embankment slopes could fail as a result of
 10 seismic shaking and as a result of high soil-water content during heavy rainfall and cause flooding of
 11 otherwise protected areas. However, because the BDCP proponents would conform with applicable
 12 design guidelines and standards, such as USACE design measures, the hazard would be controlled to a
 13 safe level and there would be no increased likelihood of loss of property, personal injury or death in the
 14 ROAs. The impact would be less than significant. No mitigation is required.

15 **Impact GEO-16: Loss of Property, Personal Injury, or Death from Seiche or Tsunami at**
 16 **Restoration Opportunity Areas as a Result of Implementing the Conservation Actions**

17 *NEPA Effects:* Conservation measures under Alternative 8 would be similar to that as under Alternative
 18 1A. See description and findings under Alternative 1A. There would be no adverse effect.

19 *CEQA Conclusion:* Based on recorded tsunami heights at the Golden Gate, the height of a tsunami wave
 20 reaching the ROAs would be small because of the distance from the ocean and attenuating effect of the
 21 San Francisco Bay. Similarly, the potential for a significant seiche to occur in the Plan Area that would
 22 cause loss of property, personal injury, or death at the ROAs is considered low because conditions for a
 23 seiche to occur near conveyance facilities are not favorable. The impact would be less than significant.
 24 No mitigation is required.

25 **9.3.3.16 Alternative 9—Through Delta/Separate Corridors (15,000 cfs;**
 26 **Operational Scenario G)**

27 **Impact GEO-1: Loss of Property, Personal Injury, or Death from Structural Failure Resulting**
 28 **from Strong Seismic Shaking of Water Conveyance Features during Construction**

29 Construction of water conveyance facilities under Alternative 9 would involve two screened intakes the
 30 Delta Cross Channel and Georgiana Slough near Locke and Walnut Grove, culvert siphons, canals,
 31 pumping plants, borrow areas, enlargement of a channel, operable barriers, and other facilities. The
 32 locations of some of the Alternative 9 facilities would be different than those of any of the other
 33 alternatives. The operable barriers along Delta channels and the two pumping plants on Old River and
 34 Middle River would be in locations not discussed for other alternatives (see Figure 3-16).

35 Table 9-28 lists the expected PGA and 1.0- S_a values in 2020 at selected facility locations. As with other
 36 alternatives, ground motions with a return period of 72 years and calculated for 2005 are used to
 37 represent the construction period (2020) motions.

Table 9-28. Expected Earthquake Ground Motions at Locations of Selected Major Facilities during Construction (2020)—Alternative 9

Major Facilities	72-year Return Period Ground Motions			
	Peak Ground Acceleration (g)		1.0-sec S_a (g)	
	Stiff Soil ^a	Local Soil ^b	Stiff Soil ^a	Local Soil ^b
Fish Screen Area ^c	0.11	0.14	0.13	0.21
Corridor Location near Venice Island ^d	0.20	0.26	0.22	0.35
Clifton Court Forebay / Byron Tract Forebay	0.18	0.23	0.20	0.32

g = gravity

S_a = second spectral acceleration

^a Stiff soil site, with a V_{s100ft} value of 1,000 ft/s.

^b Site-adjusted factors of 1.3 and 1.6 were applied to PGA and 1.0-sec S_a values, respectively (adjustments from a stiff soil site to a soft soil site).

^c The results of California Department of Water Resources 2007a for the Sacramento site were used.

^d The results of California Department of Water Resources 2007a for the Sherman Island site were used.

NEPA Effects: The seismic study employed time-dependent seismic source models for several major faults in the region. These models were characterized based on the elapsed times since the last major seismic events on the faults. Therefore, the exposure risks predicted by the seismic study would increase if no major events take place on these faults through 2020. The effect could be substantial because seismically-induced ground shaking could cause loss of property or personal injury at the Alternative 9 construction sites (including intake locations, canals, and operable barriers) as a result of collapse of facilities. For example, facilities lying directly on or near active blind faults, such as the concrete batch plant and fuel station north of Locke, both intakes, the operable barriers on the Mokelumne River near Lost Slough and on Snodgrass Slough near the Mokelumne River, extension of Meadows Slough to the Sacramento River, and operable barrier on Meadows Slough, the boat lock and channel at the diversion structure at Georgiana Slough, the operable barrier at Threemile Slough, the operable barrier at Fisherman's Cut at False River for Alternative 9, which may result in an increased likelihood of loss of property or personal injury at these sites in the event of seismically-induced ground shaking. Although these blind thrusts are not expected to rupture to the ground surface under the forebays during earthquake events, they may produce ground or near-ground shear zones, bulging, or both (California Department of Water Resources 2007a). For a map of all permanent facilities and temporary work areas associated with this conveyance alignment, see Mapbook Figure M3-5.

The overall hazard of loss of property, personal injury, or death from structural failure caused by seismic shaking during construction would be less than that of Alternative 1A due to the fact that fewer facilities would be constructed. The same engineering design and construction requirements that apply to all the project facilities would reduce the risk of structural failure from seismic shaking. The effects of Alternative 9 would be of a similar nature but greatly reduced compared to those of Alternative 1A. See the description and findings under Alternative 1A. There would be no adverse effect.

CEQA Conclusion: Seismically induced ground shaking could cause collapse or other failure of project facilities while under construction. However, DWR would conform with Cal-OSHA and other state code requirements, such as shoring, bracing, lighting, excavation depth restrictions, required slope angles, and other measures, to protect worker safety. Conformance with these standards and codes is an environmental commitment of the project (see Appendix 3B, *Environmental Commitments*). Conformance with these health and safety requirements and the application of accepted, proven

1 construction engineering practices would reduce this risk and there would be no increased likelihood
 2 of loss of property, personal injury or death due to the construction of Alternative 9. This impact would
 3 be less than significant. No mitigation is required.

4 **Impact GEO-2: Loss of Property, Personal Injury, or Death from Settlement or Collapse Caused**
 5 **by Dewatering during Construction of Water Conveyance Features**

6 **NEPA Effects:** Construction of water conveyance facilities under Alternative 9 would involve an array of
 7 intakes, pumping plants, pipelines, culvert siphons, canals, borrow areas, enlargement of a channel, and
 8 other facilities. The locations of some of the Alternative 9 facilities would be different than that of any
 9 of the other alternatives. The operable barriers along Delta channels and the two pumping plants on
 10 Old River and Middle River would be in locations not discussed for other alternatives (see Figure 3-16).
 11 At the primary two such locations, operable barriers would be constructed. The same engineering
 12 design and construction requirements that apply to all the project facilities would prevent settlement
 13 or collapse during dewatering and would not substantially change the hazard of loss of property,
 14 personal injury, or death during construction compared to Alternative 1A. The effects of Alternative 9
 15 would, therefore, be similar to that of Alternative 1A. See the description and findings under
 16 Alternative 1A. There would be no adverse effect.

17 **CEQA Conclusion:** Settlement or failure of excavations during construction could result in loss of
 18 property or personal injury. However, DWR would conform with Cal-OSHA and other state code
 19 requirements, such as using seepage cutoff walls, shoring, and other measures, to protect worker
 20 safety. DWR would also ensure that the design specifications are properly executed during
 21 construction. DWR has made an environmental commitment to use the appropriate code and standard
 22 requirements to minimize potential risks (Appendix 3B, *Environmental Commitments*) and there would
 23 be no increased likelihood of loss of property, personal injury or death due to the construction of
 24 Alternative 9. The impact would be less than significant. No mitigation is required.

25 **Impact GEO-3: Loss of Property, Personal Injury, or Death from Ground Settlement during**
 26 **Construction of Water Conveyance Features**

27 Construction of water conveyance facilities under Alternative 9 would involve an array of intakes,
 28 pumping plants, pipelines, culvert siphons, canals, borrow areas, enlargement of a channel, fish screens,
 29 and other facilities. The locations of some of the Alternative 9 facilities would be different than that of
 30 any of the other alternatives. The operable barriers along Delta channels and the two pumping plants
 31 on Old River and Middle River would be in locations not discussed for other alternatives (Figure 3-16).
 32 At the primary two such locations, operable barriers would be constructed.

33 Table 9-29 summarizes the geology of the Alternative 9 facilities as mapped by Atwater (1982) (Figure
 34 9-3).

35 **NEPA Effects:** The overall hazard of loss of property or personal injury from ground settlement of
 36 culvert siphons during construction would be less than that of Alternative 1A. Additionally, the same
 37 engineering design and construction requirements that apply to all the project facilities would prevent
 38 ground settlement and would not substantially change the hazard of loss of property, personal injury,
 39 or death during construction compared to Alternative 1A. The effects of Alternative 9 would, therefore,
 40 be similar to those under Alternative 1A. See the discussion of Impact GEO-3. See the description and
 41 findings under Alternative 1A. There would be no adverse effect.

1 **Table 9-29. Geology of Key Facilities—Alternative 9**

Segment ^a	Geologic Unit	Geologic Unit Description
Segment 1 and Segment 2 Fish Screens	Ql	Natural levee deposits: moderately- to well-sorted sand, with some silt and clay
Segment 1, Segment 2, Segment 4, and Segment 5 Operable Barriers	Ql	Natural levee deposits: moderately- to well-sorted sand, with some silt and clay
Segment 3 Operable Barriers	Qb	Flood basin deposits: firm to stiff silty clay, clayey silt, and silt
	Ql	Natural Levee deposits: moderately to well-sorted sand with some silt and clay
Segment 6 Operable Barriers	Qds	Dredge soil, post 1900
	Qpm	Delta mud: mud and peat with minor silt or sand
Segment 7 Operable Barriers	Qpm	Delta mud: mud and peat with minor silt or sand
	Qfp	Floodplain deposits: dense sandy to silty clay
Segment 9 and Segment 16 Canal	Qfp	Floodplain deposits: dense sandy to silty clay
Segment 16 Bridges	Qfp	Floodplain deposits: dense sandy to silty clay

Source: Hansen et al. 2001 and Atwater 1982.

^a The reaches are defined in Chapter 3 and shown on Figure 9-3.

2

3 **CEQA Conclusion:** Ground settlement above the tunneling operation for the culvert siphons could
4 result in loss of property or personal injury during construction. However, DWR would conform with
5 Cal-OSHA, USACE, and other design requirements to protect worker safety. DWR would also ensure
6 that the design specifications are properly executed during construction. DWR has made an
7 environmental commitment to use the appropriate code and standard requirements to minimize
8 potential risks (Appendix 3B, *Environmental Commitments*) and there would be no increased likelihood
9 of loss of property, personal injury or death due to the construction of Alternative 9. Hazards to
10 workers and project structures would be controlled at safe levels and the impact would be less than
11 significant. No mitigation is required.

12 **Impact GEO-4: Loss of Property, Personal Injury, or Death from Slope Failure during**
13 **Construction of Water Conveyance Features**

14 **NEPA Effects:** Construction of water conveyance facilities under Alternative 9 would involve an array of
15 intakes, pumping plants, pipelines, culvert siphons, canals, borrow areas, enlargement of a channel, and
16 other facilities. The locations of some of the Alternative 9 facilities would be different than that of any
17 of the other alternatives. The operable barriers along Delta channels and the two pumping plants on
18 Old River and Middle River would be in locations not discussed for other alternatives (see Figure 3-16).
19 At the primary two such locations, operable barriers would be constructed. The overall hazard of loss
20 of property or personal injury from slope failure at borrow and spoils sites during construction would
21 be less than that of Alternative 1A. Additionally, the same engineering design and construction
22 requirements that apply to all the project facilities would prevent slope failure would not substantially
23 change the hazard of loss of property, personal injury, or death during construction compared to
24 Alternative 1A. The effects of Alternative 9 would, therefore, be similar to that of Alternative 1A. See the
25 description and findings under Alternative 1A. There would be no adverse effect.

1 **CEQA Conclusion:** Settlement/failure of cutslopes of borrow sites and failure of soil/RTM fill slopes
 2 could result in loss of property or personal injury during construction. However, because DWR would
 3 conform with Cal-OSHA requirements and conform to applicable geotechnical design guidelines and
 4 standards, such as USACE design measures, the hazard would be controlled to a safe level and there
 5 would be no increased likelihood of loss of property, personal injury or death due to the construction of
 6 Alternative 9. The impact would be less than significant. No mitigation is required.

7 **Impact GEO-5: Loss of Property, Personal Injury, or Death from Structural Failure Resulting**
 8 **from Construction-Related Ground Motions during Construction of Water Conveyance Features**

9 **NEPA Effects:** Construction of water conveyance facilities under Alternative 9 would involve an array of
 10 intakes, pumping plants, pipelines, culvert siphons, canals, borrow areas, enlargement of a channel, and
 11 other facilities. The locations of some of the Alternative 9 facilities would be different than that of any
 12 of the other alternatives. At the primary two such locations, operable barriers would be constructed.
 13 The overall hazard of loss of property or personal injury from structural failure from ground motions
 14 during construction would be overall slightly greater than that of Alternative 1A because of the greater
 15 amount pile driving that would be required. Additionally, the same engineering design and
 16 construction requirements that apply to all the project facilities would prevent structural failure from
 17 construction-related ground motions and would not substantially change the hazard of loss of property,
 18 personal injury, or death during construction. The effects of Alternative 9 would, therefore, be similar
 19 to that of Alternative 1A. See the description and findings under Alternative 1A. There would be no
 20 adverse effect.

21 **CEQA Conclusion:** Construction-related ground motions could initiate liquefaction, which could cause
 22 failure of structures during construction, which could result in injury of workers at the construction
 23 sites. However, because DWR would conform with Cal-OSHA and other state code requirements and
 24 conform to applicable design guidelines and standards, such as USACE design measures, the hazard
 25 would be controlled to a level that would protect worker safety (see Appendix 3B, *Environmental*
 26 *Commitments*) and there would be no increased likelihood of loss of property, personal injury or death
 27 due to the construction of Alternative 9. The impact would be less than significant. No mitigation is
 28 required.

29 **Impact GEO-6: Loss of Property, Personal Injury, or Death from Structural Failure Resulting**
 30 **from Rupture of a Known Earthquake Fault during Operation of Water Conveyance Features**

31 Construction of water conveyance facilities under Alternative 9 would involve an array of intakes,
 32 pumping plants, pipelines, culvert siphons, canals, borrow areas, enlargement of a channel, and other
 33 facilities. The locations of some of the Alternative 9 facilities would be different than that of any of the
 34 other alternatives.

35 According to the available AP Earthquake Fault Zone Maps, none of the Alternative 9 constructed
 36 conveyance facilities would cross or be on any known active fault zones. Numerous AP fault zones have
 37 been mapped west of the conveyance alignment. The closest AP fault zone would be the Greenville
 38 fault, approximately 10.0 miles southwest of the constructed conveyance facilities. Because of their
 39 distances from the AP fault zones, the potential that the facilities would be directly subject to fault
 40 offsets is negligible.

41 In the Delta, active or potentially active blind thrust faults were identified in the seismic study. The
 42 operable barrier on Threemile Slough would be in the Montezuma Hills fault zone, and the extreme
 43 southwestern corner of the Byron Tract Forebay (to the northwest of the Clifton Court Forebay) may be

1 underlain by the West Tracy fault (Figure 9-5). Although these blind thrusts are not expected to
 2 rupture to the ground surface under the forebay during earthquake events, they may produce ground
 3 or near-ground shear zones, bulging, or both (California Department of Water Resources 2007a).
 4 Assuming that the West Tracy fault is potentially active, it could cause surface deformation in the
 5 western part of the Clifton Court Forebay (Fugro Consultants 2011) and the Byron Tract Forebay. In
 6 the seismic study (California Department of Water Resources 2007a), the Montezuma Hills and West
 7 Tracy blind thrusts have been assigned 50% and 90% probabilities of being active, respectively. The
 8 depth to the Montezuma Hills faults is unknown. The seismic study indicates that the West Tracy fault
 9 dies out as a discernible feature within approximately 3,000 to 6,000 feet bgs (in the upper 1 to 2
 10 second depth two-way time, estimated to be approximately 3,000 to 6,000 feet using the general
 11 velocity function as published in the Association of Petroleum Geologists Pacific Section newsletter
 12 [Tolmachoff 1993]).

13 It appears that the potential of having any shear zones, bulging, or both at the depths of the facilities is
 14 low because the depth to the blind thrust faults is generally deep. However, because of there is limited
 15 information regarding depth for these faults, a geotechnical evaluation and seismic surveys would be
 16 performed at these two blind thrust locations during the design phase to determine the depths to the
 17 top of faults. The geotechnical work would provide the basis for design recommendations as would be
 18 done at the other project facilities. As with the other facilities, the facility design would conform to
 19 USACE design standards.

20 **NEPA Effects:** The effects of Alternative 9 would, therefore, be similar to that of Alternative 1A. See the
 21 description and findings under Alternative 1A. There would be no adverse effect.

22 **CEQA Conclusion:** There are no active faults capable of surface rupture that extend into the
 23 pipeline/tunnel alignment. Although the Thornton Arch and West Tracy blind thrusts occur beneath
 24 the pipeline/tunnel alignment, based on available information, they do not present a hazard of surface
 25 rupture and there would be no increased likelihood of loss of property, personal injury or death due to
 26 the operation of Alternative 9. There would be no impact. No mitigation is required.

27 **Impact GEO-7: Loss of Property, Personal Injury, or Death from Structural Failure Resulting** 28 **from Strong Seismic Shaking during Operation of Water Conveyance Features**

29 Construction of water conveyance facilities under Alternative 9 would involve an array of intakes,
 30 pumping plants, pipelines, culvert siphons, canals, borrow areas, enlargement of a channel, and other
 31 facilities. The locations of some of the Alternative 9 facilities would be different than that of any of the
 32 other alternatives. At the primary two such locations, operable barriers would be constructed.

33 Similar to the earthquake ground shaking hazard during construction, earthquake occurrences on the
 34 local and regional seismic sources for 2025 would subject the Alternative 9 facilities to ground shaking.

35 Table 9-30 lists the expected PGA and 1.0-S_a values for 2025 at selected facility locations. Earthquake
 36 ground shakings for the OBE (144-year return period) and MDE (975-year return period) were
 37 estimated for the stiff soil site, as predicted in the seismic study (California Department of Water
 38 Resources 2007a), and for the anticipated soil conditions at the facility locations. No seismic study
 39 results exist for 2025, so the ground shakings estimated for 2050 were used for 2025. The table shows
 40 that the proposed facilities would be subject to moderate-to-high earthquake ground shakings for
 41 2025.

Table 9-30. Expected Earthquake Ground Motions at Locations of Selected Major Facilities in the Early Long-Term (2025)—Alternative 9

Major Facilities	144-year Return Period Ground Motions (OBE)			
	Peak Ground Acceleration (g)		1.0-sec S_a (g)	
	Stiff Soil ^a	Local Soil ^b	Stiff Soil ^a	Local Soil ^b
Intake and Fish Screen Area ^c	0.14	0.15	0.19	0.30
Corridor Location near Venice Island ^d	0.30	0.33	0.31	0.50
Clifton Court Forebay / Byron Tract Forebay	0.28	0.31	0.30	0.48
Major Facilities	975-year Return Period Ground Motions (MDE)			
	PGA (g)		1.0-sec S_a (g)	
	Stiff Soil ^a	Local Soil ^e	Stiff Soil ^a	Local Soil ^e
Intake and Fish Screen Area ^c	0.24	0.24	0.33	0.53
Corridor Location near Venice Island ^d	0.50	0.50	0.60	0.96
Clifton Court Forebay / Byron Tract Forebay	0.50	0.50	0.61	0.98

g = gravity

MDE = maximum design earthquake

OBE = operating basis earthquake

PGA = Peak Ground Acceleration

S_a = second spectral acceleration

^a Stiff soil site, with a V_{s100ft} value of 1,000 ft/s.

^b Site-adjusted factors of 1.1 and 1.60 were applied to PGA and 1.0-sec S_a values, respectively.

^c The results of California Department of Water Resources 2007a for the Sacramento site were used.

^d The results of California Department of Water Resources 2007a for the Sherman Island site were used.

^e Site-adjusted factors of 1.0 and 1.60 were applied to PGA and 1.0-sec S_a values, respectively.

NEPA Effects: The Alternative 9 facilities would be subject to the same engineering design and construction requirements that apply to all the project facilities, which would prevent structural failure from seismic shaking and not substantially change the hazard of loss of property, personal injury, or death compared to Alternative 1A. The effects of Alternative 9 would, therefore, be similar to that of Alternative 1A. See the description and findings under Alternative 1A. There would be no adverse effect.

CEQA Conclusion: Seismically induced strong ground shaking could damage culvert siphons, intake facilities, pumping plants, and other facilities. The damage could disrupt the water supply through the conveyance system. In an extreme event, flooding and inundation of structures could result from an uncontrolled release of water from the damaged conveyance system. (Please refer to Chapter 6, *Surface Water*, for a detailed discussion of potential flood impacts.) However, through the final design process, measures to address this hazard would be required to conform to applicable design codes, guidelines, and standards. As described in Section 9.3.1, *Methods for Analysis*, and in Appendix 3B, *Environmental Commitments*, such design codes, guidelines, and standards include the California Building Code and resource agency and professional engineering specifications, such as the Division of Safety of Dams *Guidelines for Use of the Consequence Hazard Matrix and Selection of Ground Motion Parameters*, DWR's Division of Flood Management *FloodSAFE Urban Levee Design Criteria*, and USACE's *Engineering and Design—Earthquake Design and Evaluation for Civil Works Projects*. Conformance with these codes and

1 standards is an environmental commitment by DWR to ensure that ground shaking risks are minimized
2 as the water conveyance features are operated. The hazard would be controlled to a safe level and
3 there would be no increased likelihood of loss of property, personal injury or death due to the
4 operation of Alternative 9. The impact would be less than significant. No mitigation is required.

5 **Impact GEO-8: Loss of Property, Personal Injury, or Death from Structural Failure Resulting**
6 **from Seismic-Related Ground Failure (Including Liquefaction) during Operation of Water**
7 **Conveyance Features**

8 **NEPA Effects:** Construction of water conveyance facilities under Alternative 9 would involve an array of
9 intakes, pumping plants, pipelines, culvert siphons, canals, borrow areas, enlargement of a channel, and
10 other facilities. (Some of the facilities would primarily involve in-water work and would have no
11 bearing on geology and seismicity.) The locations of some of the Alternative 9 facilities would be
12 different than that of any of the other alternatives. At the primary two such locations, operable barriers
13 would be constructed. The Alternative 9 facilities would be subject to the same engineering design and
14 construction requirements that apply to all the project facilities, which would prevent structural failure
15 from liquefaction and not substantially change the hazard of loss of property, personal injury, or death
16 compared to Alternative 1A. The effects of Alternative 9 would, therefore, be similar to that of
17 Alternative 1A. See the description and findings under Alternative 1A. There would be no adverse
18 effect.

19 **CEQA Conclusion:** Seismically induced ground shaking could cause liquefaction. Liquefaction could
20 damage culvert siphons, intake facilities, pumping plants, and other facilities, and thereby disrupt the
21 water supply through the conveyance system. In an extreme event, an uncontrolled release of water
22 from the damaged conveyance system could cause flooding and inundation of structures. (Please refer
23 to Chapter 6, *Surface Water*, for a detailed discussion of potential flood impacts.) However, through the
24 final design process, measures to address the liquefaction hazard would be required to conform to
25 applicable design codes, guidelines, and standards. As described in Section 9.3.1, *Methods for Analysis*,
26 and in Appendix 3B, *Environmental Commitments*, such design codes, guidelines, and standards include
27 USACE's *Engineering and Design—Stability Analysis of Concrete Structures and Soil Liquefaction during*
28 *Earthquakes*, by the Earthquake Engineering Research Institute. Conformance with these design
29 standards is an environmental commitment by DWR to ensure that liquefaction risks are minimized as
30 the water conveyance features are operated. The hazard would be controlled to a safe level and there
31 would be no increased likelihood of loss of property, personal injury or death due to the operation of
32 Alternative 9. The impact would be less than significant. No mitigation is required.

33 **Impact GEO-9: Loss of Property, Personal Injury, or Death from Landslides and Other Slope**
34 **Instability during Operation of Water Conveyance Features**

35 **NEPA Effects:** Construction of water conveyance facilities under Alternative 9 would involve an array of
36 intakes, pumping plants, pipelines, culvert siphons, canals, borrow areas, enlargement of a channel, and
37 other facilities. (Some of the facilities would primarily involve in-water work and would have no
38 bearing on geology and seismicity.) The locations of some of the Alternative 9 facilities would be
39 different than that of any of the other alternatives. At the primary two such locations, operable barriers
40 would be constructed. The Alternative 9 facilities are subject to a similar hazard of slope instability as
41 Alternative 1A and would not substantially change the hazard of loss of property, personal injury, or
42 death compared to Alternative 1A. The effects of Alternative 9 would, therefore, be similar to that of
43 Alternative 1A. See the description and findings under Alternative 1A. There would be no adverse
44 effect.

1 **CEQA Conclusion:** Unstable levee slopes and natural stream banks may fail, either from high pore-
 2 water pressure caused by high rainfall and weak soil, or from seismic shaking. Structures constructed
 3 on these slopes could be damaged or fail entirely as a result of slope instability. However, through the
 4 final design process, measures to address this hazard would be required to conform to applicable
 5 design codes, guidelines, and standards. As described in Section 9.3.1, *Methods for Analysis*, and in
 6 Appendix 3B, *Environmental Commitments*, such design codes, guidelines, and standards include the
 7 California Building Code and resource agency and professional engineering specifications, such as
 8 USACE's *Engineering and Design—Earthquake Design and Evaluation for Civil Works Projects*.
 9 Conformance with these codes and standards is an environmental commitment by DWR to ensure cut
 10 and fill slopes and embankments will be stable as the water conveyance features are operated and
 11 there would be no increased likelihood of loss of property, personal injury or death due to the
 12 operation of Alternative 9. The hazard would be controlled to a safe level. The impact would be less
 13 than significant. No mitigation is required.

14 **Impact GEO-10: Loss of Property, Personal Injury, or Death from Seiche or Tsunami during**
 15 **Operation of Water Conveyance Features**

16 **NEPA Effects:** Construction of water conveyance facilities under Alternative 9 would involve an array of
 17 intakes, pumping plants, pipelines, culvert siphons, canals, borrow areas, enlargement of a channel, and
 18 other facilities. (Some of the facilities would primarily involve in-water work and would have no
 19 bearing on geology and seismicity.) The locations of some of the Alternative 9 facilities would be
 20 different than that of any of the other alternatives. At the primary two such locations, operable barriers
 21 would be constructed. The Alternative 9 facilities are subject to a similar hazard of a seiche or tsunami
 22 as Alternative 1A and would not substantially change the hazard of loss of property, personal injury, or
 23 death from a seiche or tsunami compared to Alternative 1A, with the exception of the Byron Tract
 24 Forebay, which would not be a component of this alternative. The effects of Alternative 9 would,
 25 therefore, be similar to or less than that of Alternative 1A. See the description and findings under
 26 Alternative 1A. There would be no adverse effect.

27 **CEQA Conclusion:** Based on recorded tsunami wave heights at the Golden Gate (Contra Costa
 28 Transportation Agency 2009) and in the interior of the San Francisco Bay and on tsunami inundation
 29 maps prepared by the California Department of Conservation (2009), the height of a tsunami wave
 30 reaching the Suisun Marsh and the Delta would be small because of the distance from the ocean and
 31 attenuating effect of the San Francisco Bay. Similarly, the potential for a significant seiche to occur in
 32 the Plan Area is considered low because the seismic hazard and the geometry of the water bodies (i.e.,
 33 wide and shallow) near conveyance facilities are not favorable for a seiche to occur. There would be no
 34 increased likelihood of loss of property, personal injury or death due to the operation of Alternative 9
 35 from seiche or tsunami. The impact would be less than significant. No mitigation is required.

36 **Impact GEO-11: Ground Failure Caused by Increased Groundwater Surface Elevations from**
 37 **Unlined Canal Seepage as a Result of Operating the Water Conveyance Facilities**

38 **NEPA Effects:** Alternative 9 would not involve construction of unlined canals; therefore, there would be
 39 no increase in groundwater surface elevations and consequently no effect caused by canal seepage.
 40 There would be no adverse effect.

41 **CEQA Conclusion:** Alternative 9 would not involve construction of unlined canals; therefore, there
 42 would be no increase in groundwater surface elevations and consequently no impact caused by canal
 43 seepage. The impact would be less than significant. No mitigation is required.

1 **Impact GEO-12: Loss of Property, Personal Injury, or Death Resulting from Structural Failure**
 2 **Caused by Rupture of a Known Earthquake Fault at Restoration Opportunity Areas**

3 **NEPA Effects:** Conservation measures under Alternative 9 would be similar to that as under Alternative
 4 1A. See description and findings under Alternative 1A. There would be no adverse effect.

5 **CEQA Conclusion:** Rupture of the Cordelia and Green Valley faults could occur at the Suisun Marsh ROA
 6 and damage ROA facilities, such as levees and berms. Damage to these features could result in their
 7 failure, causing flooding of otherwise protected areas. However, through the final design process for
 8 conservation measures in the ROAs, measures to address the fault rupture hazard would be required to
 9 conform to applicable design codes, guidelines, and standards. As described in Section 9.3.1, *Methods*
 10 *for Analysis*, and in Appendix 3B, *Environmental Commitments*, such design codes, guidelines, and
 11 standards include the Division of Safety of Dams *Guidelines for Use of the Consequence Hazard Matrix*
 12 *and Selection of Ground Motion Parameters*, DWR's Division of Flood Management *FloodSAFE Urban*
 13 *Levee Design Criteria*, and USACE's *Engineering and Design—Earthquake Design and Evaluation for Civil*
 14 *Works Projects*. Conformance with these design standards is an environmental commitment by the
 15 BDCP proponents to ensure that fault rupture risks are minimized as the conservation measures are
 16 implemented. The hazard would be controlled to a safe level and there would be no increased
 17 likelihood of loss of property, personal injury or death in the ROAs. The impact would be less than
 18 significant. No mitigation is required.

19 **Impact GEO-13: Loss of Property, Personal Injury, or Death from Structural Failure Resulting**
 20 **from Strong Seismic Shaking at Restoration Opportunity Areas**

21 **NEPA Effects:** Conservation measures under Alternative 9 would be similar to that as under Alternative
 22 1A. See description and findings under Alternative 1A. There would be no adverse effect.

23 **CEQA Conclusion:** Ground shaking could damage levees, berms, and other structures. Among all the
 24 ROAs, the Suisun Marsh ROA would be the most subject to ground shaking because of its proximity to
 25 active faults. The Suisun Marsh ROA is subject to a PGA of approximately 0.31 to 0.35 g for 200-year
 26 return interval, while the PGA for the other ROAs ranges from approximately 0.11 to 0.26 g. Damage to
 27 these features could result in their failure, causing flooding of otherwise protected areas. However, as
 28 described in Section 9.3.1, *Methods for Analysis*, and in Appendix 3B, *Environmental Commitments*,
 29 design codes, guidelines, and standards, including the California Building Code and resource agency
 30 and professional engineering specifications, such as DWR's Division of Flood Management *FloodSAFE*
 31 *Urban Levee Design Criteria* and USACE's *Engineering and Design—Earthquake Design and Evaluation*
 32 *for Civil Works Projects* would be used for final design of conservation features. Conformance with these
 33 design standards is an environmental commitment by the BDCP proponents to ensure that strong
 34 seismic shaking risks are minimized as the conservation measures are operated and there would be no
 35 increased likelihood of loss of property, personal injury or death in the ROAs. The impact would be less
 36 than significant. No mitigation is required.

37 **Impact GEO-14: Loss of Property, Personal Injury, or Death from Structural Failure Resulting**
 38 **from Seismic-Related Ground Failure (Including Liquefaction) Beneath Restoration Opportunity**
 39 **Areas**

40 **NEPA Effects:** Conservation measures under Alternative 9 would be similar to that as under Alternative
 41 1A. See description and findings under Alternative 1A. There would be no adverse effect.

1 **CEQA Conclusion:** Earthquake-induced ground shaking could cause liquefaction, resulting in damage to
 2 or failure of levees, berms, and other features constructed at the restoration areas. Failure of levees and
 3 other structures could result in flooding of otherwise protected areas. However, through the final
 4 design process, measures to address the liquefaction hazard would be required to conform to
 5 applicable design codes, guidelines, and standards. As described in Section 9.3.1, *Methods for Analysis*,
 6 and in Appendix 3B, *Environmental Commitments*, such design codes, guidelines, and standards include
 7 USACE's *Engineering and Design—Stability Analysis of Concrete Structures and Soil Liquefaction during*
 8 *Earthquakes*, by the Earthquake Engineering Research Institute. Conformance with these design
 9 standards is an environmental commitment by the BDCP proponents to ensure that liquefaction risks
 10 are minimized as the water conservation features are implemented and there would be no increased
 11 likelihood of loss of property, personal injury or death in the ROAs. The impact would be less than
 12 significant. No mitigation is required.

13 **Impact GEO-15: Loss of Property, Personal Injury, or Death from Landslides and Other Slope**
 14 **Instability at Restoration Opportunity Areas**

15 Conservation measures under Alternative 9 would be similar to that as under Alternative 1A. See
 16 description and findings under Alternative 1A.

17 **NEPA Effects:** The effect would be adverse because levee slopes and embankments may fail, either from
 18 high pore-water pressure caused by high rainfall and weak soil, or from seismic shaking. Failure of
 19 these features could result in flooding of otherwise protected areas. During project design, a
 20 geotechnical engineer would develop slope stability design criteria (such as minimum slope safety
 21 factors and allowable slope deformation and settlement) for the various anticipated loading conditions.
 22 As discussed in Chapter 3, foundation soil beneath embankments and levees could be improved to
 23 increase its strength and to reduce settlement and deformation. Foundation soil improvement could
 24 involve excavation and replacement with engineered fill; preloading; ground modifications using
 25 jet-grouting, compaction grouting, chemical grouting, shallow soil mixing, deep soil mixing,
 26 vibro-compaction, or vibro-replacement; or other methods. Engineered fill could also be used to
 27 construct new embankments and levees.

28 Site-specific geotechnical and hydrological information would be used, and the design would conform
 29 with the current standards and construction practices, as described in Chapter 3, such as USACE's
 30 *Design and Construction of Levees* and USACE's *EM 1110-2-1902, Slope Stability*.

31 The BDCP proponents would ensure that the geotechnical design recommendations are included in the
 32 design of embankments and levees to minimize the potential effects from slope failure. The BDCP
 33 proponents would also ensure that the design specifications are properly executed during
 34 implementation.

35 Conformance to the above and other applicable design specifications and standards would ensure that
 36 the hazard of slope instability would not jeopardize the integrity of levee and other features at the
 37 ROAs. There would be no adverse effect.

38 **CEQA Conclusion:** Unstable new and existing levee and embankment slopes could fail as a result of
 39 seismic shaking and as a result of high soil-water content during heavy rainfall and cause flooding of
 40 otherwise protected areas. However, because the BDCP proponents would conform with applicable
 41 design guidelines and standards, such as USACE design measures, the hazard would be controlled to a
 42 safe level and there would be no increased likelihood of loss of property, personal injury or death in the
 43 ROAs. The impact would be less than significant. No mitigation is required.

1 **Impact GEO-16: Loss of Property, Personal Injury, or Death from Seiche or Tsunami at**
 2 **Restoration Opportunity Areas as a Result of Implementing the Conservation Actions**

3 **NEPA Effects:** Conservation measures under Alternative 9 would be similar to that as under Alternative
 4 1A. See description and findings under Alternative 1A. There would be no adverse effect.

5 **CEQA Conclusion:** Based on recorded tsunami heights at the Golden Gate, the height of a tsunami wave
 6 reaching the ROAs would be small because of the distance from the ocean and attenuating effect of the
 7 San Francisco Bay. Similarly, the potential for a significant seiche to occur in the Plan Area that would
 8 cause loss of property, personal injury, or death at the ROAs is considered low because conditions for a
 9 seiche to occur near conveyance facilities are not favorable. The impact would be less than significant.
 10 No mitigation is required.

11 **9.3.3.17 Cumulative Analysis**

12 The cumulative effects analysis for geology and seismicity considers the effects of BDCP
 13 implementation in combination with other past, present, and reasonably foreseeable projects or
 14 programs. The analysis focuses on projects and programs within the Plan Area, in particular those that
 15 could create a cumulatively significant geologic or seismic risk to people or structures, including the
 16 risk of loss of property, personal injury, or death. The principal programs and projects considered in
 17 the analysis are listed in Table 9-31. This list has been drawn from a more substantial compilation of
 18 past, present, and reasonably foreseeable programs and projects included in Appendix 3D, *Defining*
 19 *Existing Conditions, the No Action/No Project Alternative, and Cumulative Impact Conditions.*

20 **Table 9-31. Cumulative Effects on Geology and Seismicity from Plans, Policies, and Programs**

Agency	Program/Project	Status	Description of Program/Project	Effects on Geology and Seismicity
USACE	Delta Dredged Sediment Long-Term Management Strategy	Ongoing	Maintaining and improving channel function, levee rehabilitation, and ecosystem restoration.	No direct effect on increased risks at BDCP construction locations from earthquakes, groundshaking, liquefaction, slope instability, seiche or tsunami.
Semitropic Water Storage District	Delta Wetlands	Final EIR released in August 2011	Transforming four low-lying islands in the Central Delta within San Joaquin and Contra Costa counties into two Reservoir Islands and two Habitat Islands by fortifying the surrounding levee systems and installing new pumps, siphons, and state-of-the-art fish screens.	No direct effect on increased risks at BDCP construction locations from earthquakes, groundshaking, liquefaction, slope instability, seiche or tsunami.
West Sacramento Area Flood Control Agency and USACE	West Sacramento Levee Improvements Program	Final EIR/EIS certified on March 10, 2011	Improvements to levees protecting West Sacramento to meet local and federal flood protection criteria.	No direct effect on increased risks at BDCP construction locations from earthquakes, groundshaking, liquefaction, slope instability, seiche or tsunami.

Agency	Program/Project	Status	Description of Program/Project	Effects on Geology and Seismicity
DWR	Levee Repair-Levee Evaluation Program	Ongoing	Repair of state and federal project levees. To date, nearly 300 levee repair sites have been identified, with more than 100 of the most critical sites having already been completed with AB 142 funds. Repairs to others are either in progress or scheduled to be completed in the near future, and still more repair sites are in the process of being identified, planned, and prioritized.	No direct effect on increased risks at BDCP construction locations from earthquakes, groundshaking, liquefaction, slope instability, seiche or tsunami.
DWR	Delta Levees Flood Protection Program	Ongoing	Levee rehabilitation projects in the Delta.	No direct effect on increased risks at BDCP construction locations from earthquakes, groundshaking, liquefaction, slope instability, seiche or tsunami.
DWR, DFW, USACE	CALFED Levee System Integrity Program	Planning phase	Levee maintenance and improvement in the Delta.	No direct effect on increased risks at BDCP construction locations from earthquakes, groundshaking, liquefaction, slope instability, seiche or tsunami.
DWR	Central Valley Flood Management Planning Program	Planning phase	Among other management actions, involves levee raising and construction of new levees for flood control purposes.	No direct effect on increased risks at BDCP construction locations from earthquakes, groundshaking, liquefaction, slope instability, seiche or tsunami.
SAFCA, Central Valley Flood Protection Board, USACE	Flood Management Program	Ongoing	South Sacramento Streams Project component consists of levee, floodwall, and channel improvements.	No direct effect on increased risks at BDCP construction locations from earthquakes, groundshaking, liquefaction, slope instability, seiche or tsunami.
USBR, DWR	2-Gates Fish Protection Demonstration Project	Delayed	Temporary gates would be placed across Old River and Connection Slough in the central Delta and operated from December to March for fish protection purposes.	No direct effect on increased risks at BDCP construction locations from earthquakes, groundshaking, liquefaction, slope instability, seiche or tsunami.

Agency	Program/Project	Status	Description of Program/Project	Effects on Geology and Seismicity
USBR, DWR	Franks Tract Project	Delayed	State and federal agencies would evaluate and implement, if appropriate and authorized, a strategy to significantly reduce salinity levels in the south Delta and at the CCWD and SWP/CVP export facilities and improve water supply reliability by reconfiguring levees and/or Delta circulation patterns around Franks Tract while accommodating recreational interests	No direct effect on increased risks at BDCP construction locations from earthquakes, groundshaking, liquefaction, slope instability, seiche or tsunami.
DWR, USBR and CCWD	Los Vaqueros Expansion Investigation	Final EIR certified by CCWD in March 2010	The existing Los Vaqueros Reservoir would be expanded up to a total of 275 thousand acre-feet to take full advantage of the existing state of the art fish screens currently in use in the Delta. New Delta intakes, pumps, and pipelines would be required to fill the additional reservoir capacity, and water deliveries would be made from the expanded reservoir to Bay Area beneficiaries through new conveyance facilities.	No direct effect on increased risks at BDCP construction locations from earthquakes, groundshaking, liquefaction, slope instability, seiche or tsunami.

1

2 **No Action Alternative**

3 The cumulative effect of the No Action Alternative is anticipated to result in the current hazard
4 resulting from earthquake-induced ground shaking from regional and local faults persisting. It is also
5 anticipated that the current hazard of earthquake-induced liquefaction triggered by regional and local
6 faults would persist. Slope instability associated with non-engineered levees would continue to present
7 a risk of levee failure and subsequent flooding of Delta islands, with a concomitant influx of seawater
8 into the Delta, thereby adversely affecting water quality and water supply. Ongoing and reasonably
9 foreseeable future projects in parts of the Delta are expected to upgrade the levees to a "flood-safe"
10 condition under the 100-year return flood elevation. However, these projects would provide very little
11 levee foundation strengthening and improvements directed at improving the stability of the levees to
12 better withstand ground shaking, liquefaction, and slope instability.

13 The Delta and vicinity is within a highly active seismic area, with a generally high potential for major
14 future earthquake events along nearby and/or regional faults, and with the probability for such events
15 increasing over time. Based on the location, extent and non-engineered nature of many existing levee
16 structures in the Delta area, the potential for significant damage to, or failure of, these structures during
17 a major local seismic event is generally moderate to high. In the instance of a large seismic event, levees
18 constructed on liquefiable foundations are expected to experience large deformations (in excess of 10
19 feet) under a moderate to large earthquake in the region. There would potentially be loss, injury or
20 death resulting from ground rupture, ground shaking and liquefaction, (See Appendix 3E, *Potential
21 Seismic and Climate Change Risks to SWP/CVP Water Supplies* for more detailed discussion). While
22 similar risks would occur under implementation of the action alternatives, these risks may be reduced

1 by BDCP-related levee improvements along with those projects identified for the purposes of flood
2 protection in Table 9-31.

3 **BDCP Alternatives**

4 **NEPA Effects:** Implementation of the BDCP and other local and regional projects as presented in Table
5 9-31, could contribute to regional impacts and hazards associated with geology and seismicity. The
6 geologic and seismic hazards that would exist and the potential adverse effects that could occur to
7 structures and persons in association with construction and operation of all BDCP alternatives would
8 be restricted to the locations of the construction and the operational activities of these alternatives.
9 Depending on which alternative is chosen, the location of these impacts would vary slightly. These
10 impacts include the potential for loss, injury or death as a result of strong seismic shaking, settlement
11 or collapse caused by dewatering, ground settlement, slope failure (including decreased levee stability
12 from construction and operation activities), seismic-related ground failure (including liquefaction),
13 ground shaking, fault rupture, seiche or tsunami. All of the impacts are mitigated by incorporating
14 standard construction and structural measures into project design and construction. No impacts
15 related to construction or operation of any of the BDCP alternatives or from implementation of the
16 conservation measures were identified for this resource area. These cumulative impacts would result
17 from construction activities and development of additional structures that may be subject to geologic,
18 seismic, or slope failure and could be reduced by implementing measures similar to those described for
19 BDCP. However, these projects would not increase the risks to structures and people at the specific
20 locations affected by BDCP alternatives. Therefore, the risks of loss of property, personal injury, or
21 death associated with the alternatives would not combine with the geologic and seismic risks from
22 other projects or programs to create a cumulatively adverse effect at any one locality in the Plan Area.
23 There would be no cumulative adverse effect.

24 **CEQA Conclusion:** The geologic and seismic hazards that would exist and the potential adverse effects
25 that could occur in association with construction and operation of all project alternatives would be
26 restricted to the locations of the construction and the operational activities of these alternatives. Other
27 past, present and probable future projects and programs in the Plan Area that are identified in Table 9-
28 31 would not increase the risks of loss, injury or death at the specific locations affected by project
29 alternatives. Therefore, the risks of loss, injury or death associated with the project alternatives would
30 not combine with the geologic and seismic risks from other projects or programs to create a substantial
31 cumulative effect at any one locality in the Plan Area. This cumulative impact is considered less than
32 significant. No mitigation is required.

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