

9.0 Summary Comparison of Alternatives

A summary comparison of important geologic impacts is provided in Figure 9-0. This figure provides information on the magnitude of both adverse and beneficial geologic impacts that are expected to result from implementation of the alternatives. Important impacts to consider include the loss of property or likelihood of personal injury or death as a result of settlement caused by dewatering during construction of water conveyance facilities.

Each alternative, with the exception of the No Action Alternative, would have conveyance segments that pose a greater risk of settlement than do Existing Conditions. Six segments would be at risk under Alternatives 1B, 2B, and 6B, whereas only one segment would be at risk under Alternatives 1C, 2C, and 6C. Alternative 4A would fall within this range, with two segments at risk.

Executive Summary Table ES-8 provides a summary of all impacts disclosed in this chapter.

9.1 Environmental Setting/Affected Environment

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 The information presented is based on existing information from published and unpublished sources.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 activities under the proposed project.

- 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 action 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.

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

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

- 6 • *Conceptual Engineering Report—Isolated Conveyance Facility—All Tunnel Option* (California
7 Department of Water Resources 2010a).
- 8 • *Conceptual Engineering Report—Isolated Conveyance Facility—Pipeline/Tunnel Option—*
9 *Addendum* (California Department of Water Resources 2010b).
- 10 • *Conceptual Engineering Report—Isolated Conveyance Facility—East Option* (California
11 Department of Water Resources 2009a).
- 12 • *Conceptual Engineering Report—Isolated Conveyance Facility—East Option—Addendum*
13 (California Department of Water Resources 2010c).
- 14 • *Conceptual Engineering Report—Isolated Conveyance Facility—West Option* (California
15 Department of Water Resources 2009b).
- 16 • *Conceptual Engineering Report—Isolated Conveyance Facility—West Option—Addendum*
17 (California Department of Water Resources 2010d).
- 18 • *Option Description Report—Separate Corridors Option* (California Department of Water
19 Resources 2010e).
- 20 • *Conceptual Engineering Report—Dual Conveyance Facility Modified Pipeline/Tunnel Option—*
21 *Clifton Court Forebay Pumping Plant (MPTO/CCO), Volume 1.* (California Department of Water
22 Resources 2015).

23 **9.1.1 Potential Environmental Effects Area**

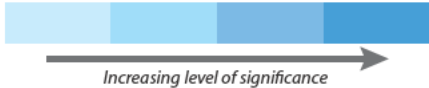
24 The Plan Area (the area covered by the proposed project) consists of the Delta and Suisun Marsh
25 which lie within California’s Central Valley, which is approximately 465 miles long and 40–60 miles
26 wide. The valley is bound by the Sierra Nevada on the east and the Coast Ranges on the west (Figure
27 9-1). Paleogeographic reconstructions of this region indicate that Miocene sedimentation was
28 similar to a modern fore-arc basin (a sea floor depression between a subduction zone and an
29 associated volcanic arc), shedding arkosic (granular quartz and feldspar or mica) and volcanoclastic
30 sediment westward from the continent. (Figure 9-2 presents a geologic time scale.) In the mid-
31 Pliocene Epoch, a shift in plate tectonics triggered uplift of the Coast Ranges, which gradually closed
32 the southern marine outlet to the basin. By the late Pliocene, sub-aerial conditions prevailed
33 throughout the valley, resulting from marine regression (i.e., where shoreline shifts oceanward,
34 exposing formerly submerged areas) and sedimentation from the west. During Pleistocene Epoch,
35 the valley separated from the Pacific Ocean and developed internal drainage, the modern outlet
36 being the Carquinez Strait, through which the Sacramento River flows to the San Francisco Bay
37 (Lettis and Unruh 1991, pp. 164–176).

38 The historical Delta formed approximately 5,000 years ago at the inland margin of the San Francisco
39 Bay Estuary as two overlapping geomorphic units. The Sacramento River Delta comprises about
40 30% of the total area and was influenced by the interaction of rising sea level and river floods that
41 created channels, natural levees, and marsh plains. During large river flood events, silt and sand

Chapter 9 – Geology and Seismology	Alternative																			
	Existing Condition	No Action	1A	1B	1C	2A	2B	2C	3	4	5	6A	6B	6C	7	8	9	4A	2D	5A
GEO-3: Loss of Property, Personal Injury, or Death from Ground Settlement during Construction of Water Conveyance Features (number of segments that pose greatest risk of settlement per alternative)	n/a	n/a	2	6	1	2	6	1	2	2	2	2	6	1	2	2	2	2	2	2
	n/a	n/a	LTS/NA	LTS/NA	LTS/NA	LTS/NA	LTS/NA	LTS/NA	LTS/NA	LTS/NA	LTS/NA	LTS/NA	LTS/NA	LTS/NA	LTS/NA	LTS/NA	LTS/NA	LTS/NA	LTS/NA	LTS/NA

Key

Level of significance or effect **before** mitigation (Quantity of impact: number of sites, structures, acres, etc. affected)



Increasing level of significance

n/a not applicable
 > greater than
 < less than
 ≈ about equal to

Level of significance or effect **after** mitigation (CEQA Finding / NEPA Finding)

CEQA Finding	NEPA Finding
NI No Impact	B Beneficial
LTS Less than significant	NE No Effect
S Significant	NA Not Adverse
SU Significant and unavoidable	A Adverse

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Figure 9-0
Comparison of Impacts on Geology and Seismology

1 were deposited adjacent to the river channel, forming natural levees above the marsh plain. In
 2 contrast, the larger San Joaquin River Delta, located in the central and southern portions of the Delta
 3 and having relatively small flood flows and low sediment supply, formed as an extensive, levee free
 4 freshwater tidal marsh dominated by tidal flows and organic soil (peat and muck) accretion
 5 (Atwater and Belknap 1980). Because the San Joaquin River Delta had less well-defined levees,
 6 sediment were deposited more uniformly across the floodplain during high water, creating an
 7 extensive tule marsh with many small branching tributary channels. As a result of the different
 8 amounts of inorganic sediment supply, the peat and muck of the San Joaquin River Delta grade
 9 northward into peaty mud and then into mud as it approaches the natural levees and flood basins of
 10 the Sacramento River Delta (Atwater and Belknap 1980).

11 **9.1.1.1 Regional Geology**

12 The Great Valley is a northwest-trending structural basin, separating the primarily granitic rock of
 13 the Sierra Nevada from the primarily Franciscan Formation rock of the California Coastal Range
 14 (Norris and Webb 1990). The basin is filled with an approximately 3- to 6-mile-thick layer of
 15 sedimentary deposits deposited by streams originating in the Sierra Nevada, Coast Ranges, and
 16 South Cascade Range, and flowing to the San Francisco Bay. Figure 9-3 is a geologic map of the Plan
 17 Area and vicinity. (Detailed geologic mapping is not available for the entire Plan Area). Figure 9-3 is
 18 primarily based on relatively detailed mapping derived from Atwater [1982] and covers most of the
 19 Delta. The geology of the remaining areas [e.g., Suisun Marsh and southern end of the Delta] is based
 20 on regional geologic mapping derived from the California Division of Mines and Geology.) Figure 9-3
 21 also shows the primary conveyance alignments subdivided into segments; these segments provide
 22 the basis for the discussion of potential effects in Section 9.3, *Environmental Consequences*. Figure 9-
 23 4, which is based on boring logs contained in the 2009 through 2012 DWR geotechnical data
 24 reports, shows a cross-section of the stratigraphy of the sediments and peat (expressed as Unified
 25 Soil Classification System abbreviations) generally oriented along the CCO alignment.

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

35 As the Suisun Marsh formed, plant detritus slowly accumulated, compressing the saturated
 36 underlying base material. Mineral sediment were added to the organic material by tidal action and
 37 during floods. Generally, mineral sediment deposition decreased with distance from the sloughs and
 38 channels (Miller et al. 1975). Suisun Marsh soils are termed “hydric” because they formed under
 39 prolonged saturated soil conditions. The soil adjacent to the sloughs is mineral soil with less than
 40 15% organic matter content, and although classified as “poorly drained,” they are better drained
 41 than the more organic soil situated farther from the sloughs.

42 Suisun Marsh organic soil is found farthest from the sloughs and at the lowest elevations. They have
 43 greater than 50% organic matter content. Other common soils in the Suisun Marsh belong to the

1 Valdez series, which formed on alluvial fans and contain very low amounts of organic matter. Valdez
2 series soils are found primarily on Grizzly Island (Miller et al. 1975).

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

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

11 **9.1.1.2 Local Geology**

12 A geologic map of the Plan Area is provided in Figure 9-3. It was necessary to use different sources
13 to compile the geologic map and descriptions of the geologic map units (Tables 9-1 through 9-5)
14 presented in this report. The primary map used in Figure 9-3 is the geologic map created by Atwater
15 (1982), which provides the greater detail but does not cover the entire Plan Area. Regional geologic
16 maps (Wagner et al. 1981; Wagner and Bortugno 1982; Wagner et al. 1991) were therefore used to
17 fill in the remaining parts of the Plan Area. Except where noted, the text descriptions provided in
18 Tables 9-1 through 9-4 are taken directly (i.e., verbatim) from the work done by Graymer et al.
19 (2002) because this work, although it did not cover as much of the Plan Area as Atwater, provides
20 the most recent and relevant general descriptions of the geologic units that occur in the Plan Area.
21 Because Graymer et al. and Atwater used different names for geologic units, Tables 9-1 through 9-4
22 include approximate correlations between the terminology in Graymer’s et al. and Atwater’s maps.

23 **Peat and Organic Soils**

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

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

1 **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.

2

3 **Alluvium**

4 Alluvium is sediment deposited by a river or other running water, and is typically composed of a
5 variety of materials, including fine particles of silt and clay and larger particles of sand and gravel.
6 A river continually picks up and drops solid particles of rock and soil from its bed throughout its
7 length. Where river flow is fast, more particles are picked up than dropped. Where the river flow is
8 slow, more particles are dropped than are picked up. Areas where more particles are dropped are
9 called *alluvial plains* or *floodplains*, and the dropped particles are called *alluvium*. Even small
10 streams make alluvial deposits, but it is in the floodplains and deltas of large rivers where large,
11 geologically substantial alluvial deposits are found. The mapped Holocene alluvial deposits found in
12 the Delta and Suisun Marsh are described in Table 9-2.

1 **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)

Map Unit Name	Map Symbol	Description ^a	Approximate Correlation to Atwater ^b
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.	
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.	
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).	Atwater mapped according to drainage basin and Graymer et al. according to type of alluvium, so correlation is very general: Qo, Qom, Qoa, Qomc
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
- 7 to the units listed in Table 9-2, which begin with Qh or Q to indicate Holocene to Holocene-to-
- 8 Pleistocene-aged deposits. Similarly, the Qo (Qop, Qom, Qoa, and Qomc) alluvial deposits are listed

1 in Table 9-2, with Qp indicating Pleistocene-aged alluvial deposits. Qch and Qcr, as mapped on the
 2 Atwater map, consist of alluvial deposits from the Corral Hollow and Calaveras creek drainage
 3 basins, respectively, and they are not broken out by age of deposits (Atwater 1982).

4 **Levee and Channel Deposits**

5 The ability of a river to carry sediment varies greatly with its flow volume and velocity. When a river
 6 floods over its banks, the water spreads out, slows down, and deposits its load of suspended
 7 sediment. Fine-grained sediment are deposited further from the channel, where coarser sediment
 8 are deposited nearer the channel. Over time, the river's banks are built up above the level of the rest
 9 of the floodplain. The resulting low ridges are called natural levees. Artificial, or human-made, levees
 10 are built to prevent flooding of lands along the river; these confine flow, resulting in higher and
 11 faster water flow than would occur naturally. Artificial levees impact sedimentation in the modern
 12 Delta. Natural and artificial levee deposits have been mapped and are described in Table 9-3.
 13 Atwater did not separately map artificial channel, levee, and stream deposits. The natural levee,
 14 floodplain, and flood basin deposits listed in Table 9-3 are designated as Ql, Qfp, and Qb,
 15 respectively, on the Atwater map (Atwater 1982).

16 **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

Map Unit Name	Map Symbol	Description ^a	Approximate Correlation to Atwater ^b
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.

1

2 **Dune Sand Deposits**

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

10 **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.

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.

11

1 **Older Alluvium**

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

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

11 The Pleistocene Mokelumne River channels that deposited older alluvium show little relation to the
 12 present stream. Whereas the modern river channels meander in its floodplain and carry fine-
 13 grained sediment, the Pleistocene rivers cut deep, canyon-like channels into underlying, older fan
 14 deposits. These ancient rivers had greater hydraulic force and carried glacially derived boulders and
 15 cobbles much farther downstream than the present river (Shlemon 1971). The older alluvial units
 16 are described in Table 9-5. These glacial deposits do not appear within the limits of the Graymer et
 17 al. map (2002).

18 **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).

19
 20 **Bedrock Units**

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

1 **9.1.1.3 Regional and Local Seismicity**

2 The California Coast Ranges physiographic province lies along the complex boundary between two
 3 tectonic plates: the North American Plate and the Pacific Plate. The geologic and tectonic conditions
 4 in the Delta and Suisun Marsh have been, and continue to be, controlled primarily by the interaction
 5 of these two massive blocks of the Earth's crust. Under the current tectonic regime, the Pacific Plate
 6 moves northwestward relative to the North American Plate at a rate of about 1.57 inches (40
 7 millimeters) per year (Working Group on California Earthquake Probabilities 2003). Although
 8 relative motion between these two plates is predominantly lateral (strike-slip), an increase in
 9 convergent motion along the plate boundary within the past few million years has resulted in the
 10 formation of mountain ranges and structural valleys of the Coast Ranges province (DeCourten
 11 2008).

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

17 The Delta and Suisun Marsh are in the eastern portion of the greater San Francisco Bay region, one
 18 of the most seismically active areas in the United States. Since 1800, several earthquakes with
 19 magnitudes greater than 6.5 have occurred in the immediate San Francisco Bay Area, including the
 20 1868 magnitude 6.8 earthquake on the Hayward fault, the 1906 magnitude 7.9 San Francisco
 21 earthquake on the San Andreas fault, and the more recent 1989 magnitude 6.9 Loma Prieta
 22 earthquake that occurred in the Santa Cruz Mountains. Figure 9-5 depicts the recorded historical
 23 seismicity in the San Francisco Bay region from 1800 to 2006.

24 **Delta**

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

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

32 **Suisun Marsh**

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

37 Two earthquakes (the 1892 Vacaville–Winters and the 1983 Coalinga earthquakes) have been
 38 associated with the Coast Ranges–Sierran Block (CRSB) seismic zone, a complex-dipping thrust fault
 39 zone that goes through the Delta and Suisun Marsh area. The epicenter of the 1892 Vacaville-
 40 Winters earthquake was approximately 8 miles west of the Delta and Suisun Marsh. The epicenter of

1 the 1983 Coalinga earthquake was approximately 110 miles south of the Delta. Both of these seismic
2 events had a magnitude greater than 6.5.

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

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

14 **Past Earthquake Ground Motion Intensity and Damage**

15 The San Francisco Bay region has been subjected to damaging ground shaking during past
16 earthquakes. Table 9-6 lists the largest earthquakes that have affected the San Francisco Bay region
17 since 1868 and the damage caused by these earthquakes, as described in the seismic study
18 (California Department of 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.

CRSB = Coast Ranges–Sierran Block.

M_L = Richter Magnitude.

M = Moment Magnitude.

MMI = Modified Mercalli Intensity.

Notes: 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
4 Intensity (MMI). MMI is a measure of ground shaking that is based on the effects of earthquakes on
5 people and buildings at a particular location. An MMI VII or greater indicates damaging effects on
6 people and 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

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

3 **Active Seismic Sources**

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

13 A recent seismic study (California Department of Water Resources 2007a) considered four
 14 categories 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
 21 the Working Group on Northern California Earthquake Potential (WGNCEP), WGCEP, and CGS
 22 seismic source model used in the USGS National Seismic Hazard Maps (Working Group on Northern
 23 California Earthquake Potential 1996; Working Group on California Earthquake Probabilities 2003;
 24 Cao et al. 2003).

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

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

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

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

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

21 **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.

23 **Thrust Faults**

24 The seismic sources underlying the Delta and Suisun Marsh are mostly “blind” thrusts (Table 9-8).
 25 A blind thrust is a seismic source that is not expected to rupture to the ground surface during an
 26 earthquake event, but is still capable of producing large and damaging ground shaking. The known
 27 blind thrusts in the Delta include the Midland, Montezuma Hills, Thornton Arch, West Tracy, and
 28 Vernalis faults. The Black Butte and Midway faults are thrust faults, with a discernible geomorphic
 29 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

Sources: 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
5 the area indicate that it is not exposed at the ground surface (California Division of Oil and Gas
6 1982). The Midland fault is divided into a Northern Midland fault zone, which characterizes the
7 northwest-striking fault splays north of Rio Vista, and a Southern Midland fault, which extends
8 southward to near Clifton Court Forebay. (The area (rather than a defined trace) referred to as the
9 Northern Midland fault zone is so-named because it encompasses numerous right-stepping
10 northwest-striking splays of the Midland fault.)

11 The Montezuma Hills seismic source is modeled as a source zone between the Delta and Suisun
12 Marsh near Rio Vista. The zone extends southward to the Sherman Island area and has been defined
13 to capture the potential active structures that may be responsible for the uplift of the Montezuma
14 Hills (California Department of Water Resources 2007a).

15 The Thornton Arch seismic zone has been defined to represent the possible existence of active
16 buried structures near the Thornton and West Thornton-Walnut Grove gas field near the Delta Cross
17 Channel area. After considering the best available evidence to date, the seismic study adopted a low
18 probability of activity and a low slip rate for this zone. The probability of activity is a measure of
19 certainty, based on the available data, that a seismic source is active (California Department of
20 Water Resources 2007a). The probability scale ranges from 0 to 1.0, with a probability of 1.0
21 strongly suggesting an active fault.

22 The West Tracy, Vernalis, Black Butte, and Midway faults are parts of the CRSB seismic zone
23 (California Department of Water Resources 2007a). As described previously in this section, the
24 CRSB is a complex zone of thrust faulting that defines the boundary between the Coast Ranges block
25 to the west and the Sierran basement rocks of the Sacramento and San Joaquin Valleys. The West
26 Tracy fault is mapped beneath the southwestern part of the Clifton Court Forebay and western part
27 of the Byron Tract Forebay. It has a total length of about 9.5 miles. Multiple east-dipping splays of
28 the fault may exist in the hanging wall (i.e., upthrown block) west of the Clifton Court Forebay, some
29 of which are underneath the intake channel to the Banks Pumping Plant (Fugro Consultants 2011).
30 The fault strikes in a northwest–southeast direction and dips westward moderately to steeply to the
31 west. The Vernalis fault is mapped at the southern end of the Delta area, extending between Tracy

1 and Patterson, at a minimum length of about 19.2 miles. Similar to the West Tracy fault, the Vernalis
 2 fault is a moderately to steeply west-dipping fault (California Department of Water Resources
 3 2007a). The Black Butte fault is a northwest–southeast striking fault approximately 6 miles
 4 southeast of Tracy. It dips moderately to steeply to the west. The Midway fault similarly strikes
 5 northwest–southeast and is separated from the northwest end of the Black Butte fault by an *en*
 6 *echelon* step across a small west–northwest-trending anticline. The seismic study (California
 7 Department of Water Resources 2007a) characterized the Black Butte and Midway faults as a single
 8 structure.

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

11 **Seismic Zones**

12 To account for seismicity not associated with known faults, such as random or floating earthquakes,
 13 two regional seismic zones—the Coast Ranges and Central Valley seismic zones—were developed
 14 for the seismic study. The maximum earthquake magnitudes assigned to these seismic zones are
 15 6.5 ± 0.3 moment magnitude. The recurrences of various earthquake magnitudes were estimated
 16 using the historical seismicity recorded in each of the two seismic zones after removing events
 17 within 10-kilometer-wide corridors along known faults (to avoid double counting seismic events
 18 that occurred on the faults). Both the uniform and gridded seismicity source models were used to
 19 model the uncertainty associated with earthquake location. In the uniform model, earthquakes are
 20 assumed to occur everywhere within the zone with equal probability. For the gridded seismicity
 21 model, the rates of earthquakes at a particular location within the zone are estimated using the
 22 seismicity recorded around the location. A Gaussian (normal) filter was used to “smooth” the data
 23 and to assign greater weights to nearby seismicity (California Department of Water Resources
 24 2007a).

25 **Subduction Zone**

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

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

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

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

- 1 • Megathrust events (magnitude 9.0 ± 0.2) that rupture the entire interface zone every 500 years
- 2 (weight of 0.67).
- 3 • Smaller events (magnitude 8.0 to 8.7) that float over the interface zone and rupture the entire
- 4 zone over a period of about 500 years (weight of 0.33).

5 **9.1.1.4 Geologic and Seismic Hazards**

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

8 **Surface Fault Ruptures**

9 **Fault Trace and Rupture Zones**

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

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

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

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

27 **Fault Offsets**

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

33 Empirical relationships are typically used to estimate fault offsets. The relationships provide
34 estimates of fault displacements, such as average and maximum offsets, as a function of fault
35 parameters. The average and maximum fault offsets for the Concord and Pittsburgh–Kirby Hills
36 faults (Table 9-9) were 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
4 near the base of the peat (or top of the sand layer) across the fault traces. The available data indicate
5 a modest 6.6–9.8 foot west-side-up step at the base of the peat across the surface trace of the
6 Midland 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
10 intake channel to the Banks Pumping Plant. The CGS and USGS show the West Tracy fault as not
11 being active. However, Fugro Consultants (2011) indicate that the fault may have experienced
12 movement within the past 35,000 years and therefore would be potentially active. If movement
13 occurred along the fault, uplift of the hanging wall of the fault could cause surface deformation in the
14 western part of the Clifton Court Forebay and the Byron Tract Forebay. Additionally, slippage of the
15 fault splays could cause surface rupture immediately west of the Clifton Court Forebay and the
16 Byron Tract Forebay (Fugro Consultants 2011).

17 **Earthquake Ground Shaking**

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

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

32 In a time-dependent model, the time of the last earthquake is used to estimate earthquake
33 recurrence interval or frequency (a non-Poissonian process). Because many of the San Francisco
34 Bay region seismic sources do not have sufficient information on the times of last earthquakes, only
35 seven of the major faults were characterized using the time-dependent model: the San Andreas,

1 Hayward–Rodgers Creek, Calaveras, Concord–Green Valley, San Gregorio, Greenville, and Mt. Diablo
2 Thrust. Therefore, the overall model used in the seismic study is not a pure time-dependent model.

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

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

17 The PSHA was conducted at six selected locations in the Delta area (Clifton Court, Delta Cross
18 Channel, Montezuma Slough, Sacramento, Sherman Island, and Stockton) for four different years:
19 2005, 2050, 2100, and 2200. The selected sites represent the north, south, east, west and central
20 regions of the Delta and the western-most section of the Plan Area. The results are expressed in
21 terms of hazard curves that relate the intensity of ground motion (PGA and response spectral
22 accelerations) to annual exceedance probability (probability that a specific value of ground motion
23 intensity will be exceeded). The distributions of hazard curve (the 5th, 15th, mean, median [50th],
24 85th, and 95th percentile hazard curves) were calculated at the six selected locations for PGA and
25 1.0-second spectral acceleration. The seismic hazard analysis was performed for a stiff soil site
26 condition, with an average shear-wave velocity of 1,000 feet per second (ft/sec) in the top 100 feet,
27 or 30 meters (V_{s100ft}).

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

32 **Controlling Seismic Sources**

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

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

Location	PGA	1.0-Second Spectral Acceleration
100-Year Return Period		
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
2,475-Year Return Period		
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.

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
11 site condition. Therefore, these motions are expected to change as they propagate upward through
12 the peaty and soft soil from the stiffer alluvium underlying the Delta and Suisun Marsh. Based on
13 CALFED Bay-Delta Program (2000), the acceleration amplification factor from the stiff base layer to
14 the levee 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.

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

5 **Table 9-11. Calculated Mean Peak Ground Motions at Selected Sites for Various Return Periods**
 6 **(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
Mean Peak Ground Acceleration in g										
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
Mean 1.0-Second Spectral Acceleration in g (5% damping)										
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.

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

7

8 **144-Year Return Period Ground Motion**

9 The calculated mean PGA and 1.0-second spectral acceleration values for a 144-year ground motion
 10 return period (or an annual frequency of 0.00694) in 2005 and 2200 are presented Table 9-11. The
 11 calculated ground motions in 2050 and 2100 are between these values (not shown in the table). The
 12 144-year return period corresponds to approximately 30% probability of exceedance in 50 years.

13 **475-Year Return Period Ground Motion**

14 The calculated mean PGA and 1.0-second spectral acceleration values for a 475-year ground motion
 15 return period (or an annual frequency of 0.0021) in 2005 and 2200 are presented in Table 9-11. The
 16 calculated ground motions in 2050 and 2100 are between these values (not shown in the table). The
 17 475-year return period corresponds to approximately 10% probability of exceedance in 50 years.

18 **975-Year Return Period Ground Motion**

19 The calculated mean PGA and 1.0-second spectral acceleration values for a 975-year ground motion
 20 return period (or an annual frequency of 0.00102) in 2005 and 2200 are presented in Table 9-11.

1 The calculated ground motions in 2050 and 2100 are between these values (not shown in the table).
 2 The 975-year return period corresponds to approximately 5% probability of exceedance in 50 years.

3 **2,475-Year Return Period Ground Motion**

4 The calculated mean PGA and 1.0-second spectral acceleration values for a 2,475-year ground
 5 motion return period (or an annual frequency of 0.0004) in 2005 and 2200 are presented in Table 9-
 6 11. The calculated ground motions in 2050 and 2100 are between these values (not shown in the
 7 table). The 2,475-year return period corresponds to approximately 2% probability of exceedance in
 8 50 years.

9 The data in Table 9-11 indicate that ground motion decreases from west to east as the distance to
 10 the San Andreas fault system increases. With a 72-year return period, for example, the mean peak
 11 ground motion at Montezuma Slough (which is the closest of the locations to the San Andreas fault
 12 system shown on Table 9-11) would be 0.23g. East of Montezuma Slough and in the west-central
 13 part of the Delta at Sherman Island, the mean peak ground acceleration would be 0.20g. And at the
 14 eastern edge of the Delta (i.e., farthest from the San Andreas fault system) in Stockton, the mean
 15 peak ground acceleration would be 0.12g. Also, the calculated ground motions are not sensitive (i.e.,
 16 they increase only slightly) to the assumed time interval from the last major earthquake (from 2005
 17 to 2200).

18 The 2008 USGS National Seismic Hazard Maps provide the values of PGA and 1.0-second spectral
 19 acceleration for the 475- and 2,475-year return periods. Table 9-12 compares the ranges of PGA and
 20 1.0-second spectral acceleration calculated in the seismic study (California Department of Water
 21 Resources 2007a) to those estimated from the USGS maps (U.S. Geological Survey 2008).

22 **Table 9-12. Comparison of Ground Motions Calculated in the Seismic Study to Estimated 2008**
 23 **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

Sources: California Department of Water Resources 2007a; U.S. Geological Survey 2008.

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)

24
 25 The 2008 USGS maps were developed for a reference site condition with an average shear-wave
 26 velocity of 2,500 ft/sec (about 760 meters per second) in the top 100 feet (Petersen et al. 2008).
 27 Consequently, the mapped values cannot be directly compared to those calculated in the seismic
 28 study, which assumed a site condition with an average shear-wave velocity of 1,000 ft/sec
 29 (California Department of Water Resources 2007a).

1 **Liquefaction**

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

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

16 **Historical Occurrences of Liquefaction**

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

25 **Conditions Susceptible to Liquefaction**

26 Along the Delta and Suisun Marsh levees, loose silty and sandy soils are present in some of the levee
27 embankments and in the underlying foundation soil. When saturated, such soils are susceptible to
28 liquefaction during earthquake events. Since the levees are constructed (not naturally occurring),
29 the loose, silty and sandy soils comprising some of the levees are likely to be more continuous than
30 those present in the foundation of the levee (CALFED Bay-Delta Program 2000). Areas with larger
31 lateral continuity of liquefied soil are expected to experience more ground failure. The available data
32 also indicate that the levees protecting Sherman Island have extensive layers of liquefiable sandy
33 soil, more so than other levees in the Delta and Suisun Marsh (CALFED Bay-Delta Program 2000).
34 See Chapter 6, *Surface Water*, for more information.

35 **Liquefaction Hazard Mapping**

36 No official Seismic Hazard Zone maps for liquefaction potential have been developed by CGS or the
37 USGS for the soils of the entire Plan Area. Also, maps of liquefaction hazard (i.e., the susceptibility of
38 the geologic or soil materials and ground water levels to liquefaction combined with shaking levels
39 anticipated for a given earthquake scenario) have not been prepared for the entire Plan Area.
40 However, the vulnerability of Delta and Suisun Marsh levees to failure caused by seismic shaking
41 alone and by seismically induced liquefaction was analyzed in two Delta Risk Management Strategy
42 reports (California Department of Water Resources 2008a, b). These analyses recognized the

1 following modes of seismically induced levee failure: 1) water overtopping a levee as a result of
 2 levee crest slumping and settlement, 2) internal soil piping and erosion caused by earthquake-
 3 induced differential levee deformations, 3) sliding blocks and lateral spreading resulting in
 4 transverse cracking, and 4) exacerbation of existing seepage problems due to levee deformations
 5 and cracking.

6 The analyses grouped levees in the Delta and Suisun Marsh that are below the mean higher high
 7 water floodplain into 22 failure vulnerability classes based on results from standard penetration test
 8 blow count and cone penetration test blow count data, thickness of peat/organic soils underlying
 9 the levees, and the steepness of the waterside of the levee slope. The 22 vulnerability classes were
 10 then combined into three vulnerability groups: low, medium, and high, which are shown in Figure 9-
 11 6. The figure shows that many of the Delta levees are in the “high” vulnerability group and smaller
 12 proportions of Delta levee are in the “low” and “medium” vulnerability groups. All of the Suisun
 13 Marsh levees are in the “medium” vulnerability group.

14 **Areas Susceptible to Slope Instability**

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

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

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

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

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

39 Since 1900, at least 158 levee failures or breaches have been reported that resulted in flooding the
 40 Delta and Suisun Marsh islands and tracts. (California Department of Water Resources 2010f)
 41 Earthquake ground shaking is not linked to any of these levee breaches. The dominant causes of the
 42 levee breaches are believed to have been water overtopping levees during high tides, erosion, piping

1 and seepage through the levee embankment and foundation soil, and burrowing animals. (California
2 Department of Water Resources 2007b)

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

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

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

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

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

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

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

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

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

33 **Ground Failure and Seismic-Induced Soil Instability**

34 **Compaction and Settlement**

35 Earthquake ground motions can cause compaction and settlement of soil deposits because of
36 rearrangement of soil particles during shaking. The amount of settlement depends on ground
37 motion intensity and duration and degree of soil compaction; looser soil subjected to higher ground
38 shaking will settle more. Empirical relationships are commonly used to provide estimates of
39 seismic-induced settlement. In these relationships, ground shaking can be represented by PGA and

1 magnitude, and soil compaction is typically measured by Standard Penetration Test (SPT) (i.e., an *in-*
2 *situ* dynamic penetration test that measures the density of granular soil) blow-counts or N-values.
3 Excessive total and differential settlements can cause damage to buried structures, including
4 utilities, which in turn may initiate larger failure to levees and other above-ground facilities.

5 **Loss of Bearing Capacity**

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

9 **Lateral Spreading**

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

15 **Increased Lateral Pressures**

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

18 **Buoyancy**

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

22 **Tsunami and Seiche**

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

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

37 Based on a tsunami wave runup of 20 feet at the Golden Gate, the 2009 (Contra Costa) Countywide
38 Comprehensive Transportation Plan indicates that tsunami attenuation in the San Francisco Bay
39 would diminish the height of the wave to approximately 10 feet along the Richmond shoreline. East

1 of Point Pinole, the wave height would diminish to approximately one-tenth of that (i.e., 2 feet) at
2 the Golden Gate (Contra Costa Transportation Agency 2009).

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

5 A seismically induced seiche is a rhythmic standing wave in a partly or fully enclosed body of water
6 caused by seismic waves generated by a landslide, earthquake-induced ground acceleration, or
7 ground offset. Elongate and deep (relative to width) bodies of water seem most likely to be subject
8 to seiches, and earthquake wave orientation may also play a role in seiche formation. The “sloshing”
9 waves generated can reach tens of feet high and have devastating effects on people and property.
10 Seiches can temporarily flood a shoreline in a manner similar to tsunami; however, their destructive
11 capacity is not as great. Seiches may cause overtopping of impoundments such as dams, particularly
12 when the impoundment is in a near-filled condition, releasing flow downstream. Earthquakes
13 occurring miles away can produce seiches in local bodies of water which could overtop and damage
14 levees and dams and cause water to inundate surroundings (Contra Costa County 2009). In 1868, an
15 earthquake along the Hayward fault in the San Francisco Bay Area generated a seiche along the
16 Sacramento River (County of Sacramento 1993).

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

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

25 **9.2 Regulatory Setting**

26 **9.2.1 Federal Plans, Policies, and Regulations**

27 **9.2.1.1 U.S. Geological Survey Quaternary Faults**

28 USGS maintains the database of Quaternary fault and fold parameters (U.S. Geological Survey 2008).
29 The database is periodically updated to reflect the latest data available and current understanding of
30 fault behaviors. These parameters were used to develop the National Seismic Hazard Maps.

31 **9.2.1.2 U.S. Geological Survey National Seismic Hazard Maps**

32 USGS provides probabilistic seismic hazard maps for the 48 conterminous states, including the
33 Delta and Suisun Marsh area (U.S. Geological Survey 2008). These maps depict contour plots of PGA
34 and spectral accelerations at selected frequencies for various ground motion return periods. The
35 USGS National Seismic Hazard Maps are updated periodically and have been adopted by many
36 building and highway codes as the minimum design requirements.

1 **9.2.1.3 U.S. Geological Survey Landslide Hazard Program**

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

5 **9.2.1.4 U.S. Army Corps of Engineers EC 1165-2-211**

6 In July 2009, USACE issued EC 1165-2-211, a water resource policy mandating that every USACE
 7 coastal activity influenced by tidal waters include potential relative sea level change in the starting
 8 water surface elevation, where appropriate. To conform, projects must determine how sensitive
 9 plans and designs are to rates of future local mean sea level change, how this sensitivity affects
 10 calculated risk, and what design or operations and maintenance measures should be implemented
 11 to minimize adverse consequences while maximizing beneficial effects.

12 The project is not a USACE activity subject to EC 1165-2-211; however, the project would include
 13 maintenance operations that would require placement of levee materials as necessary to maintain
 14 freeboard in response to actual sea level rise rates.

15 **9.2.2 State Plans, Policies, and Regulations**

16 **9.2.2.1 Delta Plan**

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

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

28 **9.2.2.2 California Division of Safety of Dams**

29 The DSOD has oversight and approval authority for structures that are considered dams under the
 30 Water Code. Some levees are “dams” as defined by California Water Code Section 6002, and as such,
 31 are required to meet DSOD’s standards and design review requirements. Dams under DSOD
 32 jurisdiction are artificial barriers that are at least 25 feet high or have an impounding capacity of at
 33 least 50 acre feet. Water Code Section 6004(c) specifically excludes structures in the Sacramento-
 34 San Joaquin Delta “...if the maximum possible water storage elevation of the impounded water does
 35 not exceed four feet above mean sea level, as established by the United States Geological Survey
 36 1929 Datum.”

37 Certain elements of various action alternatives could be subject to DSOD jurisdiction depending on
 38 the size and volume of water stored (i.e., the intermediate forebay, the Byron Tract Forebay, repairs
 39 or alterations to certain levees that might fall within DSOD jurisdiction).

1 **9.2.2.3 Liquefaction and Landslide Hazard Maps** 2 **(Seismic Hazards Mapping Act)**

3 The Seismic Hazards Mapping Act of 1990 (California Public Resources Code Sections 2690 to
4 2699.6) was passed following the Loma Prieta earthquake to reduce threats to public health and
5 safety by identifying and mapping known seismic hazard zones in California. The act directs the CGS
6 of the Department of Conservation to identify and map areas prone to earthquake hazards of
7 liquefaction, earthquake-induced landslides, and amplified ground shaking. The purpose of the maps
8 is to assist cities and counties in fulfilling their responsibilities for protecting public health and
9 safety. The Act requires site-specific geotechnical investigations be conducted identifying the
10 seismic hazard and formulating mitigation measures prior to permitting most developments
11 designed for human occupancy within areas prone to liquefaction and earthquake-induced
12 landslides (also known as a Zone of Required Investigation). Cities and counties are required to
13 incorporate the Seismic Hazard Zone Maps into their Safety Elements and the Act requires sellers of
14 real property to disclose to buyers if property is in a seismic hazard Zone of Required Investigation.

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

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

27 **9.2.2.4 Alquist-Priolo Earthquake Fault Zones**

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

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

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

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

5 **9.2.2.5 Assembly Bill 1200 (Chapter 573, Statutes of 2005)**

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

11 In response to the bill, DWR and the California Department of Fish and Wildlife have issued a report,
 12 Risks and Options to Reduce Risks to Fishery and Water Supply Uses of the Sacramento/San Joaquin
 13 Delta, dated January 2008. This report summarizes the potential risks to water supplies in the
 14 Sacramento and San Joaquin Delta attributable to future subsidence, earthquakes, floods and climate
 15 change, and identifies improvements to reduce the effects and options to deliver water.

16 **9.2.2.6 Regulatory Design Codes and Standards for Project Structures**

17 State and federal design codes and standards will regulate construction of the many structures that
 18 are part of the proposed project. These codes and standards establish minimum design and
 19 construction requirements, including design and construction of concrete and steel structures,
 20 levees, tunnels, pipelines, canals, buildings, bridges and pumping stations. They also establish
 21 construction requirements for temporary activities such as shoring of excavations and site grading.
 22 The codes and standards are intended to ensure structural integrity and to protect public health and
 23 safety. The codes and standards are developed by federal and state agencies with the participation
 24 of engineering boards or associations, and professional engineering societies. They are based on the
 25 performance history of structures under real conditions, including surface and subsurface geologic
 26 conditions and variable regional conditions such as flooding and seismic events. The following state
 27 and federal codes and standards will dictate the minimum design and construction requirements for
 28 the various elements of the water conveyance facilities and the structural aspects of other
 29 restoration actions. The minimum design and construction requirements act as performance
 30 standards for engineers and construction contractors. Because the design and construction
 31 parameters of these codes and standards are intended to reduce the potential for structural damage
 32 or risks to human health due to the geologic and seismic conditions that exist within the Plan Area
 33 and the surrounding region, their use is considered an environmental commitment of the agencies
 34 implementing the proposed project. This commitment is discussed further in Appendix 3B,
 35 *Environmental Commitments, AMMs, and CMs.*

- 36 ● American Association of State Highway and Transportation Officials (AASHTO) Guide
 37 Specifications for LRFD [load and resistance factor] Seismic Bridge Design, 1st Edition, 2009.
- 38 ○ Geotechnical seismic design guidelines are consistent with the philosophy for structure
 39 design that loss of life and serious injury due to structure collapse are minimized, to the
 40 extent possible and economically feasible.
- 41 ○ These guide specifications adopt:

- 1 • 7 percent probability of exceedance in 75 years (i.e., the same as 5 percent probability of
2 exceedance in 50 years and an approximately 1,000 year recurrence interval) for
3 development of a design spectrum.
- 4 • the NEHRP Site Classification system and include site factors in determining response
5 spectrum ordinates.
- 6 • a 1.5 safety factor (how much extra load beyond what is intended a structure will
7 actually take or be required to withstand) for minimum support length requirement to
8 ensure sufficient conservatism.
- 9 • American Railway Engineering and Maintenance-of-Way Association Manual for Railway
10 Engineering, Volume 2, Chapter 9, *Seismic Design for Railway Structures*, 2008.
- 11 ○ Provides recommended practices and guidelines for railway design in seismically active
12 areas as well as recommended practices for post-earthquake response, including
13 inspections.
- 14 ○ Three performance limit states are given for seismic design of railroad bridges.
- 15 • The serviceability limit state requires that the structure remain elastic during Level 1
16 ground motion (motion that has a reasonable probability of being exceeded during the
17 life of the bridge). Only moderate damage and no permanent deformations are
18 acceptable.
- 19 • The ultimate limit state requires that the structure suffer only readily detectable and
20 repairable damage during Level 2 ground motion (motion that has a low probability of
21 being exceeded during the life of the bridge).
- 22 • The survivability limit state requires that the bridge not collapse during Level 3 ground
23 motion (motion for a rare, intense earthquake). Extensive damage may be allowed. For
24 some structures, the railroad may elect to allow for irreparable damage, and plan to
25 replace the bridges following a Level 3 event.
- 26 ○ No seismic analysis is necessary for locations where a base acceleration of 0.1 g or less is
27 expected with a 475-year return period. However, it is good practice to detail structures for
28 seismic resistance if they are in potentially active areas.
- 29 ○ Structures classified as “important” (discussed in Section 1.3.3) should be designed to resist
30 higher seismic loads than nonimportant structures.
- 31 • American Society of Civil Engineers *Minimum Design Loads for Buildings and Other Structures*,
32 ASCE/SEI 7-10, 2010.
- 33 ○ Provides requirements for general structural design and includes means for determining
34 dead, live, soil, flood, wind, snow, rain, atmospheric ice, and earthquake loads, and their
35 combinations that are suitable for inclusion in building codes and other documents.
- 36 ○ The intent of the seismic provisions in ASCE/SEI 7-10 is to provide a low probability of
37 collapse for buildings experiencing the Maximum Considered Earthquake (MCE) shaking.
38 MCE shaking is defined either as that shaking having a 2% probability of exceedance in 50
39 years (2,475 year mean recurrence interval) or at sites near major active fault, 150% of the
40 median shaking resulting from a characteristic magnitude earthquake on that fault,
41 whichever is less.

- 1 ○ Nonstructural components (including architectural, mechanical, electrical, and plumbing
2 equipment) and their supports and attachments that are permanently attached to a
3 structure must be designed and constructed to resist the effects of the earthquakes motions
4 in accordance with the code.
- 5 ○ Provides Seismic Hazards Maps developed by USGS. Section 13.2.1 requires that mechanical
6 and electrical equipment manufacturers provide certification that components are
7 seismically qualified. Section 13.3.1 determines the magnitudes of horizontal and vertical
8 seismic forces. Use $I_p = 1.5$ for mechanical equipment and 1.75 for electrical equipment in
9 Occupancy Category IV for critical facilities as discussed in Section 4.3.5
- 10 ● California Building Standards Code, 2010 (Title 24 California Code of Regulations).
- 11 ○ Provides seismic design requirements in the design and construction of buildings,
12 associated facilities and equipment. This code applies to all building occupancies, and
13 related features and equipment throughout the state, and contains requirements to the
14 structural, mechanical, electrical, and plumbing systems, and requires measures for energy
15 conservation, green design, construction and maintenance, fire and life safety, and
16 accessibility.
- 17 ● Caltrans (California Department of Transportation) Seismic Design Criteria (SDC), Version 1.6,
18 Nov 2010.
- 19 ○ The SDC is a compilation of new and existing seismic design criteria for Ordinary bridges (a
20 bridge that spans less than 300 feet and is built on soil that is not susceptible to liquefaction,
21 lateral spreading, or scour. The document is an update of all the Structure Design (SD)
22 design manuals on a period basis to reflect the current state of practice for seismic bridge
23 design.
- 24 ● These specifications are meant to guarantee that an Ordinary bridge will remain
25 standing but may suffer significant damage requiring closure when ground shaking
26 (defined as ground motion time histories or response spectrum), liquefaction, lateral
27 spreading, surface fault rupture, and tsunami occur.
- 28 ● The criteria contained within the SDC are the minimum requirements for seismic design.
- 29 ● California Code of Regulations, Title 8.
- 30 ○ Section 3203 (Cal/OSHA Workplace Injury and Illness Prevention Program) states that a
31 workplace or construction site must devise and implement an Injury and Illness Prevention
32 Program (IIPP) for all employees within the organization. The 8 required IIPP elements are:
- 33 ● Responsibility (e.g., supervisors are responsible for all accidents on their job or under
34 their supervision, supervisors are responsible for the inspection of work areas,
35 equipment and other potential accident producing conditions daily, employees are
36 responsible for ensuring that machine guards are used and maintained in good
37 condition and reporting to the supervisor if a guard is in questionable condition, etc.)
- 38 ● Compliance (e.g., supervisors must take disciplinary action when necessary to enforce
39 safety rules and practices, etc.)
- 40 ● Communication (e.g., company policy to maintain open communication between
41 management and employees on matters pertaining to safety, company will provide

- 1 current safety news and activities, safety reading materials, signs, posters, and/or a
2 bulletin board and will hold regular safety meetings)
- 3 • Hazard Assessment (e.g., managers, supervisors, and employees will report any
4 hazardous conditions or activities noted as a result of a formal weekly and/or monthly
5 inspections or during daily routine operations to the appropriate job site foreman or
6 superintendent)
 - 7 • Accident/Exposure Investigation (e.g., each supervisor/foreman has a prominent role in
8 promptly conducting an accident investigation and must collect the facts, determine the
9 sequence of events that resulted in the accident, identify action to prevent recurrence,
10 and provide follow-up to ensure that corrective action was effective)
 - 11 • Hazard Correction (e.g., all hazards will be corrected as soon as identified and a record
12 of hazard abatement will be kept in the main office to track the steps taken to correct
13 the hazardous condition)
 - 14 • Training and Instruction (e.g., all new employees must undergo an initial orientation on
15 job site safety rules and code of safe work practices. All employees must participate in
16 scheduled safety meetings which are conducted weekly by the site foreman on all job
17 sites and additional training as job duties or work assignments are expanded or
18 changed)
 - 19 • Recordkeeping (e.g., hazard reports, employee-training records, etc. will be kept at the
20 main office)
- 21 ○ Section 1509 requires that every employer shall adopt a written Code of Safe Practices (8
22 CCR 1938, Appendix A) which related to the employer's operations. Also, supervisory
23 employees must conduct Toolbox or Tailgate safety meetings, or equivalent, with their
24 crews at least every 10 working days to emphasize safety.
 - 25 • DWR (California Department of Water Resources) Division of Safety of Dams (DSOD) *Guidelines*
26 *for Use of the Consequence-Hazard Matrix and Selection of Ground Motion Parameters*, 2002.
 - 27 ○ The loading criteria for jurisdictional dam facilities are determined using the DSOD criteria
28 as follows:
 - 29 • The statistical level of ground motion for design (50th- or 84th-percentile) is determined
30 from the DSOD Consequence-Hazard Matrix based upon the consequence of failure
31 (Total Class Weight obtained from DSOD) and the slip rate of the causative fault
32 (obtained from a Seismic Hazard Assessment).
 - 33 • The Minimum Earthquake PGA parameter of 0.15g to 0.25g now applies to all new and
34 existing jurisdictional dams undergoing re-evaluation in California (new and existing
35 dams undergoing re-evaluation must resist a horizontal force of 0.15g to 0.25g).
 - 36 • DWR Division of Flood Management *FloodSAFE Urban Levee Design Criteria*, May 2012.
 - 37 ○ Provides engineering criteria and guidance for the design, evaluation, operation, and
38 maintenance of levees and floodwalls that provide an urban level of flood protection (i.e.,
39 200-year level of flood protection) in California, as well as for determining design water
40 surface elevations (DWSE) along leveed and unleveed streams. Flood Safety Plan is required
41 for all agencies working at or near levee

- 1 ○ Requires analysis of seismic vulnerability of the levee system for 200-year return period
2 ground motions to meet the urban level of flood protection.
- 3 ○ Frequently loaded levees (and floodwalls), such as many levees in the Sacramento-San
4 Joaquin Delta, are required to have seismic stability sufficient to maintain the integrity of the
5 levee and its internal structures without significant deformation. In most cases, for
6 frequently loaded levees with less than 5 feet of freeboard, earthquake-induced
7 deformations should be limited to less than 3 feet of total deformation and about 1 foot of
8 vertical displacement.
- 9 ○ For intermittently loaded levees (and floodwalls), if seismic damage from 200-year-return-
10 period ground motions is expected after the urban level of flood protection is achieved, a
11 post-earthquake remediation plan is required as part of a flood safety plan that is developed
12 in coordination with pertinent local, State, and federal agencies.
- 13 ● DWR Division of Engineering *State Water Project—Seismic Loading Criteria Report*, September
14 2012.
- 15 ○ Provides DWR design guidelines in selecting appropriate seismic loading criteria for a wide
16 variety of SWP facilities including dams, canals, pipelines, tunnels, check structures, bridges,
17 buildings, pumping and power plants, and utility overcrossings. The seismic design load
18 shall be selected based on the criticality of a facility and consequences of failure. Most
19 critical facilities are expected to be functional immediately after an earthquake and thereby
20 should experience very limited damage. Other facilities may be considered less critical such
21 that they are designed to incur some damage but still return to some level of function in a
22 specified timeframe.
- 23 ● DWR *Delta Seismic Design*, June 2012.
- 24 ○ This report serves to provide literature search of Delta specific design criteria and
25 application of load to structures. It's a compilation of existing state of practice for the
26 seismic design of the type of hydraulic structures as well as recommended guidelines for
27 design criteria associated with future hydraulic structures in the Delta.
- 28 ● Federal Highway Administration *Seismic Retrofitting Manual for Highway Structures*, Parts 1
29 and 2, 2006.
- 30 ○ The manual recommends a performance-based methodology for retrofitting highway
31 bridges. It defines different performance expectations for bridges of varying importance
32 while subject to four different levels of seismic hazard. The manual goes on and provides
33 more details for defining minimal, significant, and sustained damages. It is worth noting that
34 the performance levels are varying with level of earthquake ground motion, bridge
35 importance and anticipated service life (ASL). Two ground motion levels (lower level – 100
36 year return period and upper level – 975 year return period), two importance classifications
37 (Standard and Essential), and three service life categories (ASL 1, 2, and 3) are defined.
- 38 ○ Minimum performance levels for retrofitted bridges:

	Bridge Importance and Service Life Category					
	Standard			Essential		
Earthquake Ground Motion	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

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”

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- State of California Sea-Level Rise Task Force of the Coastal and Ocean Working Group of the California Climate Action Team (CO-CAT), Sea-Level Rise Interim Guidance Document, 2010.
 - This document provides guidance for incorporating sea level rise projections into planning and decision making for projects in California. Using Year 2000 as a baseline, the sea level rise projections in California range between 10 and 17 inches by year 2050 and between 18 and 29 inches by year 2070.
 - Underestimating sea level rise in the project design will result in harmful realized impacts such as flooding. Harmful impacts are more likely to occur if the project design is based upon a low projection of sea level rise and less likely if higher estimates of sea level rise are used. In situations with high consequences (high impacts and/or low adaptive capacity), using a low sea level rise value involves a higher degree of risk. (Examples of harmful impacts that might result from underestimating sea level rise include damage to infrastructure, contamination of water supplies due to saltwater intrusion, and inundation of marsh restoration projects located too low relative to the tides).

- 1 ○ As of the date of the guidance document, the State Coastal Conservancy (SCC) and the State
2 Lands Commission (SLC) have adopted, and the Delta Vision Blue Ribbon Task Force
3 Independent Science Board has recommended, the use of 55 inches (140 cm) of sea level
4 rise for 2100. The SCC and the SLC also adopted a policy of using 16 inches (41 cm) as the
5 estimate of sea level rise for 2050. Agencies may select other values depending on their
6 particular guiding policies and considerations related to risk, ability to incorporate phased
7 adaptation into design and other factors.
- 8 ● USACE (CESPK-ED-G), *Geotechnical Levee Practice*, SOP EDG-03, 2004.
- 9 ○ This procedure covers the geotechnical practice for levee evaluation, analysis, design,
10 construction and maintenance of levees in accordance with Sacramento District and USACE
11 guidance and regulation. Sacramento District standard practice may differ from published
12 USACE guidance.
- 13 ○ Standard Levee Geometry – The minimum levee section should have a 3H:1V waterside
14 slope, a minimum 20 ft. wide crown for main line levees, major tributary levees, and bypass
15 levees, a minimum 12 ft. wide crown for minor tributary levees, a 3H:1V landside slope, a
16 minimum 20 ft. wide landside easement, and a minimum 15 ft. waterside easement. Existing
17 levees with landside slopes as steep as 2H:1V may be used in rehabilitation projects if
18 landside slope performance has been good. Easements are necessary for maintenance,
19 inspection, and floodfight access.
- 20 ○ Typically a seepage berm should be designed as a semipervious berm with a drainage layer.
21 Seepage berms should have a minimum width of 4 times the maximum levee height in a
22 reach. The maximum seepage berm width should typically be 300 ft. A seepage berm will
23 typically vary from about 5 ft. thick at the levee toe to about 3 ft. thick at the berm toe.
- 24 ● USACE *Design and Construction of Levees*, EM 1110-2-1913, 2000.
- 25 ○ This document provides guidelines or methodology for the design and construction of earth
26 levees.
- 27 ○ The manual is general in nature and not intended to supplant the judgment of the design
28 engineer on a particular project.
- 29 ● USACE *Engineering and Design—Earthquake Design and Evaluation for Civil Works Projects*,
30 ER 1110-2-1806, 1995.
- 31 ○ The manual provides guidance in evaluating and assessing the ground motions, site
32 characterization, structural response, functional consequences, and potential hazards in the
33 design and construction of Civil Work projects including dams and levees.
- 34 ○ The seismic design for new projects and the seismic evaluation or reevaluation for existing
35 projects should be accomplished in accordance with this regulation. This regulation applies
36 to all projects which have the potential to malfunction or fail during major seismic events
37 and cause hazardous conditions related to loss of human life, appreciable property damage,
38 disruption of lifeline services, or unacceptable environmental consequences. The scope of
39 each seismic study should be aimed at assessing the ground motions, site characterization,
40 structural response, functional consequences, and potential hazards in a consistent, well-
41 integrated, and cost-effective effort that will provide a high degree of confidence in the final
42 conclusions.

- 1 ○ Survival of operating equipment and utility lines is as essential as survival of the structural
2 and geotechnical features of the project.
- 3 ● USACE *Engineering and Design – Earthquake Design and Evaluation of Concrete Hydraulic*
4 *Structures*, EM 1110-2-6053, 2007.
- 5 ○ This manual provides guidance for performance-based design and evaluation of concrete
6 hydraulic structures (CHS). It introduces procedures that show how to design or evaluate a
7 hydraulic structure to have a predictable performance for specified levels of seismic hazard.
8 Traditional design and evaluation procedures may still be used for feasibility and screening
9 purposes. However, for critical facilities, they should be followed by the procedures of this
10 manual to prevent sudden collapse even though the structure may suffer severe damage, to
11 limit damage to a repairable level, or to maintain functionality immediately after the
12 earthquake.
- 13 ○ This manual contains mandatory requirements at the end of each chapter. These
14 requirements usually pertain to critical elements of the design and evaluation, such as loads
15 and load combinations, to analytical procedures used to determine force and displacement
16 demands, and to methods used to determine member strength and displacement capacities.
17 The purpose of the mandatory requirements is to assure that the structure meets minimum
18 safety and performance objectives.
- 19 ○ Performance requirements for stability shall be in accordance with EM 1110-2-2100,
20 *Stability Analysis of Concrete Structures*.
- 21 ● USACE *Engineering and Design—General Design and Construction Considerations for Earth and*
22 *Rock-Fill Dams*, EM 1110-2-2300, 2004.
- 23 ○ This manual provides guidance on the design and construction, and performance
24 monitoring of and modifications to embankment dams. The manual presents general
25 guidance and is not intended to supplant the creative thinking and judgment of the designer
26 for a particular project.
- 27 ○ To meet the dam safety requirements, the design, construction, operation, and modification
28 of an embankment dam must comply with the following technical and administrative
29 requirements:
- 30 ● Technical requirements
- 31 ○ The dam, foundation, and abutments must be stable under all static and dynamic
32 loading conditions
- 33 ○ Seepage through the foundation, abutments, and embankment must be controlled
34 and collected to ensure safe operation. The intent is to prevent excessive uplift
35 pressures, piping of materials, sloughing, removal of material by solution, or erosion
36 of this material into cracks, joints, and cavities. In addition, the project purpose may
37 impose a limitation on allowable quantity of seepage. The design should include
38 seepage control measures such a foundation cutoffs, adequate and nonbrittle
39 impervious zones, transition zones, drainage material and blankets, upstream
40 impervious blankets, adequate core contact area, and relief wells.
- 41 ○ The freeboard must be sufficient to prevent overtopping by waves and include an
42 allowance for settlement of the foundation and embankment.

- 1 ○ The spillway and outlet capacity must be sufficient to prevent over-topping of the
2 embankment by the reservoir.
- 3 ● Administrative requirements
- 4 ○ Environmental responsibility
- 5 ○ Operation and maintenance manual
- 6 ○ Monitoring and surveillance plan
- 7 ○ Adequate instrumentation to monitor performance
- 8 ○ Documentation of all the design, construction, and operational records
- 9 ○ Emergency Action Plan: Identification, notification, and response subplan
- 10 ○ Schedule for periodic inspections, comprehensive review, evaluation, and
11 modifications as appropriate.
- 12 ○ The following criteria must be met to ensure satisfactory earth and rock-fill structures:
- 13 ● Technical requirements
- 14 ○ The embankment, foundation, and abutments must be stable under all conditions of
15 construction and reservoir operation including seismic loading conditions.
- 16 ○ Seepage through the embankment, foundation and abutments must be controlled
17 and collected to prevent excessive uplift pressures, piping, sloughing, removal of
18 material by solution, or erosion of this material into cracks, joints, and cavities. In
19 addition, the project purpose may impose a limitation on allowable quantity of
20 seepage. The design should include seepage control measures such a foundation
21 cutoffs, adequate and nonbrittle impervious zones, transition zones, drainage
22 blankets, upstream impervious blankets, and relief wells.
- 23 ○ The freeboard must be sufficient to prevent overtopping by waves and include an
24 allowance for settlement of the foundation and embankment as well as for seismic
25 effects where applicable.
- 26 ○ The spillway and outlet capacity must be sufficient to prevent over-topping of the
27 embankment.
- 28 ● USACE *Engineering and Design—Response Spectra and Seismic Analysis for Concrete Hydraulic*
29 *Structures*, EM 1110-2-6050, 1999.
- 30 ○ This manual describes the development and use of response spectra for the seismic analysis
31 of concrete hydraulic structures. The manual provides guidance regarding how earthquake
32 ground motions are characterized as design response spectra and how they are then used in
33 the process of seismic structural analysis and design. The manual is intended to be an
34 introduction to the seismic analysis of concrete hydraulic structures.
- 35 ○ The design and evaluation of hydraulic structures for earthquake loading must be based on
36 appropriate criteria that reflect both the desired level of safety and the nature of the design
37 and evaluation procedures (ER 1110-2-1806). The first requirement is to establish
38 earthquake ground motions to be used as the seismic input by considering safety,
39 economics, and the designated operational functions. The second involves evaluating the

- 1 earthquake performance of the structure to this input by performing a linear elastic
 2 dynamic analysis based on a realistic idealization of the structure, foundation, and water.
- 3 • For an operating basis earthquake (OBE) that can reasonably be expected to occur
 4 within the service life of the project (that is, with a 50 percent probability of exceedance
 5 during the service life), structures located in regions of high seismicity should
 6 essentially respond elastically to the event with no disruption to services, but limited
 7 localized damage is permissible and should be repairable. In such cases, a low to
 8 moderate level of damage can be expected.
 - 9 • For a maximum design earthquake (MDE) which is a maximum level of ground motion
 10 for which a structure is designed or evaluated, the associated performance requirement
 11 is the that the project performs without catastrophic failure, such as uncontrolled
 12 release of a reservoir, although severe damage or economic loss may be tolerated. The
 13 damage during an MDE event could be substantial, but should not be catastrophic in
 14 terms of loss of life, economics, and social and environmental impacts.
 - 15 • For critical structures (structures of high downstream hazard whose failure during or
 16 immediately following an earthquake could result in loss of life), the MDE is set equal to
 17 the MCE (the greatest earthquake that can reasonably be expected to be generated by a
 18 specific source on the basis of seismological and geological evidence). For other than
 19 critical structures, the MDE is selected as a lesser earthquake than the MCE.
 - 20 • USACE *Engineering and Design—Stability Analysis of Concrete Structures*, EM 1110-2-2100, 2005.
 - 21 ○ This manual establishes and standardizes stability criteria for use in the design and
 22 evaluation of the many various types of concrete structures common to USACE civil works
 23 projects. As used in this manual, the term “stability” applies to external global stability
 24 (sliding, rotation, flotation and bearing), not to internal stability failures such as sliding on
 25 lift surfaces or exceedance of allowable material strengths. The manual prescribes the safety
 26 factors, which govern stability requirements for the structure for various load combinations.
 - 27 • USACE *Engineering and Design—Structural Design and Evaluation of Outlet Works*,
 28 EM 1110-2-2400, 2003.
 - 29 ○ This manual provides guidance for the planning and structural design and analysis of intake
 30 structures and other outlet works features used on USACE projects for the purpose of flood
 31 control, water supply, water quality and temperature control, recreation, or hydropower.
 - 32 ○ The following are minimum required safety factors for seismic sliding analysis:
 - 33 • OBE = 1.7 for critical structures, and 1.3 for other structures
 - 34 • MDE = 1.3 for critical structures, and 1.1 for other structures
 - 35 ○ The associated performance level with the OBE is the requirement that the structure will
 36 function within the elastic range with little or no damage and without interruption of
 37 function.
 - 38 ○ The MDE is the maximum level of ground motion for which the structure is designed or
 39 evaluated. The tower may be damaged but retains its integrity. The purpose of the MDE is to
 40 protect against economic losses from damage or loss of services. Ordinarily the MDE is
 41 defined for intake towers as a ground motion having a 10 percent probability of exceedance
 42 during the service life of 100 years.

- 1 ● USACE *Engineering and Design—Structural Design and Evaluation of Outlet Works*, EM 1110-2-
2 2400, 2003.
- 3 ○ This manual provides guidance for the planning and structural design and analysis of intake
4 structures and other outlet works features used on USACE projects for the purpose of flood
5 control, water supply, water quality and temperature control, recreation, or hydropower.
- 6 ○ Seismic design for new towers and the evaluation of existing towers must demonstrate that
7 the tower has adequate strength, ductility, and stability to resist the specified earthquake
8 ground motions. The ultimate strength or capacity of new and existing towers will be
9 determined using the principles and procedures described in EM 1110-2-2104. Capacities
10 are based on ultimate strength, or the nominal strength multiplied by a capacity reduction
11 factor. Intake tower sections shall have the strength to resist load combinations involving
12 dead load, live load, and earthquake load.
- 13 ● USACE *Engineering and Design—Time-History Dynamic Analysis of Concrete Hydraulic Structures*,
14 EM 1110-2-6051, 2003.
- 15 ○ This manual describes the procedures for the linear-elastic time-history dynamic analysis and
16 development of acceleration time-histories for seismic design and evaluation of concrete
17 hydraulic structures. It provides guidance on the formulation and performance of the linear-
18 elastic time-history dynamic analyses and how the earthquake input time-histories are
19 developed and applied.
- 20 ○ Design and safety evaluation earthquakes for concrete hydraulic structures are the OBE and
21 the MDE as required by ER 1110-2-1806.
- 22 ● The OBE is defined in ER 1110-2-1806 as an earthquake that can reasonably be expected
23 to occur within the service life of the project, that is, with a 50 percent probability of
24 exceedance during the service life. The associated performance requirement is that the
25 project function with little or no damage, and without interruption of function. The
26 purpose of the OBE is to protect against economic losses from damage or loss of service.
- 27 ● The MDE is defined in ER 1110-2-1806 as the maximum level of ground motion for which
28 a structure is designed or evaluated. The associated performance requirement is that the
29 project performs without catastrophic failure, such as uncontrolled release of a reservoir,
30 although severe damage or economic loss may be tolerated.
- 31 ● For critical structures, ER 1110-2-1806 requires the MDE to be set equal to the MCE.
32 Critical structures are defined as structures whose failure during or immediately following
33 an earthquake could result in loss of life. The MCE is defined as the greatest earthquake
34 that can reasonably be expected to be generated by a specific source on the basis of
35 seismological and geological evidence (ER 1110-2-1806)
- 36 ● For other than critical structures the MDE is selected as a less severe earthquake than the
37 MCE, which provides for an economical design meeting specified safety standards. In
38 these cases, the MDE is defined as that level of ground motion having as a minimum a 10
39 percent probability in exceedance in 100 years.
- 40 ● USACE *Slope Stability*, EM 1110-2-1902, 2003.
- 41 ○ This engineer manual (EM) provides guidance for analyzing the static stability of slopes of
42 earth and rock-fill dams, slopes of other types of embankments, excavated slopes, and
43 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 pile behavior during installation. The understanding of pile foundation behavior is actively expanding by ongoing research, prototype, model pile, and pile group testing and development of more refined analytical models. However, this manual is intended to provide examples and procedures of proven technology. This manual will be updated as changes in design and installation procedures are developed.
 - The pile foundation must perform as designed for the life of the structure. Performance can be described in terms of structural displacements which may be just as harmful to a structure as an actual pile failure. The load capacity should not degrade over time due to deterioration of the pile material.
 - For most hydraulic structures, designers should have a high level of confidence in the soil and pile parameters and the analysis. Therefore, uncertainty in the analysis and design parameters should be minimized rather than requiring a high factor of safety. For less significant structures, it is permissible to use larger factors of safety if it is not economical to reduce the uncertainty in the analysis and design by performing additional studies, testing, etc. Also factors of safety must be selected to assure satisfactory performance for service

- 1 conditions. Failure of critical components to perform as expected can be as detrimental as
 2 an actual collapse.
- 3 ○ It is normal to apply safety factors to the ultimate load predicted. In general, safety factors
 4 for 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.

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

9.3 Environmental Consequences

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

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

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

Potential adverse effects associated with near-surface soils, including erosion; subsidence caused by oxidation of organic matter; and expansive, corrosive, and compressible soils, are assessed in Chapter 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

1 structures being proposed and because changed operations upstream and within the water user
 2 service areas do not increase geologic or seismic hazards in those areas. Both quantitative and
 3 qualitative methods were used to evaluate these effects, depending on the availability of data.
 4 Conservation and restoration activities were evaluated on a programmatic level using qualitative
 5 methods to estimate potential effects.

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

- 9 • *Conceptual Engineering Report—Isolated Conveyance Facility—All Tunnel Option* (California
 10 Department of Water Resources 2010a).
- 11 • *Conceptual Engineering Report—Isolated Conveyance Facility—Pipeline/Tunnel Option—*
 12 *Addendum* (California Department of Water Resources 2010b).
- 13 • *Conceptual Engineering Report—Isolated Conveyance Facility—East Option* (California
 14 Department of Water Resources 2009a).
- 15 • *Conceptual Engineering Report—Isolated Conveyance Facility—East Option—Addendum*
 16 (California Department of Water Resources 2010c).
- 17 • *Conceptual Engineering Report—Isolated Conveyance Facility—West Option* (California
 18 Department of Water Resources 2009b).
- 19 • *Conceptual Engineering Report—Isolated Conveyance Facility—West Option—Addendum*
 20 (California Department of Water Resources 2010d).
- 21 • *Conceptual Engineering Report—Dual Conveyance Facility Modified Pipeline/Tunnel Option —*
 22 *Clifton Court Forebay Pumping Plant (MPTO/CCO), Volume 1.* (California Department of Water
 23 Resources 2015)
- 24 • *Option Description Report—Separate Corridors Option* (California Department of Water
 25 Resources 2010e).
- 26 • *Draft Phase II Geotechnical Investigation—Geotechnical Data Report—Pipeline/Tunnel Option*
 27 (California Department of Water Resources 2011).
- 28 • *Draft Phase I Geotechnical Investigation—Geotechnical Data Report—Isolated Conveyance Facility*
 29 *West* (California Department of Water Resources 2010g).
- 30 • *Draft Phase I Geotechnical Investigation—Geotechnical Data Report—Isolated Conveyance Facility*
 31 *East* (California Department of Water Resources 2010h).

32 Other study results and applicable maps and information published by various regulatory agencies,
 33 researchers and consultants were also used (e.g., California Department of Water Resources 1992;
 34 CALFED Bay-Delta Program 2000; California Department of Water Resources and California
 35 Department of Fish and Wildlife 2008, Shlemon and Begg 1975; Fugro Consultants 2011). The
 36 emphasis in the impact analysis has been to identify where the existing data suggest that geologic or
 37 seismic conditions pose a potentially serious threat to structural integrity. The analysis determines
 38 whether these conditions and associated risk can be reduced to less than significant by conformance
 39 with existing codes, standards and the application of accepted, proven construction engineering
 40 practices. A range of specific design and construction approaches are normally available to address a
 41 specific circumstance. For example, the potential for liquefaction to affect structural integrity could

1 be controlled using a range of engineering approaches, such as by removal and replacement of the
 2 liquefiable soil with engineered fill and construction of the structure on pilings founded on non-
 3 liquefiable material. Specific control measures have not been developed for all site conditions at this
 4 point in the BDCP/California WaterFix planning process. Regardless of the control method used, the
 5 same stability criteria must be met to conform to code and standards requirements. Design solutions
 6 would be guided by relevant building codes and state and federal standards for constructing
 7 foundations, bridges, tunnels, earthworks, and all other project facilities, listed in Section 9.2.2.6,
 8 *Regulatory Design Codes and Standards for Project Structures*. This evaluation process is described in
 9 more detail below in Section 9.3.1.1. Methodologies for evaluating specific geologic and seismic
 10 hazards are further defined in Section 9.3.1.3, *Evaluation of Operations*.

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

15 **9.3.1.1 Process and Methods of Review for Geologic and Seismic** 16 **Hazards**

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

23 As the proposed project has been developed by DWR in anticipation of agency and public review
 24 through the CEQA/NEPA processes, the agency has developed geologic and geotechnical information
 25 for all of the conveyance alignment alternatives. This information has been developed under the
 26 supervision of professional engineers and documented in the geotechnical data reports prepared by
 27 DWR for the project. As is appropriate for a project of this scale, these documents show project and
 28 alternative feasibility by identifying site geotechnical conditions along with associated constraints
 29 and opportunities. The geology and seismicity analyses in this chapter include review of the
 30 geotechnical data reports and other existing reports and data to determine whether significant risks
 31 might occur from implementing the proposed project.

32 Seismic and geologic hazards are determined to be adverse under NEPA or significant under CEQA if
 33 their related effects pose a substantial risk of damage to structures or pose a substantial human
 34 health threat. The criteria used to evaluate significance do not require the elimination of the
 35 potential for structural damage from the site's geologic and seismic conditions. Rather, the criteria
 36 require evaluation of whether site conditions can be overcome through engineering design solutions
 37 that reduce the substantial risk to people and structures. The codes and design standards referred to
 38 above ensure that buildings and structures are designed and constructed so that, while they may
 39 sustain damage during a major earthquake, the substantial risk of loss of property, personal injury
 40 or death due to structure failure or collapse is reduced. The CEQA/NEPA evaluation considers
 41 whether conformance with existing codes and standards, and application of accepted, proven
 42 construction engineering practices, would reduce the substantial risk to people and structures.

1 Configuration of the proposed action alternatives will be determined when the CEQA/NEPA review
2 is completed. Development of final-level design and inclusion of more detailed information would
3 not be likely to substantially modify any CEQA/NEPA conclusions. After CEQA/NEPA document
4 certification, the final design of structures will be developed; this will require additional subsurface
5 geotechnical investigations to identify very localized conditions that must be reflected in the final
6 engineering design. DWR has developed a Draft Geotechnical Exploration Plan (Phase 2) for the
7 Alternative 4 conveyance alignment (MPTO), which will support the final engineering design. The
8 Geotechnical Exploration Plan provides additional details regarding the rationale, investigation
9 methods and locations, and criteria for obtaining subsurface soil information and laboratory test
10 data (California Department of Water Resources 2014). The proposed exploration is designed as a
11 two-part program (Phases 2a and 2b) to collect geotechnical data. The two-part program will allow
12 refinement of the second part of the program (Phase 2b) to respond to findings from the first part
13 (Phase 2a). The proposed subsurface exploration will focus on geotechnical considerations of the
14 following aspects of water conveyance facility development: engineering considerations,
15 construction-related considerations, permitting and regulatory requirements, and seismic
16 characterization considerations. These geotechnical investigation will characterize, log, and test
17 soils and bedrock at selected construction sites to further refine anticipated site responses to
18 seismic activity and the various loads created by structures. They will also refine the design
19 parameters that must be met. The geotechnical investigations and their recommendations will be
20 presented in a report that is reviewed and approved by a California-registered civil engineer or a
21 certified engineering geologist who is competent in the field of seismic hazard evaluation and
22 mitigation. The requirements for evaluating seismic hazards other than surface fault rupture and for
23 recommending mitigation measures that the California-registered civil engineer or certified
24 engineering geologist or geologist must follow are specified in *Guidelines for Evaluating and*
25 *Mitigating Seismic Hazards in California* (California Geological Survey 2008). The project proponents
26 have made an environmental commitment that final design of all constructed components will meet
27 the standards listed in Section 9.2.2.6, *Regulatory Design Codes and Standards for Project Structures*
28 and contained in Appendix 3B, *Environmental Commitments, AMMs, and CMs*. The constructed
29 components may include canals, tunnels, intake structures, pipelines, transmission lines, levees,
30 temporary and permanent access roads, bridges, borrow areas, and spoils storage sites.

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

43 **9.3.1.2 Evaluation of Construction Activities**

44 Construction activities for the water conveyance facilities as they are currently defined, were
45 evaluated on a project level for potential effects relating to existing geologic hazards and to conform

1 to federal and state regulations and guidance pertaining to geologic hazard mitigation. Construction
 2 activities in the ROAs were evaluated on a programmatic level for potential effects relating to
 3 existing geologic hazards. These effects will need to be discussed in greater detail in subsequent
 4 project-level environmental documentation after specific restoration activities are finalized.

5 Geologic and seismic analysis of construction-related effects included these methodologies and
 6 approaches.

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

21 **Surface Fault Rupture**

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

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

34 **Earthquake Ground Shaking**

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

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

8 **Liquefaction**

9 Regional variations in the seismic vulnerability of existing levees in the Delta and Suisun Marsh to
10 failure caused by seismic shaking alone and by seismically induced liquefaction were assessed based
11 on two Delta Risk Management Strategy reports (California Department of Water Resources 2008a,
12 b). See the *Liquefaction* section under Section 9.1.1.4, *Geological and Seismic Hazards*, for a more
13 detailed discussion.

14 Liquefaction hazard for specific conveyance facility locations was assessed using the available soil
15 data from the CERs. The assessment was performed primarily through correlations with basic soil
16 characteristics (soil type, water content, depositional environment, and age). For areas where
17 adequate soil engineering data were not available, additional analyses were performed, including
18 assessments based on SPT sampler penetration blow-counts (SPT blow-counts), Cone Penetration
19 Test (CPT) measurements, and shear-wave velocity of the soil. The liquefaction analysis (for areas
20 where adequate soil engineering data were available) was performed for earthquake ground
21 motions with return periods of 475 years and 975 years, corresponding to 10% and 5%
22 probabilities of being exceeded in 50 years, respectively. The controlling earthquake magnitudes
23 were determined from the results of the seismic study (California Department of Water Resources
24 2007a) and/or the U.S. Geological Survey National Seismic Hazard Mapping Program.

25 **Ground Failure and Seismic-Induced Soil Instability**

26 **Compaction and Settlement**

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

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

34 **Loss of Bearing Capacity**

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

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

4 **Lateral Spreading**

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

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

11 **Increased Lateral Soil Pressure**

12 When soil liquefies, it behaves as a heavy liquid and may induce increased soil lateral pressure to
13 walls or buried pipes and tunnels. The increased soil lateral pressure was estimated using liquefied
14 soil unit weight, which is roughly twice the unit weight of water. Even when a soil does not liquefy
15 during a seismic event, lateral earth pressures will increase mainly because of inertia earthquake
16 forces.

17 **Buoyancy**

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

21 **Slope Instability**

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

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

31 **Soft, Loose, and Compressible Soils**

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

36 **Seismic-Induced Seiche and Tsunami**

37 The basis for determining the hazard for seismically induced seiche and tsunami is discussed
38 Section 9.1.1.3, *Regional and Local Seismicity*.

1 **9.3.1.3 Evaluation of Operations**

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

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

9 **9.3.2 Determination of Effects**

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

- 15 • Earthquake fault rupture.
- 16 • Strong seismic ground shaking.
- 17 • Liquefaction.
- 18 • Seismic-related ground failure.
- 19 • Slope instability (landslides).
- 20 • Soft, loose and compressible soils.
- 21 • Seiche, tsunami, or mudflow.

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

27 **9.3.2.1 Compatibility with Plans and Policies**

28 Constructing the proposed water conveyance facility and implementing CM2–CM21, or
29 Environmental Commitments 3, 4, 6-12, 15 and 16 under the non-HCP alternatives, could potentially
30 result in incompatibilities with plans and policies related to geologic/seismic hazards. Section 9.2,
31 *Regulatory Setting*, provides an overview of federal, state, regional and agency-specific plans and
32 policies applicable to seismic safety and levee stability. This section summarizes ways in which the
33 proposed project is compatible or incompatible with those plans and policies. Potential
34 incompatibilities with local plans or policies do not necessarily translate into adverse environmental
35 effects under NEPA or CEQA. Even where an incompatibility “on paper” exists, it does not by itself
36 constitute an adverse physical effect on the environment, but rather may indicate the potential for a
37 proposed activity to have a physical effect on the environment. The relationship between plans,
38 policies, and regulations and impacts on the physical environment is discussed in Chapter 13, *Land*
39 *Use*, Section 13.2.3.

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

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

32 **9.3.3 Effects and Mitigation Approaches**

33 **9.3.3.1 No Action Alternative**

34 The No Action Alternative is the future condition at 2060 that would occur if none of the action
 35 alternatives were approved and if no change from current management direction or the level of
 36 management intensity of existing programs by federal, state, and local agencies occurred. The No
 37 Action Alternative considers changes in risk from geology and seismicity that would take place as a
 38 result of the continuation of existing plans, policies, and operations, as described in Chapter 3,
 39 *Description of Alternatives*. The No Action Alternative includes projects and programs with defined
 40 management or operational plans, including facilities under construction as of February 13, 2009,
 41 because those actions would be consistent with the continuation of existing management direction
 42 or level of management for plans, policies, and operations by the project proponents and other
 43 agencies. The No Action Alternative assumptions also include projects and programs that are

1 permitted or are assumed to be constructed by 2060. The No Action Alternative would result in the
2 following effects on geology and seismicity.

3 **Earthquake-Induced Ground Shaking, Liquefaction, and Slope Instability**

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

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

15 The current hazard of earthquake-induced slope instability (e.g., levee failure) triggered by regional
16 and local faults would continue under the No Action Alternative. Slope instability associated with
17 non-engineered levees would continue to present a risk of levee failure and subsequent flooding of
18 Delta islands. Ongoing and reasonably foreseeable future projects in parts of the Delta are expected
19 to upgrade the levees to a “flood-safe” condition under the 100-year return flood elevation.
20 However, these projects would provide very little levee foundation strengthening and
21 improvements directed at improving the stability of the levees to better withstand ground shaking,
22 liquefaction, and slope instability.

23 **Tsunami and Seiche**

24 Under the No Action Alternative, it is anticipated that the current hazard resulting from tsunami and
25 seismically induced seiche on Delta and Suisun Marsh levees would continue. As reported above, the
26 hazard of a substantial tsunami affecting the Delta and the Suisun Marsh appears to be minor
27 because of their distance from the Pacific Ocean and the attenuating effect of San Francisco and
28 Suisun bays. With respect to the hazard of a seiche, the existing water bodies in the Delta and Suisun
29 Marsh tend to be wide and shallow. This geometry and distance to seismic sources generally are not
30 conducive to the occurrence of a substantial seismically induced seiche, as described in Section
31 9.1.1.3, *Regional and Local Seismicity*. However, because of its proximity to the potentially active
32 West Tracy fault, there is a potential hazard for a seiche to occur in the Clifton Court Forebay (Fugro
33 Consultants 2011).

34 **Ongoing Plans, Policies, and Programs**

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

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

6 **Climate Change and Catastrophic Seismic Risks**

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

17 **CEQA Conclusion:** In total, the plans and programs would result in a beneficial effect on an
 18 undetermined extent of levees in the Delta. Under the No Action Alternative, these plans, policies,
 19 and programs would be deemed to have an indirect and beneficial effect upon the potential hazard
 20 of tsunami and seiche in the Delta. These plans and programs, however, would not decrease the
 21 risks associated with climate change or a catastrophic seismic event, as discussed above and more
 22 thoroughly in Appendix 3E, *Seismic and Climate Change Risks to SWP/CVP Water Supplies*. Given that
 23 construction and operation of any new water facilities and habitat restoration would be undertaken
 24 following appropriate state codes and standards, there would be no impact of the No Action
 25 Alternative related to geology and seismicity (i.e., Impacts GEO-1 to GEO-15).

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

Agency	Program/Project	Status	Description of Program/Project	Effects on Geology and Seismicity
U.S. Army Corps of Engineers	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.
California Department of Water Resources	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 U.S. Army Corps of Engineers	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.

Agency	Program/Project	Status	Description of Program/Project	Effects on Geology and Seismicity
California Department of Water Resources	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.
California Department of Water Resources	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.
California Department of Water Resources	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.
Sacramento Area Flood Control Agency, Central Valley Flood Protection Board, U.S. Army Corps of Engineers	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.

1

2 **9.3.3.2 Alternative 1A—Dual Conveyance with Pipeline/Tunnel and** 3 **Intakes 1–5 (15,000 cfs; Operational Scenario A)**

4 **Impact GEO-1: Loss of Property, Personal Injury, or Death from Structural Failure Resulting** 5 **from Strong Seismic Shaking of Water Conveyance Features during Construction**

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

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

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

9 **Table 9-14. Expected Earthquake Ground Motions at Locations of Selected Major Facilities during**
 10 **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.

11
 12 **NEPA Effects:** The seismic study employed time-dependent seismic source models for several major
 13 faults in the region. These models were characterized based on the elapsed times since the last
 14 major seismic events on the faults. Therefore, the exposure risks predicted in the seismic study
 15 would increase if no major events take place on these faults through 2020. The effect could be
 16 substantial because seismically induced ground shaking could cause loss of property or personal
 17 injury at the Alternative 1A construction sites (including intake locations, pipelines from intakes to
 18 the intermediate forebay, the tunnel, and the Byron Tract Forebay) as a result of collapse of
 19 facilities. For example, facilities lying directly on or near active blind faults, such as the concrete
 20 batch plant and fuel station on Tyler Island and Byron Tract Forebay for Alternative 1A may have an
 21 increased likelihood of loss of property or personal injury at these sites in the event of seismically
 22 induced ground shaking. Although these blind thrusts are not expected to rupture to the ground
 23 surface under the forebays during earthquake events, they may produce ground or near-ground
 24 shear zones, bulging, or both (California Department of Water Resources 2007a). For a map of all
 25 permanent facilities and temporary work areas associated with this conveyance alignment, see
 26 Figure M3-1 in the Mapbook Volume.

27 However, during construction, all active construction sites would be designed and managed to meet
 28 the safety and collapse-prevention requirements of the relevant state codes and standards listed
 29 earlier in this chapter and expanded upon in Appendix 3B, *Environmental Commitments, AMMs, and*
 30 *CMs*, for the above-anticipated seismic loads. In particular, conformance with the following codes
 31 and standards would reduce the potential risk for increased likelihood of loss of property or

1 personal injury from structural failure resulting from strong seismic shaking of water conveyance
2 features during construction.

- 3 • DWR Division of Engineering *State Water Project—Seismic Loading Criteria Report*, September
4 2012.
- 5 • USACE *Engineering and Design—Earthquake Design and Evaluation for Civil Works Projects*,
6 ER 1110-2-1806, 1995.
- 7 • USACE *Engineering and Design—Earthquake Design and Evaluation of Concrete Hydraulic*
8 *Structures*, EM 1110-2-6053, 2007.
- 9 • USACE *Engineering and Design—Response Spectra and Seismic Analysis for Concrete Hydraulic*
10 *Structures*, EM 1110-2-6050, 1999.
- 11 • USACE *Engineering and Design—Stability Analysis of Concrete Structures*, EM 1110-2-2100, 2005.
- 12 • 8 CCR Sections 1509 and 3203.

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

32 **CEQA Conclusion:** Seismically induced ground shaking that is estimated to occur and the resultant
33 ground motion anticipated at Alternative 1A construction sites, including the intake locations, the
34 tunnel, the pipelines and the forebays, could cause collapse or other failure of project facilities while
35 under construction. For example, facilities lying directly on or near active blind faults, such as the
36 concrete batch plant and fuel station on Tyler Island and the Byron Tract Forebay for Alternative 1A
37 may have an increased likelihood of loss of property or personal injury at these sites in the event of
38 seismically induced ground shaking. However, DWR would conform to Cal-OSHA and other state
39 code requirements, such as shoring, bracing, lighting, excavation depth restrictions, required slope
40 angles, and other measures, to protect worker safety. Conforming to these standards and codes is an
41 environmental commitment of the project (see Appendix 3B, *Environmental Commitments, AMMs,*
42 *and CMs*). Conforming to these health and safety requirements and the application of accepted,
43 proven construction engineering practices would reduce any potential risk such that construction of

1 Alternative 1A would not create an increased likelihood of loss of property, personal injury or death
2 of individuals. This risk would be less than significant. No mitigation is required.

3 **Impact GEO-2: Loss of Property, Personal Injury, or Death from Settlement or Collapse** 4 **Caused by Dewatering during Construction of Water Conveyance Features**

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

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

24 **NEPA Effects:** The hazard of settlement and subsequent collapse of excavations would be evaluated
25 by assessing site-specific geotechnical and hydrological conditions at intake locations and adjacent
26 pumping plants, as well as where intake and forebay pipelines cross waterways and major irrigation
27 canals. A California-registered civil engineer or California-certified engineering geologist would
28 recommend measures in a geotechnical report to address these hazards, such as seepage cutoff
29 walls and barriers, shoring, grouting of the bottom of the excavation, and strengthening of nearby
30 structures, existing utilities, or buried structures. As described in Section 9.3.1, *Methods for Analysis*,
31 the measures would conform to applicable design and building codes, guidelines, and standards,
32 such as the California Building Code and USACE's *Engineering and Design—Structural Design and*
33 *Evaluation of Outlet Works*. See Appendix 3B, *Environmental Commitments, AMMs, and CMs*. In
34 particular, conformance with the following codes and standards would reduce the potential risk for
35 increased likelihood of loss of property or personal injury from structural failure resulting from
36 settlement or collapse at the construction site caused by dewatering during construction.

- 37 • DWR Division of Flood Management *FloodSAFE Urban Levee Design Criteria*, May 2012.
- 38 • USACE *Engineering and Design—Settlement Analysis*, EM 1110-1-1904, 1990.
- 39 • 8 CCR Sections 1509 and 3203.

40 Generally, the applicable codes require that facilities be built in such a way that settlement is
41 minimized. DWR would ensure that the geotechnical design recommendations are included in the
42 design of project facilities and construction specifications to minimize the potential effects from
43 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
 2 to appropriate code and standard requirements to minimize potential risks (Appendix 3B,
 3 *Environmental Commitments, AMMs, and CMs*).

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

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

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

27 **Impact GEO-3: Loss of Property, Personal Injury, or Death from Ground Settlement during** 28 **Construction of Water Conveyance Features**

29 Two types of ground settlement could be induced during tunneling operations: large settlement and
 30 systematic settlement. Large settlement occurs primarily as a result of over-excavation by the
 31 tunneling shield. The over-excavation is caused by failure of the tunnel boring machine to control
 32 unexpected or adverse ground conditions (for example, running, raveling, squeezing, and flowing
 33 ground) or operator error. Minor settlement occurrences may not be discernible while large
 34 settlement can range from interruption of utilities to hindrance of road access. Below the surface,
 35 large settlement can lead to the creation of voids and/or sinkholes above the tunnel. This settlement
 36 can also affect the ground surface. While this could potentially cause property loss or personal
 37 injury above the tunneling operation, instances of large settlement are extremely unlikely to occur
 38 due to pre-construction measures and other protective strategies and safety practices during
 39 construction. Site-specific geotechnical investigations are needed to design the extent and type of
 40 ground improvement that may be required. Ground improvement would be required to facilitate
 41 support of tunnel shafts, control groundwater at the locations of the shafts, prevent development of
 42 undesired tunnel-induced surface settlements and provide pre-defined zones for tunnel boring
 43 machines (TBM) maintenance interventions. The types of ground improvement that would be
 44 considered include jet-grouting, permeation or compaction grouting, and ground freezing. The

1 choice usually depends on ground conditions and the methods preferred by the contractor.
 2 Additionally, the use of earth pressure balance (EPB) TBMs decreases the potential for over-
 3 excavation. EPB machines hold the excavated tunnel spoils in a pressurized chamber behind the
 4 cutter head. This chamber is used to counterbalance earth pressures. Pressure is held at the tunnel
 5 face by carefully controlling the rate of spoils withdrawal from the chamber using a screw auger
 6 while the machine is pushed forward. The use of an EPB TBM enables the construction of tunnels in
 7 soft ground conditions and a high water table. The TBM shield supports the walls and roof of the
 8 excavation until the precast segmental liner is erected at the end of the shield. The pressure at the
 9 face is maintained by the controlled release of excavated material via a screw conveyor. Reusable
 10 tunnel material (RTM) is discharged into cars or onto conveyors to be removed off site. Proper use
 11 of the EPB technique allows only the removal of the theoretically correct amount of material, thus
 12 greatly reducing the potential of surface settlement.

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

18 The geologic units in the area of the Alternative 1A pipeline/tunnel alignment are shown on Figure
 19 9-3 and summarized in Table 9-15. The characteristics of each unit would affect the potential for
 20 settlement during tunneling operations. Segments 1 and 3 contain higher amounts of sand than the
 21 other segments, so they pose a greater risk of settlement.

22 **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
Segment 3	Qm2e	Eolian sand: well-sorted fine- to medium-grained sand
	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; Atwater 1982.

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

23

1 Operator errors or highly unfavorable/unexpected ground conditions could result in larger
 2 settlement. Large ground settlements caused by tunnel construction are almost always the result of
 3 using inappropriate tunneling equipment (incompatible with the ground conditions), improperly
 4 operating the machine, or encountering sudden or unexpected changes in ground conditions.

5 Given the likely design depth of the tunnel, the amount of settlement beneath developed areas and
 6 critical infrastructure (i.e., the village of Hood, SR 4 and SR 12, the EBMUD aqueduct, and a
 7 potentially sensitive satellite dish facility) would be minor. At the evaluated infrastructure, the
 8 predicted maximum ground surface settlement would range from 0.0 to 2.9 inches, with a change in
 9 ground slope ratio ranging from 0 to 1:714 (the higher value corresponding to a 0.14% slope). The
 10 width of the settlement “trough,” as a cross-section oriented perpendicular to the tunnel alignment,
 11 would be 328 to 525 feet among the evaluated facilities. Other facilities that may be determined to
 12 be critical infrastructure include natural gas pipelines, the proposed EBMUD tunnel, levees, and local
 13 electrical distribution and communication lines.

14 **NEPA Effects:** Although the potential effect is expected to be minor, during detailed project design, a
 15 site-specific subsurface geotechnical evaluation would be conducted along the pipeline/tunnel
 16 alignment to verify or refine the findings of the preliminary geotechnical investigations. The
 17 tunneling equipment and drilling methods would be reevaluated and refined based on the results of
 18 the investigations, and field procedures for sudden changes in ground conditions (e.g., excavate and
 19 replace soft soil; staged construction to allow soft soil to gain strength through consolidation) would
 20 be implemented to minimize or avoid ground settlement. A California-registered civil engineer or
 21 California-certified engineering geologist would recommend measures to address these hazards,
 22 such as specifying the type of tunnel boring machine to be used in a given segment. The results of
 23 the site-specific evaluation and the engineer’s recommendations would be documented in a detailed
 24 geotechnical report, which will contain site-specific evaluations of the settlement hazard associated
 25 with the site-specific soil conditions overlying the tunnel throughout the alignment. The report will
 26 also contain recommendations for the type of tunnel boring machine to be used and the tunneling
 27 techniques to be applied to avoid excessive settlement for specific critical assets, such as buildings,
 28 major roads, natural gas pipelines, electrical and communication lines, aqueducts, bridges, levees,
 29 and sensitive satellite dish facilities. Also included in the report will be recommendations for
 30 geotechnical and structural instrumentation for monitoring of settlement.

31 As described in Section 9.3.1, *Methods for Analysis*, the measures would conform to applicable design
 32 guidelines and standards, such as USACE design measures. See Appendix 3B, *Environmental*
 33 *Commitments, AMMs, and CMs*. In particular, conformance with the following federal design manuals
 34 and professional society and geotechnical literature would be used to predict the maximum amount
 35 of settlement that could occur for site-specific conditions, to identify the maximum allowable
 36 settlement for individual critical assets, and to develop recommendations for tunneling to avoid
 37 excessive settlement, all to minimize the likelihood of loss of property or personal injury from
 38 ground settlement above the tunneling operation during construction.

- 39 ● *Technical Design Manual for Design and Construction of Road Tunnels* (U.S. Department of
 40 Transportation, Federal Highway Administration 2009).
- 41 ● *A Method of Estimating Surface Settlement above Tunnels Constructed in Soft Ground* (National
 42 Research Council of Canada 1983).
- 43 ● *Predicting the Dynamics of Ground Settlement and its Derivatives Caused by Tunnelling in Soil*
 44 (Attewell and Woodman 1982).

- 1 • *Predicting the Settlements above Twin Tunnels Constructed in Soft Ground* (Chapman et al. 2004).
- 2 • *Report on Settlements Induced by Tunneling in Soft Ground* (International Tunneling Association
- 3 2007).
- 4 • *Closed-Face Tunnelling Machines and Ground Stability: A Guideline for Best Practice* (British
- 5 Tunnelling Society 2005).

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

12 Generally, the applicable codes require that facilities be built so that they are designed for slope
 13 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
 15 standards specify protective measures that must be taken at construction sites to minimize the risk
 16 of injury or death from structural or earth failure. The relevant codes and standards represent
 17 performance standards that must be met by contractors and these measures are subject to
 18 monitoring by state and local agencies. Cal-OSHA requirements for an IIPP and the terms of the IIPP
 19 to protect worker safety are the principal measures that would be enforced at construction sites.

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

23 **CEQA Conclusion:** Ground settlement above the tunneling operation could result in loss of property
 24 or personal injury during construction. However, DWR would conform to Cal-OSHA, USACE, and
 25 other design requirements to protect worker safety. DWR would also ensure that the design
 26 specifications are properly executed during construction. DWR has made an environmental
 27 commitment to use the appropriate code and standard requirements to minimize potential risks
 28 (Appendix 3B, *Environmental Commitments, AMMs, and CMs*). Conformance with these requirements
 29 and the application of accepted, proven construction engineering practices would reduce any
 30 potential risk such that construction of Alternative 1A would not create an increased likelihood of
 31 loss of property, personal injury or death of individuals from ground settlement. This risk would be
 32 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
 36 spoils and RTM at storage sites could cause excessive settlement in the spoils at the construction
 37 sites leading to collapse of slopes. Soil and sediment, especially those consisting of loose alluvium
 38 and soft peat or mud, would be particularly prone to failure and movement. Additionally,
 39 groundwater is expected to be within a few feet of the ground surface in these areas; this may make
 40 excavations more prone to failure.

41 Borrow and spoils areas for construction of intakes, sedimentation basins, pumping plants, forebays,
 42 and other supporting facilities would be sited near the locations of these structures (generally

1 within 10 miles). Along the pipeline/tunnel alignment, selected areas would also be used for
 2 disposing of the byproduct (RTM) of tunneling operations. Table 9-16 describes the geology of these
 3 areas as mapped by Atwater (1982) (Figure 9-3).

4 **Table 9-16. Geology Underlying Borrow/Spoils and Reusable Tunnel Material Storage Areas—**
 5 **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

Sources: Hansen et al. 2001; Atwater 1982.
^a The segments are shown on Figure 9-3.

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

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

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

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

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

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

- 1 • DWR Division of Engineering *State Water Project—Seismic Loading Criteria Report*, September
- 2 2012.
- 3 • DWR Division of Flood Management *FloodSAFE Urban Levee Design Criteria*, May 2012.
- 4 • 8 CCR Sections 1509 and 3203.

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

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

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

31 **Impact GEO-5: Loss of Property, Personal Injury, or Death from Structural Failure Resulting** 32 **from Construction-Related Ground Motions during Construction of Water Conveyance** 33 **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
 37 terms of compaction or settlement, loss of bearing capacity, lateral spreading (horizontal soil
 38 movement), increased lateral soil pressure, and buoyancy within zones of liquefaction. These
 39 consequences could cause loss of property or personal injury and could damage nearby structures
 40 and levees.

41 The lateral extent (or influenced distance) of damage potential caused by pile driving and heavy
 42 equipment operations depends on many factors, including soil conditions, the piling hammer used,
 43 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. In addition to pile driving activities,
3 construction of the water conveyance facilities would require an increased volume of truck and
4 heavy equipment traffic that may occur at some of these locations. Although the trucks and heavy
5 equipment could generate vibrations in the levees, the severity of the vibrations is not expected to
6 be capable of initiating liquefaction. Construction related to conveyance facilities would also require
7 regular access to construction sites, extending the length of the project. Some of the existing public
8 roads would be used as haul routes for the construction of conveyance facilities. Use of the state
9 highway system as haul routes will be maximized where feasible because these roadways are rated
10 for truck traffic and would generally provide the most direct and easily maneuverable routes for
11 large loads. As part of future engineering phases, haul routes needed for the construction of the
12 approved project would be refined. Construction traffic may need to access levee roads at various
13 points along SR 160 and other state routes as shown in Figure 9-7, as well as at locations shown
14 along the Pipeline/Tunnel Alignment in Figure 9-8a. Because of the volume of truck traffic that may
15 occur at some of these locations, there is the potential for some effect on levee integrity at various
16 locations depending on the site specific levee conditions along access routes.

17 During project design, site-specific geotechnical and groundwater investigations would be
18 conducted to build upon existing data (e.g., California Department of Water Resources 2010a,
19 2010b, 2011) to identify and characterize the vertical (depth) and horizontal (spatial) variability in
20 soil bearing capacity and extent of liquefiable soil. Engineering soil parameters that could be used to
21 assess the liquefaction potential, such as (SPT) blow counts, (CPT) penetration tip
22 pressure/resistance, and gradation of soil, would also be obtained. SPT blow counts and CPT tip
23 pressure are used to estimate soil resistance to cyclic loadings by using empirical relationships that
24 were developed based on occurrences of liquefaction (or lack of them) during past earthquakes.
25 The resistance then can be compared to cyclic shear stress induced by the design earthquake (i.e.,
26 the earthquake that is expected to produce the strongest level of ground shaking at a site to which it
27 is appropriate to design a structure to withstand). If soil resistance is less than induced stress, the
28 potential of having liquefaction during the design earthquakes is high. It is also known that soil with
29 high “fines” (i.e., silt- and clay-sized particles) content are less susceptible to liquefaction.

30 **NEPA Effects:** The potential effect could be substantial because construction-related ground motions
31 could initiate liquefaction, which could cause failure of structures during construction. Some of the
32 potential levee effects that could occur during the construction in the absence of corrective
33 measures may include rutting, settlement, and slope movement.

34 During design, the facility-specific potential for liquefaction would be investigated by a geotechnical
35 engineer. The potential effects of construction vibrations on nearby structures, levees, and utilities
36 would be evaluated using specific piling information (such as pile type, length, spacing, and pile-
37 driving hammer to be used). In areas determined to have a potential for liquefaction, the California-
38 registered civil engineer or California-certified engineering geologist would develop design
39 strategies and construction methods to ensure that pile driving and heavy equipment operations do
40 not damage facilities under construction and surrounding structures, and do not threaten the safety
41 of workers at the site (e.g., compaction grouting, which consists of pumping a thick grout mixture
42 into the soil under high pressure forming a grout bulb which compacts the surrounding soil by
43 displacement; removal and replacement of liquefaction susceptible soil; etc.). As shown in Figure 9-
44 6, much of the pipeline/tunnel alignment beginning with the Pierson District and extending south to
45 Clifton Court Forebay is in the “high” seismic vulnerability group. Two fuel stations, a concrete batch
46 plant, as well as a barge unloading facility are located in this medium to medium-high potential for

1 levee liquefaction damage area. Design strategies may include predrilling or jetting, using
 2 open-ended pipe piles to reduce the energy needed for pile penetration, using
 3 cast-in-place-drill-hole (CIDH) piles/piers that do not require driving, using pile jacking to press
 4 piles into the ground by means of a hydraulic system, or driving piles during the drier summer
 5 months. Field data collected during design also would be evaluated to determine the need for and
 6 extent of strengthening levees, embankments, and structures to reduce the effect of vibrations.
 7 These construction methods would conform to current seismic design codes and requirements, as
 8 described in Appendix 3B, *Environmental Commitments, AMMs, and CMs*. Such design standards
 9 include USACE's *Engineering and Design—Stability Analysis of Concrete Structures and Soil*
 10 *Liquefaction during Earthquakes*, by the Earthquake Engineering Research Institute.

11 As with the effects related to design of conveyance facilities, potential construction traffic effects on
 12 levees would be assessed prior to project construction to determine specific geotechnical issues
 13 related to construction traffic loading. Based on the initial assessment from field reconnaissance,
 14 geotechnical exploration and analyses would be performed for levee sections that need further
 15 evaluations. Should the geotechnical evaluations indicate that certain segments of existing levee
 16 roads need improvements to carry the expected construction truck traffic loads, DWR is committed
 17 to carry out the necessary improvements to the affected levee sections or to find an alternative route
 18 that would avoid the potential deficient levee sections (Mitigation Measures TRANS-2a through 2c).
 19 As discussed in Chapter 19, *Transportation*, Mitigation Measure TRANS-2c, all affected roadways
 20 would be returned to preconstruction condition or better following construction. Implementation of
 21 this measure would ensure that construction activities would not worsen pavement and levee
 22 conditions, relative to existing conditions. Prior to construction, DWR would make a good faith effort
 23 to enter into mitigation agreements with or to obtain encroachment permits from affected agencies
 24 to verify what the location, extent, timing, and fair share cost to be paid by the DWR for any
 25 necessary pre- and post-construction physical improvements. Levee roads that are identified as
 26 potential haul routes and expected to carry significant construction truck traffic would be monitored
 27 to ensure that truck traffic is not adversely affecting the levee and to identify the need for corrective
 28 action.

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

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

- 37 ● USACE *Engineering and Design—Design of Pile Foundations*, EM 1110-2-2906, 1991.
- 38 ● USACE *Engineering and Design—Earthquake Design and Evaluation for Civil Works Projects*,
 39 ER 1110-2-1806, 1995.
- 40 ● 8 CCR Sections 1509 and 3203.

41 Generally, the applicable codes require that facilities be built so that if soil in the foundation or
 42 surrounding area are subject to liquefaction, the removal or densification of the liquefiable material
 43 should be considered, along with alternative foundation designs. Additionally, any modification to a
 44 federal levee system would require USACE approval under 33 USC 408 (a 408 Permit).

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

8 Conformance to construction method recommendations and other applicable specifications, as well
 9 as implementation of Mitigation Measures TRANS-2a through 2c, would ensure that construction of
 10 Alternative 1A would not create an increased likelihood of loss of property, personal injury or death
 11 of individuals due to construction- and traffic-related ground motions and resulting potential
 12 liquefaction in the work area. Therefore, there would be no adverse effect.

13 **CEQA Conclusion:** Construction-related ground motions and traffic effects could initiate
 14 liquefaction, which could cause failure of structures during construction and result in injury of
 15 workers at the construction sites. The impact could be significant. However, DWR would conform to
 16 Cal-OSHA and other state code requirements and conform to applicable design guidelines and
 17 standards, such as USACE design measures. Conformance with these requirements and the
 18 application of accepted, proven construction engineering practices, in addition to implementation of
 19 Mitigation Measures TRANS-2a and TRANS-2b, as well as the maintenance and reconstruction of
 20 levees through Mitigation Measure TRANS-2c, would reduce any potential risk such that
 21 construction of Alternative 1A would not create an increased likelihood of loss of property, personal
 22 injury or death of individuals from construction-related ground motion and resulting potential
 23 liquefaction in the work area and the hazard would be controlled to a level that would protect
 24 worker safety (see Appendix 3B, *Environmental Commitments, AMMs, and CMs*). The impact would
 25 be less than significant.

26 **Mitigation Measure TRANS-2a: Prohibit Construction Activity on Physically Deficient**
 27 **Roadway Segments**

28 Please refer to Mitigation Measure TRANS-2a in Alternative 1A, Impact TRANS-2, in Chapter 19,
 29 *Transportation*.

30 **Mitigation Measure TRANS-2b: Limit Construction Activity on Physically Deficient**
 31 **Roadway Segments**

32 Please refer to Mitigation Measure TRANS-2b in Alternative 1A, Impact TRANS-2, in Chapter 19,
 33 *Transportation*.

34 **Mitigation Measure TRANS-2c: Improve Physical Condition of Affected Roadway Segments**
 35 **as Stipulated in Mitigation Agreements or Encroachment Permits**

36 Please refer to Mitigation Measure TRANS-2c in Alternative 1A, Impact TRANS-2, in Chapter 19,
 37 *Transportation*.

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 According to the available AP Fault Zone Maps, none of the Alternative 1A facilities would cross or
 4 be within any known active fault zones. However, numerous AP fault zones have been mapped west
 5 of the conveyance alignment (Figure 9-5). The closest AP fault zone would be the Greenville fault,
 6 located approximately 7.6 miles west of the conveyance facilities. Because none of the Alternative
 7 1A constructed facilities would be within any of the fault zones (which include the area
 8 approximately 200 to 500 feet on each side of the mapped surface trace to account for potential
 9 branches of active faults), the potential that the facilities would be directly subject to fault offsets is
 10 negligible.

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

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

32 **NEPA Effects:** The effect would not be adverse because no active faults extend into the Alternative
 33 1A alignment. Additionally, although the Thornton Arch and West Tracy blind thrusts occur beneath
 34 the Alternative 1A alignment, they do not present a hazard of surface rupture based on available
 35 information, including the AP Earthquake Fault Zone Map showing faults capable of surface rupture
 36 (Figure 9-5).

37 However, because there is limited information regarding the depths of the Thornton Arch and West
 38 Tracy blind thrusts, seismic surveys would be performed on the blind thrust during the design phase
 39 to determine the depths to the top of the faults. More broadly, design-level geotechnical studies
 40 would be prepared by a geotechnical engineer licensed in the state of California during project
 41 design. The studies would further assess site-specific conditions at and near all the project facility
 42 locations, including seismic activity, soil liquefaction, and other potential geologic and soil-related
 43 hazards. This information would be used to verify assumptions and conclusions included in the
 44 EIR/EIS. The geotechnical engineer's recommended measures to address adverse conditions would

1 conform to applicable design codes, guidelines, and standards. Potential design strategies or
 2 conditions could include avoidance (deliberately positioning structures and lifelines to avoid
 3 crossing identified shear rupture zones), geotechnical engineering (using the inherent capability of
 4 unconsolidated geomaterials to “locally absorb” and distribute distinct bedrock fault movements)
 5 and structural engineering (engineering the facility to undergo some limited amount of ground
 6 deformation without collapse or significant damage).

7 As described in Section 9.3.1, *Methods for Analysis*, such design codes, guidelines, and standards are
 8 environmental commitments by DWR (see also Appendix 3B, *Environmental Commitments, AMMs,*
 9 *and CMs*). For construction of the water conveyance facilities, the codes and standards would
 10 include the California Building Code and resource agency and professional engineering
 11 specifications, such as the Division of Safety of Dams *Guidelines for Use of the Consequence-Hazard*
 12 *Matrix and Selection of Ground Motion Parameters*, DWR’s Division of Flood Management *FloodSAFE*
 13 *Urban Levee Design Criteria*, and USACE’s *Engineering and Design—Earthquake Design and*
 14 *Evaluation for Civil Works Projects*. These codes and standards include minimum performance
 15 standards for structural design, given site-specific subsurface conditions.

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

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

- 23 ● DWR Division of Engineering *State Water Project—Seismic Loading Criteria Report*, September
 24 2012.
- 25 ● USACE *Engineering and Design—Time-History Dynamic Analysis of Concrete Hydraulic Structures*,
 26 EM 1110-2-6051, 2003.
- 27 ● USACE *Engineering and Design—Response Spectra and Seismic Analysis for Concrete Hydraulic*
 28 *Structures*, EM 1110-2-6050, 1999.
- 29 ● American Society of Civil Engineers *Minimum Design Loads for Buildings and Other Structures*,
 30 ASCE/SEI 7-10, 2010.
- 31 ● California Code of Regulations, Title 8, Section 3203.

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

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

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

7 **CEQA Conclusion:** There are no active faults capable of surface rupture that extend into the
 8 pipeline/tunnel alignment. Although the Thornton Arch and West Tracy blind thrusts occur beneath
 9 the pipeline/tunnel alignment, they do not present a hazard of surface rupture based on available
 10 information. Conformance to applicable design specifications and standards would ensure that
 11 operation of Alternative 1A would not create an increased likelihood of loss of property or injury of
 12 individuals in the event of ground movement in the vicinity of the Thornton Arch fault zone and
 13 West Tracy blind thrusts. Therefore, such ground movements would not jeopardize the integrity of
 14 the surface and subsurface facilities along the Alternative 1A conveyance alignment or the proposed
 15 forebay and associated facilities adjacent to the Clifton Court Forebay. There would be no impact. No
 16 mitigation is required.

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

19 Earthquake events may occur on the local and regional seismic sources during operation of the
 20 Alternative 1A water conveyance facilities. The ground shaking could damage pipelines, tunnels,
 21 intakes, pumping plants, and other facilities, disrupting the water supply through the conveyance
 22 system. Table 9-17 shows that the proposed facilities would be subject to moderate-to-high
 23 earthquake ground shaking through 2025. All facilities would be designed and constructed in
 24 accordance with the requirements of the design guidelines and building codes described in
 25 Appendix 3B, *Environmental Commitments, AMMs, and CMs*. Site-specific geotechnical information
 26 would be used to further assess the effects of local soil on the OBE and MDE ground shaking and to
 27 develop design criteria that minimize damage potential facilities, pumping plants, and other
 28 facilities disrupting the water supply through the conveyance system. In an extreme event of strong
 29 seismic shaking, uncontrolled release of water from damaged pipelines, tunnels, intake facilities,
 30 pumping plants, and other facilities could cause flooding, disruption of water supplies to the south,
 31 inundation of structures, property loss, and injury. These effects are discussed more fully in
 32 Appendix 3E, *Potential Seismicity and Climate Change Risks to SWP/CVP Water Supplies*.

33 Table 9-17 lists the expected PGA and 1.0-S_a values in 2025 at selected facility locations. For early
 34 long-term, earthquake ground motions with return periods of 144 years and 975 years were
 35 estimated from the results presented in the seismic study (California Department of Water
 36 Resources 2007a). The 144-year and 975-year ground motions correspond to the OBE (i.e., an
 37 earthquake that has a 50% probability of exceedance in a 100-year period (which is equivalent to a
 38 144-year return period event) and the MDE (i.e., an earthquake that causes ground motions that
 39 have a 10% chance of being exceeded in 100 years) design ground motions, respectively. Values
 40 were estimated for a stiff soil site (as predicted in the seismic study), and for the anticipated soil
 41 conditions at the facility locations. No seismic study results exist for 2025, so the ground shaking
 42 estimated for the 2050 were used for Early Long-term (2025).

1 **Table 9-17. Expected Earthquake Ground Motions at Locations of Selected Major Facilities in the Early**
 2 **Long-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.

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

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

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

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

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

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

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

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

- 41 • DWR Division of Engineering *State Water Project—Seismic Loading Criteria Report*, September
 42 2012.

- 1 • USACE *Engineering and Design—Time-History Dynamic Analysis of Concrete Hydraulic Structures*,
2 EM 1110-2-6051, 2003.
- 3 • USACE *Engineering and Design—Response Spectra and Seismic Analysis for Concrete Hydraulic*
4 *Structures*, EM 1110-2-6050, 1999.
- 5 • American Society of Civil Engineers *Minimum Design Loads for Buildings and Other Structures*,
6 ASCE/SEI 7-10, 2010.
- 7 • 8 CCR 3203.

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

13 **NEPA Effects:** Conformance with the aforementioned standards and codes are an environmental
14 commitment of the project (see Appendix 3B, *Environmental Commitments, AMMs, and CMs*). The
15 worker safety codes and standards specify protective measures that must be taken at workplaces to
16 minimize the risk of injury or death from structural or earth failure (e.g., utilizing personal
17 protective equipment). The relevant codes and standards represent performance standards that
18 must be met by employers 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
20 principal measures that would be enforced at workplaces during operations.

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

26 **CEQA Conclusion:** Seismically induced strong ground shaking could damage pipelines, tunnels,
27 intake facilities, pumping plants, and other facilities and result in loss of property or personal injury.
28 The damage could disrupt the water supply through the conveyance system. In an extreme event, an
29 uncontrolled release of water from the damaged conveyance system could cause flooding and
30 inundation of structures. However, through the final design process, measures to address this
31 hazard would be required to conform to applicable design codes, guidelines, and standards. As
32 described in Section 9.3.1, *Methods for Analysis*, and in Appendix 3B, *Environmental Commitments,*
33 *AMMs, and CMs*, such design codes, guidelines, and standards include the California Building Code
34 and resource agency and professional engineering specifications, such as the Division of Safety of
35 *Dams Guidelines for Use of the Consequence-Hazard Matrix and Selection of Ground Motion*
36 *Parameters*, DWR's Division of Flood Management *FloodSAFE Urban Levee Design Criteria*, and
37 USACE's *Engineering and Design—Earthquake Design and Evaluation for Civil Works Projects*.
38 Conformance with these codes and standards is an environmental commitment by DWR to ensure
39 that ground shaking risks are minimized as the Alternative 1A water conveyance features are
40 operated and there would be no increased likelihood of loss of property, personal injury or death of
41 individuals. The hazard would be controlled to a safe level. The impact would be less than
42 significant. No mitigation is 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 in 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
 8 zones of liquefaction. Failure of tunnels, pipelines, levees, bridges, and other structures and facilities
 9 could result in loss of property or personal injury, and disrupt SWP and CVP water supply deliveries.
 10 The potential for adverse impacts from flooding as a result of levee or dam failure is also discussed
 11 in Chapter 6, *Surface Water*.

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

23 The silty and sandy soil deposits underlying the peaty and organic soil over parts of the Delta are
 24 late-Pleistocene age dune sand, which are liquefiable during major earthquakes. The tops of these
 25 materials are exposed in some areas, but generally lie beneath the peaty soil at depths of about 10–
 26 40 feet bgs along the pipeline/tunnel alignment (Real and Knudsen 2009). Liquefaction hazard
 27 mapping by Real and Knudsen (2009), which covers only the southwestern part of the Plan Area,
 28 including the part of the alignment from near Isleton to the Palm Tract, indicates that the lateral
 29 ground deformation potential would range from <0.1 to 6.0 feet. Liquefaction-induced ground
 30 settlement during the 1906 San Francisco earthquake was also reported near Alternative 1A
 31 facilities at a bridge crossing over Middle River just north of Woodward Island (Youd and Hoose
 32 1978). Local variations in thickness and lateral extent of liquefiable soil may exist, and they may
 33 have important influence on liquefaction-induced ground deformations.

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

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

41 The potential effect could be substantial because seismically induced ground shaking could cause
 42 liquefaction, which could result in loss of property or personal injury, and damage pipelines, tunnels,
 43 intake facilities, pumping plants, and other facilities. The damage could disrupt the water supply

1 through the conveyance system. In an extreme event, an uncontrolled release of water from the
2 damaged conveyance system could cause flooding and inundation of structures.

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

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

33 DWR would ensure that the geotechnical design recommendations are included in the design of
34 project facilities and construction specifications to minimize the potential effects from liquefaction
35 and associated hazards. DWR would also ensure that the design specifications are properly executed
36 during construction.

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

- 40 ● DWR Division of Engineering *State Water Project—Seismic Loading Criteria Report*, September
- 41 2012.
- 42 ● USACE *Engineering and Design—Time-History Dynamic Analysis of Concrete Hydraulic Structures*,
- 43 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/SEI 7-10, 2010.
- 5 • USACE *Engineering and Design—Design of Pile Foundations*, EM 1110-2-2906, 1991
- 6 • 8 CCR 3203.

7 Generally, the applicable codes require that facilities be built so that if soil in the foundation or
 8 surrounding area are subject to liquefaction, the removal or densification of the liquefiable material
 9 should be considered, along with alternative foundation designs. Additionally, any modification to a
 10 federal levee system would require USACE approval under 33 USC 408 (a 408 Permit).

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

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

22 **CEQA Conclusion:** Seismically induced ground shaking could cause liquefaction. Liquefaction could
 23 damage pipelines, tunnels, intake facilities, pumping plants, and other facilities, and thereby disrupt
 24 the water supply through the conveyance system. In an extreme event, an uncontrolled release of
 25 water from the damaged conveyance system could cause flooding and inundation of structures.
 26 However, through the final design process, measures to address the liquefaction hazard would be
 27 required to conform to applicable design codes, guidelines, and standards. As described in Section
 28 9.3.1, *Methods for Analysis*, and in Appendix 3B, *Environmental Commitments, AMMs, and CMs*, such
 29 design codes, guidelines, and standards include USACE's *Engineering and Design—Stability Analysis*
 30 *of Concrete Structures and Soil Liquefaction during Earthquakes*, by the Earthquake Engineering
 31 Research Institute. Conformance with these design standards is an environmental commitment by
 32 DWR to ensure that liquefaction risks are minimized as the Alternative 1A water conveyance
 33 features are operated and there would be no increased likelihood of loss of property, personal injury
 34 or death of individuals. The hazard would be controlled to a safe level. The impact would be less
 35 than significant. No mitigation is 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 Alternative 1A would involve excavation that creates new cut-and-fill slopes and construction of
 39 new embankments and levees. As a result of ground shaking and high soil-water content during
 40 heavy rainfall, existing and new slopes that are not properly engineered and natural stream banks
 41 could fail and cause damage to facilities. Levees can fail for several reasons: 1) high velocities of
 42 water flow can result in high rates of erosion and erode and overtop a levee; 2) the higher velocities

1 of water flow can also lead to higher rates of erosion along the inner parts of levees and lead to
2 undercutting and clumping of the levee into the river. Heavy rainfall or seepage into the levee from
3 the river can increase fluid pressure in the levee and lead to slumping on the outer parts of the levee.
4 If the slumps grow to the top of the levee, large sections of the levee may slump onto the floodplain
5 and lower the elevation of the top of the levee, leading to overtopping; 3) increasing levels of water
6 in the river will cause the water table in the levee to rise which will increase fluid pressure and may
7 result in seepage and eventually lead to internal erosion called piping. Piping will erode the material
8 under the levee, undermining it and causing its collapse and failure.

9 With the exception of levee slopes and natural stream banks, the topography along the Alternative
10 1A conveyance alignment is nearly level to very gently sloping. The areas that may be susceptible to
11 slope failure are along existing levee slopes, and at intakes, pumping plants, forebay, and certain
12 access road locations. Outside these areas, the land is nearly level and consequently has a negligible
13 potential for slope failure. Based on review of topographic maps and a landslide map of Alameda
14 County (Roberts et al. 1999), the conveyance facilities would not be constructed on, nor would it be
15 adjacent to, slopes that are subject to mudflows/debris flows from natural slopes.

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

26 During project design, a geotechnical engineer would develop slope stability design criteria (such as
27 minimum slope safety factors and allowable slope deformation and settlement) for the various
28 anticipated loading conditions. The design criteria would be documented in a detailed geotechnical
29 report prepared in accordance with state guidelines, in particular *Guidelines for Evaluating and*
30 *Mitigating Seismic Hazards in California* (California Geological Survey 2008). As discussed in Chapter
31 3, *Description of the Alternatives*, the foundation soil beneath slopes, embankments, or levees could
32 be improved to increase its strength and to reduce settlement and deformation. Foundation soil
33 improvement could involve excavation and replacement with engineered fill; preloading; ground
34 modifications using jet-grouting, compaction grouting, chemical grouting, shallow soil mixing, deep
35 soil mixing, vibro-compaction, or vibro-replacement; or other methods. Engineered fill also would
36 be used to construct new slopes, embankments, and levees. Surface and internal drainage systems
37 would be installed as necessary to reduce erosion and piping (internal erosion) potential.

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

1 fill slopes, embankments, and levees to minimize the potential effects from slope failure. DWR would
2 also ensure that the design specifications are properly executed during construction.

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

- 6 • DWR Division of Engineering *State Water Project—Seismic Loading Criteria Report*, September
7 2012.
- 8 • DWR Division of Flood Management *FloodSAFE Urban Levee Design Criteria*, May 2012.
- 9 • USACE *Slope Stability*, EM 1110-2-1902, 2003.
- 10 • 8 CCR 3203.

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
13 parameters.

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

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

24 **CEQA Conclusion:** Unstable levee slopes and natural stream banks may fail, either from high pore-
25 water pressure caused by high rainfall and weak soil, or from seismic shaking. Structures built on
26 these slopes could be damaged or fail entirely as a result of slope instability. 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. The measures would be described in a detailed geotechnical
29 report prepared in accordance with state guidelines, in particular *Guidelines for Evaluating and*
30 *Mitigating Seismic Hazards in California* (California Geological Survey 2008). As described in Section
31 9.3.1, *Methods for Analysis*, and in Appendix 3B, *Environmental Commitments, AMMs, and CMs*, such
32 design codes, guidelines, and standards include the California Building Code and resource agency
33 and professional engineering specifications, such as USACE's *Engineering and Design—Earthquake*
34 *Design and Evaluation for Civil Works Projects*. Conformance with these codes and standards is an
35 environmental commitment by DWR to ensure cut and fill slopes and embankments will be stable as
36 the Alternative 1A water conveyance features are operated and there would be no increased
37 likelihood of loss of property, personal injury or death of individuals. The impact would be less than
38 significant. No mitigation is required.

1 **Impact GEO-10: Loss of Property, Personal Injury, or Death from Seiche or Tsunami during** 2 **Operation of Water Conveyance Features**

3 Based on recorded tsunami wave heights at the Golden Gate (Contra Costa Transportation Agency
4 2009) and in the interior of the San Francisco Bay and on tsunami inundation maps prepared by the
5 California Department of Conservation (2009), the height of a tsunami wave reaching the Suisun
6 Marsh and the Delta would be small because of the distance from the ocean and attenuating effect of
7 the San Francisco Bay. Therefore, the potential hazard of loss of property or personal injury as a
8 result of a tsunami on the water conveyance facilities is low.

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

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

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

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

39 However, design-level geotechnical studies would be conducted by a licensed civil engineer who
40 practices in geotechnical engineering. The studies would determine the peak ground acceleration
41 caused by movement of the West Tracy fault and the maximum probable seiche wave that could be
42 generated by the ground shaking. The California-registered civil engineer or California-certified
43 engineering geologist's recommended measures to address this hazard, as well as the hazard of a
44 seiche overtopping the Clifton Court Forebay embankment and subsequent adverse effect on the

1 Byron Tract Forebay embankment, would conform to applicable design codes, guidelines, and
 2 standards. As described in Section 9.3.1, *Methods for Analysis*, and in Appendix 3B, *Environmental*
 3 *Commitments, AMMs, and CMs*, such design codes, guidelines, and standards include the Division of
 4 Safety of Dams' *Guidelines for Use of the Consequence-Hazard Matrix and Selection of Ground Motion*
 5 *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
 8 that the adverse effects of a seiche are controlled to an acceptable level while the forebay facility is
 9 operated.

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

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

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

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

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

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

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

41 Similarly, the potential for a significant seiche to occur in most parts of the Plan Area is considered
 42 low because the seismic hazard and the geometry of the water bodies (i.e., wide and shallow) near

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

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

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

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

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

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

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

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

40 Because there is limited information regarding the depths of the blind faults mentioned above,
 41 seismic surveys would be performed in the vicinity of the faults as part of final design. These surveys
 42 would be used to verify fault depths where levees and other features would be constructed.

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

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

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

- 24 ● DWR Division of Engineering *State Water Project—Seismic Loading Criteria Report*, September
 25 2012.
- 26 ● DWR DSOD *Guidelines for Use of the Consequence-Hazard Matrix and Selection of Ground Motion*
 27 *Parameters*, 2002.
- 28 ● USACE *Engineering and Design—Earthquake Design and Evaluation for Civil Works Projects*,
 29 ER 1110-2-1806, 1995.
- 30 ● USACE *Design and Construction of Levees*, EM 1110-2-1913, 2000.
- 31 ● USACE (CESPK-ED-G), *Geotechnical Levee Practice*, SOP EDG-03, 2004.
- 32 ● DWR Division of Flood Management *FloodSAFE Urban Levee Design Criteria*, May 2012.
- 33 ● 8 CCR Sections 1509 and 3203.

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

39 The worker safety codes and standards specify protective measures that must be taken at
 40 workplaces to minimize the risk of injury or death from structural or earth failure (e.g., utilizing
 41 personal protective equipment, practicing crane and scaffold safety measures). The relevant codes
 42 and standards represent performance standards that must be met by employers and these measures

1 are subject to monitoring by state and local agencies. Cal-OSHA requirements for an IIPP and the
 2 terms of the IIPP to protect worker safety are the principal measures that would be enforced at
 3 workplaces.

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

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

24 **Impact GEO-13: Loss of Property, Personal Injury, or Death from Structural Failure Resulting** 25 **from Strong Seismic Shaking at Restoration Opportunity Areas**

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

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

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

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

11 As described in Section 9.3.1, *Methods for Analysis*, and in Appendix 3B, *Environmental Commitments*,
 12 *AMMs, and CMs*, such design codes, guidelines, and standards include the California Building Code
 13 and resource agency and professional engineering specifications, such as the Division of Safety of
 14 *Dams Guidelines for Use of the Consequence-Hazard Matrix and Selection of Ground Motion*
 15 *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 design standards is an environmental commitment by the BDCP
 18 proponents to ensure that strong seismic shaking risks are minimized as the conservation measures
 19 are implemented.

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

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

- 27 • DWR Division of Engineering *State Water Project—Seismic Loading Criteria Report*, September
 28 2012.
- 29 • DWR DSOD *Guidelines for Use of the Consequence-Hazard Matrix and Selection of Ground Motion*
 30 *Parameters*, 2002.
- 31 • USACE *Engineering and Design—Earthquake Design and Evaluation for Civil Works Projects*,
 32 ER 1110-2-1806, 1995.
- 33 • USACE *Design and Construction of Levees*, EM 1110-2-1913, 2000.
- 34 • USACE (CESPK-ED-G), *Geotechnical Levee Practice*, SOP EDG-03, 2004.
- 35 • DWR Division of Flood Management *FloodSAFE Urban Levee Design Criteria*, May 2012.
- 36 • 8 CCR Sections 1509 and 3203.

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

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

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

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

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

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

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

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

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

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

30 In particular, conformance with the following codes and standards would reduce the potential risk
 31 for increased likelihood of loss of property or personal injury from structural failure resulting from
 32 seismic-related ground failure.

- 33 • USACE *Engineering and Design—Design of Pile Foundations*, EM 1110-2-2906, 1991.
- 34 • USACE *Engineering and Design—Stability Analysis of Concrete Structures*, EM 1110-2-2100, 2005.
- 35 • USACE *Engineering and Design—Earthquake Design and Evaluation for Civil Works Projects*,
 36 ER 1110-2-1806, 1995.
- 37 • 8 CCR Sections 1509 and 3203.

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

41 The worker safety codes and standards specify protective measures that must be taken at
 42 workplaces to minimize the risk of injury or death from structural or earth failure (e.g., utilizing
 43 personal protective equipment, practicing crane and scaffold safety measures). The relevant codes

1 and standards represent performance standards that must be met by employers and these measures
 2 are subject to monitoring by state and local agencies. Cal-OSHA requirements for an IIPP and the
 3 terms of the IIPP to protect worker safety are the principal measures that would be enforced at
 4 workplaces.

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

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

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

26 Implementation of CM2–CM7, would involve breaching, modification or removal of existing levees
 27 and construction of new levees and embankments. CM4 which provides for the restoration of up to
 28 65,000 acres of tidal perennial aquatic, tidal mudflat, tidal freshwater emergent wetland, and tidal
 29 brackish emergent wetland natural communities within the ROAs involves the greatest amount of
 30 modifications to levees. Levee modifications, including levee breaching or lowering, may be
 31 performed to reintroduce tidal exchange, reconnect remnant sloughs, restore natural remnant
 32 meandering tidal channels, encourage development of dendritic channel networks, and improve
 33 floodwater conveyance.

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

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

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

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

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

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

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

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

43 Site-specific geotechnical and hydrological information would be used, and the design would
 44 conform to the current standards and construction practices, as described in Chapter 3, *Description*

1 *of the Alternatives, such as USACE's Design and Construction of Levees and USACE's EM 1110-2-1902,*
2 *Slope Stability.*

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

7 In particular, conformance with the following codes and standards would reduce the potential risk
8 for increased likelihood of loss of property or personal injury from structural failure resulting from
9 landslides or other slope instability.

- 10 • DWR Division of Engineering *State Water Project—Seismic Loading Criteria Report*, September
11 2012.
- 12 • DWR Division of Flood Management *FloodSAFE Urban Levee Design Criteria*, May 2012.
- 13 • USACE *Slope Stability*, EM 1110-2-1902, 2003.
- 14 • 8 CCR 3203.

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

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

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

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

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

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

39 **CEQA Conclusion:** Based on recorded tsunami heights at the Golden Gate, the height of a tsunami
40 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.

9.3.3.3 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 Neugebauer 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.

25

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
 3 major seismic events on the faults. Therefore, the exposure risks predicted by the seismic study
 4 would increase if no major events occur on these faults through 2020. The effect would be adverse
 5 because seismically induced ground shaking could cause loss of property or personal injury at the
 6 Alternative 1B construction sites (including intake locations, pipelines between transition structures
 7 and canal transition structures, the canal, bridge crossings along the conveyance alignment, and the
 8 Byron Tract Forebay) as a result of collapse of facilities. The Byron Tract Forebay is located near an
 9 active blind fault and the portion of the canal located east of Locke, as well as the portion of the canal
 10 which lies between Beaver Slough and Hog Slough, lie directly over an active blind fault and within
 11 the Thornton Arch Zone, resulting in an increased likelihood of loss of property or personal injury at
 12 these sites in the event of seismically induced ground shaking. Although these blind thrusts are not
 13 expected to rupture to the ground surface under the forebays during earthquake events, they may
 14 produce ground or near-ground shear zones, bulging, or both (California Department of Water
 15 Resources 2007a). For a map of all permanent facilities and temporary work areas associated with
 16 this conveyance alignment, see Mapbook Figure M3-2.

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

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

- 24 • DWR Division of Engineering *State Water Project—Seismic Loading Criteria Report*, September
 25 2012.
- 26 • USACE *Engineering and Design—Earthquake Design and Evaluation for Civil Works Projects*,
 27 ER 1110-2-1806, 1995.
- 28 • USACE *Engineering and Design—Earthquake Design and Evaluation of Concrete Hydraulic*
 29 *Structures*, EM 1110-2-6053, 2007.
- 30 • USACE *Engineering and Design—Response Spectra and Seismic Analysis for Concrete Hydraulic*
 31 *Structures*, EM 1110-2-6050, 1999.
- 32 • USACE *Engineering and Design—Stability Analysis of Concrete Structures*, EM 1110-2-2100, 2005.
- 33 • 8 CCR Sections 1509 and 3203.

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

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

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

10 **CEQA Conclusion:** Seismically induced ground shaking that is estimated to occur and the resultant
 11 ground motion anticipated at Alternative 1B construction sites, including the canal, pipelines and
 12 the forebays, could cause collapse or other failure of project facilities while under construction. For
 13 example, facilities lying directly on or near active blind faults, such as the Byron Tract Forebay as
 14 well as along the canal near Locke and between Beaver Slough and Hog Slough, may have in an
 15 increased likelihood of loss of property or personal injury at these sites in the event of seismically
 16 induced ground shaking. However, DWR would conform to Cal-OSHA and other state code
 17 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
 19 is an environmental commitment of the project (see Appendix 3B, *Environmental Commitments,*
 20 *AMMs, and CMs*). Conformance with these health and safety requirements and the application of
 21 accepted, proven construction engineering practices would reduce any potential risk such that
 22 construction of Alternative 1B would not create an increased likelihood of loss of property, personal
 23 injury or death of 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**
 25 **Caused by Dewatering during Construction of Water Conveyance Features**

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

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

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

- 16 • DWR Division of Flood Management *FloodSAFE Urban Levee Design Criteria*, May 2012.
- 17 • USACE *Engineering and Design—Settlement Analysis*, EM 1110-1-1904, 1990.
- 18 • 8 CCR Sections 1509 and 3203.

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

23 DWR would ensure that the geotechnical design recommendations are included in the design of
 24 project facilities and construction specifications to minimize the potential effects from settlement
 25 and failure of excavations. DWR would also ensure that the design specifications are properly
 26 executed during construction. DWR has made an environmental commitment to use the appropriate
 27 code and standard requirements to minimize potential risks (Appendix 3B, *Environmental*
 28 *Commitments, AMMs, and CMs*).

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

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

40 **CEQA Conclusion:** Settlement or failure of excavations during construction could result in loss of
 41 property or personal injury. However, DWR would conform to Cal-OSHA and other state code
 42 requirements, such as using seepage cutoff walls, shoring, and other measures, to protect worker
 43 safety. DWR would also ensure that the design specifications are properly executed during

1 construction. DWR has made an environmental commitment to use the appropriate code and
2 standard requirements to minimize potential risks (Appendix 3B, *Environmental Commitments*,
3 *AMMs*, and *CMs*). Conformance with these requirements and the application of accepted, proven
4 construction engineering practices would reduce any potential risk such that construction of
5 Alternative 1B would not create an increased likelihood of direct loss, injury or death of individuals
6 from settlement or collapse caused by dewatering. This risk would be less than significant. No
7 mitigation is required.

8 **Impact GEO-3: Loss of Property, Personal Injury, or Death from Ground Settlement during** 9 **Construction of Water Conveyance Features**

10 Two types of ground settlement could be induced during construction of alternative 1B tunnel
11 siphons: large settlement and systematic settlement. Large settlement occurs primarily as a result of
12 over-excavation by the tunneling shield. The over-excavation is caused by failure of the tunnel
13 boring machine to control unexpected or adverse ground conditions (for example, running, raveling,
14 squeezing, and flowing ground) or operator error. Large settlement can lead to the creation of voids
15 and/or sinkholes above the tunnel siphon. In extreme circumstances, the settlement effects could
16 translate to the ground surface, potentially causing loss of property or personal injury above the
17 tunnel siphon construction.

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

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

30 Operator errors or highly unfavorable/unexpected ground conditions could result in larger
31 settlement. Large ground settlements caused by tunnel siphon construction are almost always the
32 result of using inappropriate tunneling equipment (incompatible with the ground conditions),
33 improperly operating the machine, or encountering sudden or unexpected changes in ground
34 conditions.

35 Given the likely design depth of the tunnel, the amount of settlement beneath developed areas and
36 critical infrastructure (i.e., the village of Hood, SR 4 and SR 12, the EBMUD aqueduct, and a
37 potentially sensitive satellite dish facility) would be minor. At the evaluated infrastructure, the
38 predicted maximum ground surface settlement would range from 0.0 to 2.9 inches, with a change in
39 ground slope ratio ranging from 0 to 1:714 (the higher value corresponding to a 0.14% slope). The
40 width of the settlement trough, as a cross-section oriented perpendicular to the tunnel alignment,
41 would be 328 to 525 feet among the evaluated facilities. Other facilities that may be determined to
42 be critical infrastructure include natural gas pipelines, the proposed EBMUD tunnel, levees, and local
43 electrical distribution and communication lines.

1 **NEPA Effects:** Although the potential effect is expected to be minor, during detailed project design, a
2 site-specific subsurface geotechnical review would be conducted along the water conveyance facility
3 alignment to verify or refine the findings of the preliminary geotechnical investigations. The
4 tunneling equipment and drilling methods would be reevaluated and refined based on the results of
5 the investigations, and field procedures for sudden changes in ground conditions would be
6 implemented to minimize or avoid ground settlement. A California-registered civil engineer or
7 California-certified engineering geologist would recommend measures to address these hazards,
8 such as specifying the type of tunnel boring machine to be used in a given segment. The results of
9 the site-specific evaluation and the engineer's recommendations would be documented in a detailed
10 geotechnical report, which will contain site-specific evaluations of the settlement hazard associated
11 with the site-specific soil conditions overlying the tunnel throughout the alignment. The report will
12 also contain recommendations for the type of tunnel boring machine to be used and the tunneling
13 techniques to be applied to avoid excessive settlement for specific critical assets, such as buildings,
14 major roads, natural gas pipelines, electrical and communication lines, aqueducts, bridges, levees,
15 and sensitive satellite dish facilities. Also included in the report will be recommendations for
16 geotechnical and structural instrumentation for monitoring of settlement.

17 As described in Section 9.3.1, *Methods for Analysis*, the measures would conform to applicable design
18 guidelines and standards, such as USACE design measures. See Appendix 3B, *Environmental*
19 *Commitments, AMMs, and CMs*. In particular, conformance with the following federal design manuals
20 and professional society and geotechnical literature would be used to predict the maximum amount
21 of settlement that could occur for site-specific conditions, to identify the maximum allowable
22 settlement for individual critical assets, and to develop recommendations for tunneling to avoid
23 excessive settlement, all to minimize the likelihood of loss of property or personal injury from
24 ground settlement above the tunneling operation during construction.

- 25 • *Technical Design Manual for Design and Construction of Road Tunnels* (U.S. Department of
26 Transportation, Federal Highway Administration 2009).
- 27 • *A Method of Estimating Surface Settlement above Tunnels Constructed in Soft Ground* (National
28 Research Council of Canada 1983).
- 29 • *Predicting the Dynamics of Ground Settlement and its Derivatives Caused by Tunnelling in Soil*
30 (Attewell and Woodman 1982).
- 31 • *Predicting the Settlements above Twin Tunnels Constructed in Soft Ground* (Chapman et al. 2004).
- 32 • *Report on Settlements Induced by Tunneling in Soft Ground* (International Tunneling Association
33 2007).
- 34 • *Closed-Face Tunnelling Machines and Ground Stability: A Guideline for Best Practice* (British
35 Tunnelling Society 2005).

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
Segment 12 and Segment 13	Qfp	Floodplain deposits: dense, sandy to silty clay
	Qfp	Floodplain deposits: dense, sandy to silty clay
Segment 14 (Tunnel Siphon Segment)	Qfp	Floodplain deposits: dense sandy to silty clay

Sources: Hansen et al. 2001; Atwater 1982.

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

2

3 As described in detail in Impacts GEO-1 and GEO-2, DWR would ensure that the geotechnical design
4 recommendations are included in the design of project facilities and construction specifications to
5 minimize the potential effects from settlement. DWR would also ensure that the design

1 specifications are properly executed during construction. DWR has made this conformance and
2 monitoring process an environmental commitment of the BDCP (Appendix 3B, *Environmental*
3 *Commitments, AMMs, and CMs*).

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

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

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

25 **Impact GEO-4: Loss of Property, Personal Injury, or Death from Slope Failure during** 26 **Construction of Water Conveyance Features**

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

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

1 **Table 9-20. Geology of Alternative 1B Borrow/Spoils and Reusable 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
Segment 3 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.
	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 Reusable 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 Reusable Tunnel Material Area	Qfp	Floodplain deposits: dense, sandy to silty clay

Sources: Hansen et al. 2001; Atwater 1982.

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

2

3 **NEPA Effects:** The potential effect could be substantial because excavation of borrow material and
4 the resultant cutslopes and potential failure of spoils/RTM fill slopes could cause injury of workers
5 at the 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
3 be placed in 12-inch lifts with proper compaction and stored no higher than 12 feet above
4 preconstruction ground elevation with maximum side slopes of 5H:1V. During design, the potential
5 for native ground settlement below the spoils would be evaluated by a geotechnical engineer using
6 site-specific geotechnical and hydrological information. The use of shoring, seepage cutoff walls, and
7 ground modifications to prevent slope instability, soil boiling, or excessive settlement would be
8 considered in the design.

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

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

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

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

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

- 11 ● DWR Division of Engineering *State Water Project—Seismic Loading Criteria Report*, September
 12 2012.
- 13 ● DWR Division of Flood Management *FloodSAFE Urban Levee Design Criteria*, May 2012.
- 14 ● 8 CCR Sections 1509 and 3203.

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

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

31 **CEQA Conclusion:** Settlement/failure of cutslopes of borrow sites and failure of soil/RTM fill slopes
 32 could result in loss of property or personal injury during construction. However, DWR would
 33 conform to Cal-OSHA and other state code requirements and conform to applicable geotechnical
 34 design guidelines and standards, such as USACE design measures. Conformance with these
 35 requirements and the application of accepted, proven construction engineering practices would
 36 reduce any potential risk such that construction of Alternative 1B would not create an increased
 37 likelihood of loss of property, personal injury or death of individuals from slope failure at borrow
 38 sites and spoils and RTM storage sites. The maintenance and reconstruction of levees would
 39 improve levee stability over existing conditions due to improved side slopes, erosion control
 40 measures, seepage reduction measures, and overall mass. The impact would be less than significant.
 41 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**
3 **Features**

4 Pile driving and other heavy equipment operations would cause vibrations that could initiate
5 liquefaction and associated ground movements in places where soil and groundwater conditions are
6 present to allow liquefaction to occur. The consequences of liquefaction could be manifested in
7 terms of compaction or settlement, loss of bearing capacity, lateral spreading (horizontal soil
8 movement), increased lateral soil pressure, and buoyancy within zones of liquefaction. These
9 consequences could damage nearby structures and levees.

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

13 Pile driving would be conducted at the intakes, where, based on boring logs, soil materials subject to
14 liquefaction (e.g., saturated, poorly graded sand) are present. In addition to pile driving activities,
15 construction of the water conveyance facilities would require an increased volume of truck and
16 heavy equipment traffic that may occur at some of these locations. Although the trucks and heavy
17 equipment could generate vibrations in the levees, the severity of the vibrations is not expected to
18 be capable of initiating liquefaction. Construction related to conveyance facilities would also require
19 regular access to construction sites, extending the length of the project. Some of the existing public
20 roads would be used as haul routes for the construction of conveyance facilities. Use of the state
21 highway system as haul routes would be maximized where feasible because these roadways are
22 rated for truck traffic and would generally provide the most direct and easily maneuverable routes
23 for large loads. As part of future engineering phases, haul routes needed for the construction of the
24 approved project would be refined. Construction traffic may need to access levee roads at various
25 points along State Route (SR) 160 and other state routes as shown in Figure 9-7, as well as at
26 locations shown along the East Alignment in Figure 9-8a. Because of the volume of truck traffic that
27 may occur at some of these locations, there is the potential for some effect on levee integrity at
28 various locations depending on the site specific levee conditions along access routes.

29 During project design, site-specific geotechnical and groundwater investigations would be
30 conducted to build upon existing data (e.g., California Department of Water Resources 2009a, 2010i)
31 to identify and characterize the vertical (depth) and horizontal (spatial) variability in soil bearing
32 capacity and extent of liquefiable soil. Engineering soil parameters that could be used to assess the
33 liquefaction potential, such as SPT blow counts, CPT penetration tip pressure/resistance, and
34 gradation of soil, would also be obtained. SPT blow counts and CPT tip pressure are used to estimate
35 soil 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 earthquake (i.e., the earthquake that is
38 expected to produce the strongest level of ground shaking at a site to which it is appropriate to
39 design a structure to withstand). If soil resistance is less than induced stress, the potential of having
40 liquefaction during the design earthquakes is high. It is also known that soil with high "fines" (i.e.,
41 silt- and clay-sized particles) content are less susceptible to liquefaction.

42 **NEPA Effects:** The potential effect could be substantial because construction-related ground motions
43 could initiate liquefaction, which could cause failure of structures during construction, which could
44 result in injury of workers at the construction sites. Some of the potential levee effects that could

1 occur during the construction in the absence of corrective measures may include rutting, settlement,
2 and slope movement.

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

23 As with the effects related to design of conveyance facilities, potential construction traffic effects on
24 levees would be assessed prior to project construction to determine specific geotechnical issues
25 related to construction traffic loading. Based on the initial assessment from field reconnaissance,
26 geotechnical exploration and analyses would be performed for levee sections that need further
27 evaluations. Should the geotechnical evaluations indicate that certain segments of existing levee
28 roads need improvements to carry the expected construction truck traffic loads, DWR is committed
29 to carry out the necessary improvements to the affected levee sections or to find an alternative route
30 that would avoid the potential deficient levee sections (Mitigation Measures TRANS-2a through 2c).
31 As discussed in Chapter 19, *Transportation*, Mitigation Measure TRANS-2c, all affected roadways
32 would be returned to preconstruction condition or better following construction. Implementation of
33 this measure would ensure that construction activities would not worsen pavement and levee
34 conditions, relative to existing conditions. Prior to construction, DWR would make a good faith effort
35 to enter into mitigation agreements with or to obtain encroachment permits from affected agencies
36 to verify what the location, extent, timing, and fair share cost to be paid by the DWR for any
37 necessary pre- and post-construction physical improvements. Levee roads that are identified as
38 potential haul routes and expected to carry significant construction truck traffic would be monitored
39 to ensure that truck traffic is not adversely affecting the levee and to identify the need for corrective
40 action.

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

1 In particular, conformance with the following codes and standards would reduce the potential risk
 2 for 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*,
 6 ER 1110-2-1806, 1995.
- 7 • 8 CCR Sections 1509 and 3203.

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).

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

19 Conformance to construction methods recommendations and other applicable specifications, as well
 20 as implementation of Mitigation Measures TRANS-2a through 2c, would ensure that construction of
 21 Alternative 1B would not create an increased likelihood of loss of property, personal injury or death
 22 of individuals due to construction- and traffic-related ground motions and resulting potential
 23 liquefaction in the work area. The effect would not be adverse.

24 **CEQA Conclusion:** Construction-related ground motions and traffic effects could initiate
 25 liquefaction, which could cause failure of structures during construction, which could result in injury
 26 of workers at the construction sites. The impact would be significant. However, DWR has committed
 27 to conform to Cal-OSHA and other state code requirements and conform to applicable design
 28 guidelines and standards, such as USACE design measures. Conformance with these requirements
 29 and the application of accepted, proven construction engineering practices, in addition to
 30 implementation of Mitigation Measures TRANS-2a and TRANS-2b, as well as the maintenance and
 31 reconstruction of levees through Mitigation Measure TRANS-2c, would reduce any potential risk
 32 such that construction of Alternative 1A would not create an increased likelihood of loss of property,
 33 personal injury or death of individuals from construction-related ground motion and resulting
 34 potential liquefaction in the work area, and the hazard would be controlled to a level that would
 35 protect worker safety (see Appendix 3B, *Environmental Commitments, AMMs, and CMs*). The impact
 36 would be less than significant.

37 **Mitigation Measure TRANS-2a: Prohibit Construction Activity on Physically Deficient** 38 **Roadway Segments**

39 Please refer to Mitigation Measure TRANS-2a in Alternative 1A, Impact TRANS-2, in Chapter 19,
 40 *Transportation*.

1 **Mitigation Measure TRANS-2b: Limit Construction Activity on Physically Deficient**
 2 **Roadway Segments**

3 Please refer to Mitigation Measure TRANS-2b in Alternative 1A, Impact TRANS-2, in Chapter 19,
 4 *Transportation*.

5 **Mitigation Measure TRANS-2c: Improve Physical Condition of Affected Roadway Segments**
 6 **as Stipulated in Mitigation Agreements or Encroachment Permits**

7 Please refer to Mitigation Measure TRANS-2c in Alternative 1A, Impact TRANS-2, in Chapter 19,
 8 *Transportation*.

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 According to the available AP Earthquake Fault Zone Maps, none of the Alternative 1B facilities
 12 would cross or be within any known active fault zones. However, numerous AP fault zones have
 13 been mapped west of the conveyance alignment (Figure 9-5). The closest AP fault zone would be the
 14 Greenville fault, located approximately 13 miles west of the Alternative 1B conveyance alignment.
 15 Because none of the Alternative 1B constructed facilities would be within any of the fault zones
 16 (which include the area approximately 200 to 500 feet on each side of the mapped surface trace to
 17 account for potential branches of active faults), the potential that the facilities would be directly
 18 subject to fault offsets is negligible.

19 In the Delta, active or potentially active blind thrust faults were identified in the seismic study.
 20 Segments 2, 3, 4, and 5 of Alternative 1B conveyance alignment would cross the Thornton Arch fault
 21 zone. The western part of the proposed Byron Tract Forebay adjacent to the Clifton Court Forebay is
 22 underlain by the West Tracy fault. Although these blind thrusts are not expected to rupture to the
 23 ground surface under the forebays during earthquake events, they may produce ground or
 24 near-ground shear zones, bulging, or both (California Department of Water Resources 2007a).
 25 Assuming that the West Tracy fault is potentially active, it could cause surface deformation in the
 26 western part of the Clifton Court Forebay. Because the western part of the Byron Tract Forebay is
 27 also underlain by the hanging wall of the fault, this part of the forebay may also experience uplift
 28 and resultant surface deformation (Fugro Consultants 2011). In the seismic study (California
 29 Department of Water Resources 2007a), the Thornton Arch and West Tracy blind thrusts have been
 30 assigned 20% and 90% probabilities of being active, respectively. The depth to the Thornton Arch
 31 blind thrust is unknown. The seismic study indicates that the West Tracy fault dies out as a
 32 discernible feature within approximately 3,000 to 6,000 feet bgs (in the upper 1 to 2 second depth
 33 two-way time, estimated to be approximately 3,000 to 6,000 feet using the general velocity function
 34 as published in the Association of Petroleum Geologists Pacific Section newsletter [Tolmachoff
 35 1993]).

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

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

1 However, because of the limited information regarding the depths of the Thornton Arch and West
 2 Tracy blind thrusts, seismic surveys would be performed on the faults during the design phase to
 3 determine the depths to the top of the faults. More broadly, design-level geotechnical studies would
 4 be prepared by a geotechnical engineer licensed in the state of California during project design. The
 5 studies would further assess site-specific conditions at and near all the project facility locations,
 6 including seismic activity, soil liquefaction, and other potential geologic and soil-related hazards.
 7 This information would be used to verify assumptions and conclusions included in the EIR/EIS. The
 8 geotechnical engineer's recommended measures to address adverse conditions would conform to
 9 applicable design codes, guidelines, and standards. Potential design strategies or conditions could
 10 include avoidance (deliberately positioning structures and lifelines to avoid crossing identified
 11 shear rupture zones), geotechnical engineering (using the inherent capability of unconsolidated
 12 geomaterials to "locally absorb" and distribute distinct bedrock fault movements) and structural
 13 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*, such design codes, guidelines, and standards are
 16 environmental commitments by DWR (see also Appendix 3B, *Environmental Commitments, AMMs,*
 17 *and CMs*). For construction of the water conveyance facilities, the codes and standards would
 18 include the California Building Code and resource agency and professional engineering
 19 specifications, such as the Division of Safety of Dams *Guidelines for Use of the Consequence-Hazard*
 20 *Matrix and Selection of Ground Motion Parameters*, DWR's Division of Flood Management *FloodSAFE*
 21 *Urban Levee Design Criteria*, and USACE's *Engineering and Design—Earthquake Design and*
 22 *Evaluation for Civil Works Projects*. These codes and standards include minimum performance
 23 standards for structural design, given site-specific subsurface conditions.

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

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

- 31 ● DWR Division of Engineering *State Water Project—Seismic Loading Criteria Report*, September
 32 2012.
- 33 ● USACE *Engineering and Design—Time-History Dynamic Analysis of Concrete Hydraulic Structures*,
 34 EM 1110-2-6051, 2003.
- 35 ● USACE *Engineering and Design—Response Spectra and Seismic Analysis for Concrete Hydraulic*
 36 *Structures*, EM 1110-2-6050, 1999.
- 37 ● American Society of Civil Engineers *Minimum Design Loads for Buildings and Other Structures*,
 38 ASCE/SEI 7-10, 2010.
- 39 ● 8 CCR 3203.

40 Generally, the applicable codes require that facilities be built so that they incur minimal damage in
 41 the event of a foreseeable seismic event and that they remain functional following such an event and
 42 that the facility is able to perform without catastrophic failure in the event of a maximum design

1 earthquake (the greatest earthquake reasonably expected to be generated by a specific source on
2 the basis of seismological and geological evidence).

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

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

15 **CEQA Conclusion:** There are no active fault capable of surface rupture that extend into the
16 Alternative 1B alignment. Although the Thornton Arch and West Tracy blind thrusts occur beneath
17 the Alternative 1B alignment, based on available information, they do not present a hazard of
18 surface rupture. Conformance to applicable design specifications and standards would ensure that
19 operation of Alternative 1B would not create an increased likelihood of loss of property, injury or
20 death of individuals in the event of ground movement in the vicinity of the Thornton Arch fault zone
21 or West Tracy blind thrusts and would not jeopardize the integrity of the surface and subsurface
22 facilities along the Alternative 1B conveyance alignment or the proposed forebay and associated
23 facilities adjacent to the Clifton Court Forebay. There would be no impact. 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 Earthquake events may occur on the local and regional seismic sources during operation of the
27 Alternative 1B water conveyance facilities. The ground shaking could damage the canals, pipelines,
28 tunnel and culvert siphons, intake facilities, pumping plants, and other facilities, disrupting the
29 water supply through the conveyance system. In an extreme event of strong seismic shaking,
30 uncontrolled release of water from the damaged canal, pipelines, tunnel siphons, intake facilities,
31 pumping plants, and other facilities could cause flooding, disruption of water supplies to the south,
32 and inundation of structures. These effects are discussed more fully in Appendix 3E, *Potential*
33 *Seismicity and Climate Change Risks to SWP/CVP Water Supplies*. The potential of earthquake ground
34 shaking in the early long-term (2025) was estimated using the results of the seismic study
35 (California Department of Water Resources 2007a). Table 9-21 lists the expected PGA and 1.0-S_a
36 values for early long-term. Earthquake ground shakings for the OBE (144-year return period) and
37 MDE (975-year return period) were estimated for the stiff soil site, as predicted in the seismic study
38 (California Department of Water Resources 2007a), and for the anticipated soil conditions at the
39 facility locations. No seismic study results exist for 2025, so the ground shakings estimated for 2050
40 were used for early long-term.

41 Table 9-21 shows that the proposed facilities would be subject to moderate-to-high earthquake
42 ground shakings in the Early Long-term through 2025. All facilities would be designed and
43 constructed in accordance with the requirements of the design measures described in Appendix 3B,
44 *Environmental Commitments, AMMs, and CMs*. Site-specific geotechnical information would be used

1 to further assess the effect of local soil on the OBE and MDE ground shakings and to develop design
2 criteria to minimize the potential of damage.

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

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

15 **Table 9-21. Expected Earthquake Ground Motions at Locations of Selected Major Facilities in the Early**
16 **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.

17
18 As described in Section 9.3.1, *Methods for Analysis*, and in Appendix 3B, *Environmental Commitments*,
19 *AMMs*, and *CMs*, such design codes, guidelines, and standards include the California Building Code
20 and resource agency and professional engineering specifications, such as the Division of Safety of
21 *Dams Guidelines for Use of the Consequence-Hazard Matrix and Selection of Ground Motion*
22 *Parameters*, DWR's Division of Flood Management *FloodSAFE Urban Levee Design Criteria*, and

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
 3 that ground shaking risks are minimized as the water conveyance features are operated.

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

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

- 12 • DWR Division of Engineering *State Water Project—Seismic Loading Criteria Report*, September
 13 2012.
- 14 • USACE *Engineering and Design—Time-History Dynamic Analysis of Concrete Hydraulic Structures*,
 15 EM 1110-2-6051, 2003.
- 16 • USACE *Engineering and Design—Response Spectra and Seismic Analysis for Concrete Hydraulic*
 17 *Structures*, EM 1110-2-6050, 1999.
- 18 • American Society of Civil Engineers *Minimum Design Loads for Buildings and Other Structures*,
 19 ASCE/SEI 7-10, 2010.
- 20 • 8 CCR 3203.

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

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

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 from strong seismic shaking of surface and subsurface facilities along
 37 the Alternative 1B conveyance alignment. Therefore, there would be no adverse effect.

38 **CEQA Conclusion:** Seismically induced strong ground shaking could damage the canals, pipelines,
 39 tunnel and culvert siphons, intake facilities, pumping plants, and other facilities. The damage could
 40 disrupt SWP and CVP water supply deliveries through the conveyance system. In an extreme event,
 41 an uncontrolled release of water from the damaged conveyance system could cause flooding and
 42 inundation of structures. (Please refer to Appendix 3E, *Potential Seismicity and Climate Change Risks*

1 to SWP/CVP Water Supplies, for a detailed discussion of potential flood impacts.) However, through
 2 the final design process, measures to address this hazard would be required to conform to
 3 applicable design codes, guidelines, and standards. As described in Section 9.3.1, *Methods for*
 4 *Analysis*, and in Appendix 3B, *Environmental Commitments, AMMs, and CMs*, such design codes,
 5 guidelines, and standards include the California Building Code and resource agency and professional
 6 engineering specifications, such as the Division of Safety of Dams' *Guidelines for Use of the*
 7 *Consequence-Hazard Matrix and Selection of Ground Motion Parameters*, DWR's Division of Flood
 8 Management *FloodSAFE Urban Levee Design Criteria*, and USACE's *Engineering and Design—*
 9 *Earthquake Design and Evaluation for Civil Works Projects*. Conformance with these codes and
 10 standards is an environmental commitment by DWR to ensure that ground shaking risks are
 11 minimized as the Alternative 1B water conveyance features are operated and there would be no
 12 increased likelihood of loss of property, personal injury or death of individuals. The hazard would be
 13 controlled to a safe level. The impact would be less than significant. No mitigation is required.

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

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

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

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

38 In the process of preparing final facility designs, site-specific geotechnical and groundwater
 39 investigations would be conducted to identify and characterize the vertical (depth) and horizontal
 40 (spatial) extents of liquefiable soil. Engineering soil parameters that could be used to further assess
 41 the liquefaction potential, such as SPT blow counts, CPT penetration tip pressure/resistance, and
 42 gradation of soil, would also be obtained. SPT blow counts and CPT tip pressure are used to estimate
 43 soil resistance to cyclic loadings by using empirical relationships that were developed based on
 44 occurrences of liquefaction (or lack of them) during past earthquakes. The resistance then can be

1 compared to cyclic shear stress induced by the design earthquakes. If soil resistance is less than
 2 induced stress, the potential of having liquefaction during the design earthquakes is high. It is also
 3 known that soil with high “fines” (i.e., silt- and clay-sized particles) content are less susceptible to
 4 liquefaction.

5 During final design, site-specific potential for liquefaction would be investigated by a geotechnical
 6 engineer. In areas determined to have a potential for liquefaction, a California-registered civil
 7 engineer or California-certified engineering geologist would develop design measures and
 8 construction methods to meet design criteria established by building codes and construction
 9 standards to ensure that the design earthquake does not cause damage to or failure of the facility.
 10 Such measures and methods include removing and replacing potentially liquefiable soil,
 11 strengthening foundations (for example, and using post-tensioned slab, reinforced mats, and piles)
 12 to resist excessive total and differential settlements, using *in situ* ground improvement techniques
 13 (such as deep dynamic compaction, vibro-compaction, vibro-replacement, compaction grouting, and
 14 other similar methods). The results of the site-specific evaluation and California-registered civil
 15 engineer or California-certified engineering geologist’s recommendations would be documented in a
 16 detailed geotechnical report prepared in accordance with state guidelines, in particular *Guidelines*
 17 *for Evaluating and Mitigating Seismic Hazards in California* (California Geological Survey 2008). As
 18 described in Section 9.3.1, *Methods for Analysis*, and in Appendix 3B, *Environmental Commitments,*
 19 *AMMs, and CMs*, such design codes, guidelines, and standards include USACE’s *Engineering and*
 20 *Design—Earthquake Design and Evaluation for Civil Works Projects* and *Soil Liquefaction during*
 21 *Earthquakes*, by the Earthquake Engineering Research Institute. Conformance with these design
 22 requirements is an environmental commitment by DWR to ensure that liquefaction risks are
 23 minimized as the water conveyance features are operated.

24 DWR would ensure that the geotechnical design recommendations are included in the design of
 25 project facilities and construction specifications to minimize the potential effects from liquefaction
 26 and associated hazard. DWR would also ensure that the design specifications are properly executed
 27 during construction.

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

- 31 ● DWR Division of *Engineering State Water Project—Seismic Loading Criteria Report*, September
 32 2012.
- 33 ● USACE *Engineering and Design—Time-History Dynamic Analysis of Concrete Hydraulic Structures*,
 34 EM 1110-2-6051, 2003.
- 35 ● USACE *Engineering and Design—Response Spectra and Seismic Analysis for Concrete Hydraulic*
 36 *Structures*, EM 1110-2-6050, 1999.
- 37 ● American Society of Civil Engineers *Minimum Design Loads for Buildings and Other Structures*,
 38 ASCE/SEI 7-10, 2010.
- 39 ● USACE *Engineering and Design—Design of Pile Foundations*, EM 1110-2-2906, 1991
- 40 ● 8 CCR 3203.

41 Generally, the applicable codes require that facilities be built so that if soil in the foundation or
 42 surrounding area are subject to liquefaction, the removal or densification of the liquefiable material

1 should be considered, along with alternative foundation designs. Additionally, any modification to a
2 federal levee system would require USACE approval under 33 USC 408 (a 408 Permit).

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

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

14 **CEQA Conclusion:** Seismically induced ground shaking could cause liquefaction. Liquefaction could
15 damage the canals, pipelines, tunnel and culvert siphons, intake facilities, pumping plants, and other
16 facilities, and thereby disrupt the water supply through the conveyance system. In an extreme event,
17 flooding and inundation of structures could result from an uncontrolled release of water from the
18 damaged conveyance system. (Please refer to Chapter 6, *Surface Water*, for a detailed discussion of
19 potential flood effects.) However, through the final design process, measures to address the
20 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, AMMs, and CMs*, such design codes, guidelines, and standards include USACE's
23 *Engineering and Design—Stability Analysis of Concrete Structures and Soil Liquefaction during*
24 *Earthquakes*, by the Earthquake Engineering Research Institute. Conformance with these design
25 standards is an environmental commitment by DWR to ensure that liquefaction risks are minimized
26 as the Alternative 1B water conveyance features are operated and there would be no increased
27 likelihood of loss of property, personal injury or death of individuals. The hazard would be
28 controlled to a safe level. The impact would be 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 Alternative 1B would involve excavation that creates new cut-and-fill slopes and construction of
32 new embankments and levees. As a result of ground shaking and high soil-water content during
33 heavy rainfall, existing and new slopes that are not properly engineered and natural stream banks
34 could fail. Levees can fail for several reasons: 1) high velocities of water flow can result in high rates
35 of erosion and erode and overtop a levee; 2) the higher velocities of water flow can also lead to
36 higher rates of erosion along the inner parts of levees and lead to undercutting and clumping of the
37 levee into the river. Heavy rainfall or seepage into the levee from the river can increase fluid
38 pressure in the levee and lead to slumping on the outer parts of the levee. If the slumps grow to the
39 top of the levee, large sections of the levee may slump onto the floodplain and lower the elevation of
40 the top of the levee, leading to overtopping; 3) increasing levels of water in the river will cause the
41 water table in the levee to rise which will increase fluid pressure and may result in seepage and
42 eventually lead to internal erosion called piping. Piping will erode the material under the levee,
43 undermining it and causing its collapse and failure.

1 With the exception of levee slopes and natural stream banks, the topography along the Alternative
2 1B conveyance alignment is nearly level to very gently sloping. The areas susceptible to slope failure
3 are along existing levee slopes and at intake, pumping plant, forebay, and certain access road
4 locations. Outside these areas, the land is nearly level and consequently has a negligible potential for
5 slope failure.

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

8 **NEPA Effects:** The potential effect could be substantial because levee slopes and stream banks may
9 fail, either from high pore-water pressure caused by high rainfall and weak soil, or from seismic
10 shaking. Structures constructed on these slopes could be damaged or fail entirely as a result of slope
11 instability. As discussed in Impact SW-2 in Chapter 6, *Surface Water*, operation of the water
12 conveyance features under Alternative 1B would not result in an increase in potential risk for flood
13 management compared to existing conditions. Peak monthly flows under Alternative 1B in the
14 locations considered were similar to or less than those that would occur under existing conditions.
15 Since flows would not be substantially greater, the potential for increased rates of erosion or
16 seepage are low. For additional discussion on the possible exposure of people or structures to a
17 significant risk of loss or injury from flooding due to levee failure, please refer to Impact SW-6 in
18 Chapter 6, *Surface Water*.

19 During project design, a geotechnical engineer would develop slope stability design criteria (such as
20 minimum slope safety factors and allowable slope deformation and settlement) for the various
21 anticipated loading conditions. The design criteria would be documented in a detailed geotechnical
22 report prepared in accordance with state guidelines, in particular *Guidelines for Evaluating and*
23 *Mitigating Seismic Hazards in California* (California Geological Survey 2008). As discussed in Chapter
24 3, *Description of the Alternatives*, the foundation soil beneath slopes, embankments, or levees could
25 be improved to increase its strength and to reduce settlement and deformation. Foundation soil
26 improvement could involve excavation and replacement with engineered fill; preloading; ground
27 modifications using jet-grouting, compaction grouting, chemical grouting, shallow soil mixing, deep
28 soil mixing, vibro-compaction, or vibro-replacement; or other methods. Engineered fill also would
29 be used to construct new slopes, embankments, and levees. Surface and internal drainage systems
30 would be installed as necessary to reduce erosion and piping (internal erosion) potential.

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

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

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

- 1 • DWR Division of Engineering *State Water Project—Seismic Loading Criteria Report*, September
- 2 2012.
- 3 • DWR Division of Flood Management *FloodSAFE Urban Levee Design Criteria*, May 2012.
- 4 • USACE *Slope Stability*, EM 1110-2-1902, 2003.
- 5 • 8 CCR 3203.

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

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

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

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

34 **Impact GEO-10: Loss of Property, Personal Injury, or Death from Seiche or Tsunami during** 35 **Operation of Water Conveyance Features**

36 Based on recorded tsunami wave heights at the Golden Gate (Contra Costa Transportation Agency
 37 2009) and in the interior of the San Francisco Bay and on tsunami inundation maps prepared by the
 38 California Department of Conservation (2009), the height of a tsunami wave reaching the Suisun
 39 Marsh and the Delta would be small because of the distance from the ocean and attenuating effect of
 40 the San Francisco Bay. Therefore, the potential hazard of loss of property or personal injury as a
 41 result of a tsunami on the water conveyance facilities is low.

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

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

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

19 However, design-level geotechnical studies would be conducted by a licensed civil engineer who
 20 practices in geotechnical engineering. The studies would determine the peak ground acceleration
 21 caused by movement of the West Tracy fault and the maximum probable seiche wave that could be
 22 generated by the ground shaking. The engineer's recommended measures to address this hazard, as
 23 well as the hazard of a seiche overtopping the Clifton Court Forebay embankment and subsequent
 24 adverse effect on the Byron Tract Forebay embankment, would conform to applicable design codes,
 25 guidelines, and standards. As described in Section 9.3.1, *Methods for Analysis*, and in Appendix 3B,
 26 *Environmental Commitments, AMMs, and CMs*, such design codes, guidelines, and standards include
 27 the Division of Safety of Dams *Guidelines for Use of the Consequence-Hazard Matrix and Selection of*
 28 *Ground Motion Parameters*, DWR's Division of Flood Management *FloodSAFE Urban Levee Design*
 29 *Criteria*, and USACE's *Engineering and Design—Earthquake Design and Evaluation for Civil Works*
 30 *Projects*. Conformance with these codes and standards is an environmental commitment by DWR to
 31 ensure that the adverse effects of a seiche are controlled to an acceptable level while the forebay
 32 facility is operated.

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

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

- 39 ● U.S. Department of the Interior and USGS *Climate Change and Water Resources Management: A*
 40 *Federal Perspective*, Circular 1331.
- 41 ● State of California Sea-Level Rise Task Force of the CO-CAT, *Sea-Level Rise Interim Guidance*
 42 *Document*, 2010.
- 43 ● 8 CCR 3203.

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

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

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

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

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

32 **Impact GEO-11: Ground Failure Caused by Increased Groundwater Surface Elevations from** 33 **Unlined Canal Seepage as a Result of Operating the Water Conveyance Facilities**

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

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

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

- 9 • Use of a drainage ditch parallel to the canal to control seepage. Water in the drainage ditch
 10 would then be pumped into the sloughs or back into the canal.
- 11 • Installation of pressure-relief wells to collect subsurface water and direct it into the parallel
 12 drainage ditch.

13 As indicated above and in Chapter 3, *Description of the Alternatives*, engineers would use site-specific
 14 geotechnical and hydrological information to design the canal, and the design would conform to the
 15 current standards and construction practices specified by USACE and DWR design standards. As
 16 described in Section 9.3.1, *Methods for Analysis*, such design codes, guidelines, and standards are
 17 environmental commitments by DWR (see also Appendix 3B, *Environmental Commitments, AMMs,*
 18 *and CMs*). For construction of the canal and any required seepage control measures, the codes and
 19 standards would include the California Building Code and resource agency and professional
 20 engineering specifications, such as USACE's *Engineering and Design—Earthquake Design and*
 21 *Evaluation for Civil Works Projects*. These codes and standards include minimum performance
 22 standards for structural design, given site-specific subsurface conditions.

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

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

- 29 • USACE *Engineering and Design—Earthquake Design and Evaluation for Civil Works Projects*,
 30 ER 1110-2-1806, 1995.
- 31 • USACE *Engineering and Design—Settlement Analysis*, EM 1110-1-1904, 1990.
- 32 • USACE *Slope Stability*, EM 1110-2-1902, 2003.
- 33 • DWR Division of Flood Management *FloodSAFE Urban Levee Design Criteria*, May 2012.
- 34 • 8 CCR 3203.

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

38 The worker safety codes and standards specify protective measures that must be taken at
 39 workplaces to minimize the risk of injury or death from structural or earth failure (e.g., utilizing
 40 personal protective equipment). The relevant codes and standards represent performance
 41 standards that must be met by employers and these measures are subject to monitoring by state and

1 local agencies. Cal-OSHA requirements for an IIPP and the terms of the IIPP to protect worker safety
2 are the principal measures that would be enforced at workplaces during operations.

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

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

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

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

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

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

37 Because there is limited information regarding the depths of the blind faults mentioned above,
38 seismic surveys would be performed in the vicinity of the faults as part of final design. These surveys
39 would be used to verify fault depths where levees and other features would be constructed.
40 Collection of this depth information would be part of broader, design-level geotechnical studies
41 prepared by a licensed engineer to support all aspects of site-specific project design. The studies
42 would assess site-specific conditions at and near all the project facility locations, including the
43 nature and engineering properties of all soil horizons and underlying geologic strata, and

1 groundwater conditions. The engineer's information would be used to develop final engineering
 2 solutions to any hazardous condition, consistent with the code and standards requirements of
 3 federal, state and local oversight agencies. As described in Section 9.3.1, *Methods for Analysis*, and in
 4 Appendix 3B, *Environmental Commitments, AMMs, and CMs*, such design codes, guidelines, and
 5 standards include the California Building Code and resource agency and professional engineering
 6 specifications, such as the Division of Safety of Dams' *Guidelines for Use of the Consequence-Hazard*
 7 *Matrix and Selection of Ground Motion Parameters*, DWR's Division of Flood Management *FloodSAFE*
 8 *Urban Levee Design Criteria*, and USACE's *Engineering and Design—Earthquake Design and*
 9 *Evaluation for Civil Works Projects*. Conformance with these design standards is an environmental
 10 commitment by the BDCP proponents to ensure that risks from a fault rupture are minimized as
 11 levees for habitat restoration areas are constructed and maintained. The hazard would be controlled
 12 to a safe level by following the proper design standards.

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

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

- 20 ● DWR Division of Engineering *State Water Project—Seismic Loading Criteria Report*, September
 21 2012.
- 22 ● DWR DSOD *Guidelines for Use of the Consequence-Hazard Matrix and Selection of Ground Motion*
 23 *Parameters*, 2002.
- 24 ● USACE *Engineering and Design—Earthquake Design and Evaluation for Civil Works Projects*,
 25 ER 1110-2-1806, 1995.
- 26 ● USACE *Design and Construction of Levees*, EM 1110-2-1913, 2000.
- 27 ● USACE (CESPK-ED-G), *Geotechnical Levee Practice*, SOP EDG-03, 2004.
- 28 ● DWR Division of Flood Management *FloodSAFE Urban Levee Design Criteria*, May 2012.
- 29 ● 8 CCR Sections 1509 and 3203.

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

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

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

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

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

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

30 Among all the ROAs, the Suisun Marsh ROA would be most subject to ground shaking because of its
 31 proximity to active faults. The Suisun Marsh ROA is subject to a PGA of approximately 0.31 to 0.35 g
 32 for 200-year return interval, while the PGA for the other ROAs ranges from approximately 0.11 to
 33 0.26 g. The ground shaking could damage levees and other structures, and in an extreme event cause
 34 levees to fail such that protected areas flood.

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

42 Design-level geotechnical studies would be prepared by a geotechnical engineer licensed in the state
 43 of California during project design. The studies would assess site-specific conditions at and near all

1 the project facility locations and provide the basis for designing the levees and other features to
 2 withstand the peak ground acceleration caused by fault movement in the region. The geotechnical
 3 engineer's recommended measures to address this hazard would conform to applicable design
 4 codes, guidelines, and standards. Potential design strategies or conditions could include avoidance
 5 (deliberately positioning structures and lifelines to avoid crossing identified shear rupture zones),
 6 geotechnical engineering (using the inherent capability of unconsolidated geomaterials to "locally
 7 absorb" and distribute distinct bedrock fault movements) and structural engineering (engineering
 8 the facility to undergo some limited amount of ground deformation without collapse or significant
 9 damage).

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

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

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

- 26 • DWR Division of Engineering *State Water Project—Seismic Loading Criteria Report*, September
 27 2012.
- 28 • DWR DSOD *Guidelines for Use of the Consequence-Hazard Matrix and Selection of Ground Motion*
 29 *Parameters*, 2002.
- 30 • USACE *Engineering and Design—Earthquake Design and Evaluation for Civil Works Projects*,
 31 ER 1110-2-1806, 1995.
- 32 • USACE *Design and Construction of Levees*, EM 1110-2-1913, 2000.
- 33 • USACE (CESPK-ED-G), *Geotechnical Levee Practice*, SOP EDG-03, 2004.
- 34 • DWR Division of Flood Management *FloodSAFE Urban Levee Design Criteria*, May 2012.
- 35 • 8 CCR Sections 1509 and 3203.

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

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

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

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
 14 to active faults. The Suisun Marsh ROA is subject to a PGA of approximately 0.31 to 0.35 g for 200-
 15 year return interval, while the PGA for the other ROAs ranges from approximately 0.11 to 0.26 g.
 16 Damage to 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, AMMs, and CMs*, design codes, guidelines, and standards, including the California
 19 Building Code and resource agency and professional engineering specifications, such as DWR's
 20 Division of Flood Management *FloodSAFE Urban Levee Design Criteria* and USACE's *Engineering and*
 21 *Design—Earthquake Design and Evaluation for Civil Works Projects* would be used for final design of
 22 conservation features. Conformance with these design standards is an environmental commitment
 23 by the BDCP proponents to ensure that strong seismic shaking risks are minimized as the
 24 conservation measures are operated and there would be no increased likelihood of loss of property,
 25 personal injury or death of individuals in the ROAs. The impact would be less than significant. No
 26 mitigation is required.

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

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

38 The ROAs vary with respect to their liquefaction hazard (Figure 9-6). Levees in the Suisun Marsh
 39 ROA generally have a “medium” vulnerability to seismically induced failure. The liquefaction
 40 damage potential among the other ROAs is generally low to medium.

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

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

12 During final design, the facility-specific potential for liquefaction would be investigated by a
 13 geotechnical engineer. In areas determined to have a potential for liquefaction, the engineer would
 14 develop design parameters and construction methods to meet the design criteria established to
 15 ensure that design earthquake does not cause damage to or failure of the facility. Such measures and
 16 methods include removing and replacing potentially liquefiable soil, strengthening foundations (for
 17 example, using post-tensioned slab, reinforced mats, and piles) to resist excessive total and
 18 differential settlements, using *in situ* ground improvement techniques (such as deep dynamic
 19 compaction, vibro-compaction, vibro-replacement, compaction grouting, and other similar
 20 methods), and conforming to current seismic design codes and requirements, as described in
 21 Section 9.3.1, *Methods for Analysis*, and in Appendix 3B, *Environmental Commitments, AMMs, and*
 22 *CMs*, 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 the BDCP proponents to ensure that liquefaction risks are minimized as the
 26 conservation measures are implemented. The hazard would be controlled to a safe level.

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

- 30 • USACE *Engineering and Design—Design of Pile Foundations*, EM 1110-2-2906, 1991.
- 31 • USACE *Engineering and Design—Stability Analysis of Concrete Structures*, EM 1110-2-2100, 2005.
- 32 • USACE *Engineering and Design—Earthquake Design and Evaluation for Civil Works Projects*,
 33 ER 1110-2-1806, 1995.
- 34 • 8 CCR Sections 1509 and 3203.

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.

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

1 terms of the IIPP to protect worker safety are the principal measures that would be enforced at
2 workplaces.

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

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

22 **Impact GEO-15: Loss of Property, Personal Injury, or Death from Landslides and Other Slope** 23 **Instability at Restoration Opportunity Areas**

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

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

40 New and existing levee slopes and stream/channel banks could fail and could damage facilities as a
41 result of seismic shaking and as a result of high soil-water content during heavy rainfall. With the
42 exception of levee slopes, natural stream banks, and part of the Suisun Marsh ROA, the topography
43 of ROAs is nearly level to gently sloping. The areas that may be susceptible to slope failure are along
44 existing Sacramento and San Joaquin River and Delta island levees and stream/channel banks

1 particularly those levees that consist of non-engineered fill and those streambanks that are steep
2 and consist of low strength soil.

3 The structures associated with conservation measures would not be constructed in, nor would they
4 be 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
6 fail, either from high pore-water pressure caused by high rainfall and weak soil, or from seismic
7 shaking. Failure of these features could result in flooding of otherwise protected areas.

8 As outlined in Chapter 3, *Description of Alternatives*, erosion protection measures and protection
9 against related failure of adjacent levees would be taken where levee breaches were developed.
10 Erosion protection could include geotextile fabrics, rock revetments, or other material selected
11 during future evaluations for each location. Aggregate rock could be placed on the remaining levees
12 to provide an access road to the breach location. Erosion protection measures would also be taken
13 where levee lowering is done for the purposes of allowing seasonal or periodic inundation of lands
14 during high flows or high tides to improve habitat or to reduce velocities and elevations of
15 floodwaters. To reduce erosion potential on the new levee crest, a paved or gravel access road could
16 be constructed with short (approximately 1 foot) retaining walls on each edge of the crest to reduce
17 undercutting of the roadway by high tides. Levee modifications could also include excavation of
18 watersides of the slopes to allow placement of slope protection, such as riprap or geotextile fabric,
19 and to modify slopes to provide levee stability. Erosion and scour protection could be placed on the
20 landside of the levee and continued for several feet onto the land area away from the levee toe.
21 Neighboring levees could require modification to accommodate increased flows or to reduce effects
22 of changes in water elevation or velocities along channels following inundation of tidal marshes.
23 Hydraulic modeling would be used during subsequent analyses to determine the need for such
24 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
27 described for the new levees at intake locations. Any new levees would be required to be designed
28 and implemented to conform to applicable flood management standards and permitting processes.
29 This would be coordinated with the appropriate flood management agencies, which may include
30 USACE, 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
33 the various anticipated loading conditions. As required by design standards and building codes (see
34 Appendix 3B, *Environmental Commitments, AMMs, and CMs*), foundation soil beneath embankments
35 and levees could be improved to increase its strength and to reduce settlement and deformation.
36 Foundation soil improvement could involve excavation and replacement with engineered fill;
37 preloading; ground modifications using jet-grouting, compaction grouting, chemical grouting,
38 shallow soil mixing, deep soil mixing, vibro-compaction, or vibro-replacement; or other methods.
39 Engineered fill could also be used to construct new embankments and levees.

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

1 The BDCP proponents would ensure that the geotechnical design recommendations are included in
 2 the design of embankments and levees to minimize the potential effects from slope failure. The
 3 BDCP 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
 6 for 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*, September
 9 2012.
- 10 • DWR Division of Flood Management *FloodSAFE Urban Levee Design Criteria*, May 2012.
- 11 • USACE *Slope Stability*, EM 1110-2-1902, 2003.
- 12 • 8 CCR 3203.

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
 15 parameters.

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

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

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

32 **Impact GEO-16: Loss of Property, Personal Injury, or Death from Seiche or Tsunami at** 33 **Restoration Opportunity Areas as a Result of Implementing the Conservation Actions**

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

37 **CEQA Conclusion:** Based on recorded tsunami wave heights at the Golden Gate, the height of a
 38 tsunami wave reaching the ROAs would be small because of the distance from the ocean and
 39 attenuating effect of the San Francisco Bay. Similarly, the potential for a significant seiche to occur in
 40 the Plan Area that would cause loss of property, personal injury, or death at the ROAs is considered

1 low because conditions for a seiche to occur at the ROAs are not favorable. The impact would be less
2 than significant. No mitigation is required.

3 **9.3.3.4 Alternative 1C—Dual Conveyance with West Alignment and** 4 **Intakes W1–W5 (15,000 cfs; Operational Scenario A)**

5 **Impact GEO-1: Loss of Property, Personal Injury, or Death from Structural Failure Resulting** 6 **from Strong Seismic Shaking of Water Conveyance Features during Construction**

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

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

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

21 **Table 9-22. Expected Earthquake Ground Motions at Locations of Selected Major Facilities during**
22 **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.

23

24 **NEPA Effects:** The seismic study employed time-dependent seismic source models for several major
25 faults in the region. These models were characterized based on the elapsed times since the last
26 major seismic events on the faults. Therefore, the exposure risks predicted by the study would
27 increase if no major events occur on these faults through 2020. The effect would be adverse because

1 seismically induced ground shaking could cause collapse of facilities. For example, the concrete
 2 batch plant and fuel station on Bradford Island, several siphons, a fuel station and concrete batch
 3 plant west of Clifton Court Forebay, the entire length of the water conveyance from the middle of
 4 Ryer Island down to the Byron Tract Forebay for Alternative 1C all lie on or near the Southern
 5 Midland fault, a single, potentially seismogenic fault; or the West Tracy fault. Both are active blind
 6 faults, resulting in an increased likelihood of loss of property or personal injury at these sites in the
 7 event of seismically induced ground shaking. Although these blind thrusts are not expected to
 8 rupture to the ground surface under the forebays during earthquake events, they may produce
 9 ground or near-ground shear zones, bulging, or both (California Department of Water Resources
 10 2007a). For a map of all permanent facilities and temporary work areas associated with this
 11 conveyance alignment, see Mapbook Figure M3-3.

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

- 19 ● DWR Division of Engineering *State Water Project—Seismic Loading Criteria Report*, September
 20 2012.
- 21 ● USACE *Engineering and Design—Earthquake Design and Evaluation for Civil Works Projects*,
 22 ER 1110-2-1806, 1995.
- 23 ● USACE *Engineering and Design—Earthquake Design and Evaluation of Concrete Hydraulic*
 24 *Structures*, EM 1110-2-6053, 2007.
- 25 ● USACE *Engineering and Design—Response Spectra and Seismic Analysis for Concrete Hydraulic*
 26 *Structures*, EM 1110-2-6050, 1999.
- 27 ● USACE *Engineering and Design—Stability Analysis of Concrete Structures*, EM 1110-2-2100, 2005.
- 28 ● 8 CCR Sections 1509 and 3203.

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

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

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

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

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

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

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

1 The conveyance pipeline between Intake 4 and the canal would intersect with one canal or ditch,
 2 about 0.3 miles northwest of the facility grounds for Intake 4. The conveyance pipeline between
 3 Intake 5 and the canal would cross two canals or ditches. These lie east and southeast of Elk Slough,
 4 approximately 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
 6 the 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
 10 site-specific geotechnical and hydrological conditions along the canal, as well as where intake and
 11 forebay pipelines cross waterways and major irrigation canals. A California-registered civil engineer
 12 or California-certified engineering geologist would recommended measures in a geotechnical report
 13 to address these hazards, such as seepage cutoff walls and barriers, shoring, grouting of the bottom
 14 of the excavation, and strengthening of nearby structures, existing utilities, or buried structures. As
 15 described in Section 9.3.1, *Methods for Analysis*, the measures would conform to applicable design
 16 and building codes, guidelines, and standards, such as the California Building Code and USACE's
 17 *Engineering and Design—Structural Design and Evaluation of Outlet Works*. See Appendix 3B,
 18 *Environmental Commitments, AMMs, and CMs*.

19 In particular, conformance with the following codes and standards would reduce the potential risk
 20 for 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 • 8 CCR Sections 1509 and 3203.

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

35 The worker safety codes and standards specify protective measures that must be taken at
 36 construction sites to minimize the risk of injury or death from structural or earth failure (e.g.,
 37 utilizing personal protective equipment, practicing crane and scaffold safety measures). The
 38 relevant codes and standards represent performance standards that must be met by contractors and
 39 these measures are subject to monitoring by state and local agencies. Cal-OSHA requirements for an
 40 IIPP and the terms of the IIPP to protect worker safety are the principal measures that would be
 41 enforced at construction 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 to 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
10 standard requirements to minimize potential risks (Appendix 3B, *Environmental Commitments,*
11 *AMMs, and CMs*). Conformance with these requirements and the application of accepted, proven
12 construction engineering practices would reduce any potential risk such that construction of
13 Alternative 1C would not create an increased likelihood of loss of property, personal injury or death
14 of individuals from settlement or collapse caused by dewatering. The impact would be less than
15 significant. No mitigation is required.

16 **Impact GEO-3: Loss of Property, Personal Injury, or Death from Ground Settlement during** 17 **Construction of Water Conveyance Features**

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

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

33 The geologic units in the area of the Alternative 1C alignment are shown on Figure 9-3 and
34 summarized in Table 9-23. The characteristics of each unit would affect the potential for settlement
35 during tunnel construction. Segment 4, located from the middle of Ryer Island running south to just
36 west of Summer Lake, is primarily where the tunnel portion of Alternative 1C lies. Much of Segment
37 4 contains eolian (i.e., wind-deposited), fine- and medium-grained sand than other parts of the
38 segment, so these sandy areas pose a greater risk of settlement.

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

Sources: Hansen et al. 2001; Atwater 1982.
^a The segments are shown on Figure 9-3.

2

3 Operator errors or highly unfavorable/unexpected ground conditions could result in larger
4 settlement. Large ground settlements caused by tunnel construction are almost always the result of
5 using inappropriate tunneling equipment (incompatible with the ground conditions), improperly
6 operating the machine, or encountering sudden or unexpected changes in ground conditions.

7 Given the likely design depth of the tunnel, the amount of settlement beneath developed areas and
8 critical infrastructure (i.e., the village of Hood, SR 4 and SR 12, the EBMUD aqueduct, and a
9 potentially sensitive satellite dish facility) would be minor. At the evaluated infrastructure, the
10 predicted maximum ground surface settlement would range from 0.0 to 2.9 inches, with a change in
11 ground slope ratio ranging from 0 to 1:714 (the higher value corresponding to a 0.14% slope). The

1 width of the settlement “trough,” as a cross-section oriented perpendicular to the tunnel alignment,
 2 would be 328 to 525 feet among the evaluated facilities. Other facilities that may be determined to
 3 be critical infrastructure include natural gas pipelines, the proposed EBMUD tunnel, levees, and local
 4 electrical distribution and communication lines.

5 **NEPA Effects:** Although the potential effect is expected to be minor, during detailed project design, a
 6 site-specific subsurface geotechnical evaluation would be conducted along the water conveyance
 7 facility alignment to verify or refine the findings of the preliminary geotechnical investigations. The
 8 tunneling equipment and drilling methods would be reevaluated and refined based on the results of
 9 the investigations, and field procedures for sudden changes in ground conditions would be
 10 implemented to minimize or avoid ground settlement. A California-registered civil engineer or
 11 California-certified engineering geologist would recommend measures to address these hazards,
 12 such as specifying the type of tunnel boring machine to be used in a given segment. The results of
 13 the site-specific evaluation and the engineer’s recommendations would be documented in a detailed
 14 geotechnical report, which will contain site-specific evaluations of the settlement hazard associated
 15 with the site-specific soil conditions overlying the tunnel throughout the alignment. The report will
 16 also contain recommendations for the type of tunnel boring machine to be used and the tunneling
 17 techniques to be applied to avoid excessive settlement for specific critical assets, such as buildings,
 18 major roads, natural gas pipelines, electrical and communication lines, aqueducts, bridges, levees,
 19 and sensitive satellite dish facilities. Also included in the report will be recommendations for
 20 geotechnical and structural instrumentation for monitoring of settlement.

21 As described in Section 9.3.1, *Methods for Analysis*, the measures would conform to applicable design
 22 guidelines and standards, such as USACE design measures. See Appendix 3B, *Environmental*
 23 *Commitments, AMMs, and CMs*. In particular, conformance with the following federal design manuals
 24 and professional society and geotechnical literature would be used to predict the maximum amount
 25 of settlement that could occur for site-specific conditions, to identify the maximum allowable
 26 settlement for individual critical assets, and to develop recommendations for tunneling to avoid
 27 excessive settlement, all to minimize the likelihood of loss of property or personal injury from
 28 ground settlement above the tunneling operation during construction.

- 29 • *Technical Design Manual for Design and Construction of Road Tunnels* (U.S. Department of
 30 Transportation, Federal Highway Administration 2009).
- 31 • *A Method of Estimating Surface Settlement above Tunnels Constructed in Soft Ground* (National
 32 Research Council of Canada 1983).
- 33 • *Predicting the Dynamics of Ground Settlement and its Derivatives Caused by Tunnelling in Soil*
 34 (Attewell and Woodman 1982).
- 35 • *Predicting the Settlements above Twin Tunnels Constructed in Soft Ground* (Chapman et al. 2004).
- 36 • *Report on Settlements Induced by Tunneling in Soft Ground* (International Tunneling Association
 37 2007).
- 38 • *Closed-Face Tunnelling Machines and Ground Stability: A Guideline for Best Practice* (British
 39 Tunnelling Society 2005).

40 As described in detail in Impacts GEO-1 and GEO-2, DWR would ensure that the geotechnical design
 41 recommendations are included in the design of project facilities and construction specifications to
 42 minimize the potential effects from settlement. DWR would also ensure that the design
 43 specifications are properly executed during construction. DWR has made this conformance and

1 monitoring process an environmental commitment of the BDCP (Appendix 3B, *Environmental*
2 *Commitments, AMMs, and CMs*).

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

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

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

24 **Impact GEO-4: Loss of Property, Personal Injury, or Death from Slope Failure during** 25 **Construction of Water Conveyance Features**

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

32 Borrow and spoils areas for construction of the canal foundation, intakes, sedimentation basins,
33 pumping plants, forebays, and other supporting facilities would be sited near the locations of these
34 structures (generally within 10 miles). Along the alignment, selected areas would also be used for
35 disposing of the byproduct (RTM) of tunnel construction. Table 9-24 describes the geology of these
36 areas as mapped by Atwater (1982) (Figure 9-3).

1 **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

Sources: Hansen et al. 2001; Atwater 1982.

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

2

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

6 Excavations in borrow areas would be designed to avoid excessive ground movements on adjacent
7 areas and soil “boiling” (i.e., upwelling of groundwater) at the bottom of the excavation. Spoils would
8 be placed in 12-inch lifts with proper compaction and stored no higher than 12 feet above
9 preconstruction ground elevation with maximum side slopes of 5H:1V. During design, the potential
10 for native ground settlement below the spoils would be evaluated by a geotechnical engineer using
11 site-specific geotechnical and hydrological information. The use of shoring, seepage cutoff walls, and
12 ground modifications to prevent slope instability, soil boiling, or excessive settlement would be
13 considered in the design. As described in Section 9.3.1, *Methods for Analysis*, the measures would
14 conform to applicable design and building codes, guidelines, and standards, such as the California
15 Building Code and USACE’s *Engineering and Design—Structural Design and Evaluation of Outlet
16 Works*.

17 In addition to the risk of slope failure at borrow sites and spoils and RTM sites, there are also
18 potential impacts on levee stability resulting from construction of Alternative 1C water conveyance

1 facilities. The intakes would be sited along the existing Sacramento River levee system, requiring
2 reconstruction of levees to provide continued flood management. At each intake pumping plant site,
3 a new setback levee (ring levee) would be constructed. The space enclosed by the setback levee
4 would be filled up to the elevation of the top of the setback levee, creating a building pad for the
5 adjacent pumping plant.

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

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

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

- 1 • DWR Division of Engineering *State Water Project—Seismic Loading Criteria Report*, September
- 2 2012.
- 3 • DWR Division of Flood Management *FloodSAFE Urban Levee Design Criteria*, May 2012.
- 4 • 8 CCR Sections 1509 and 3203.

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

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

21 **CEQA Conclusion:** Settlement/failure of cutslopes of borrow sites and failure of soil/RTM fill slopes
 22 could result in loss of property or personal injury during construction. However, because DWR
 23 would conform to Cal-OSHA and other state code requirements and conform to applicable
 24 geotechnical design guidelines and standards, such as USACE design measures. Conformance with
 25 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
 27 increased likelihood of loss of property, personal injury or death of individuals from slope failure at
 28 borrow sites and spoils and RTM storage sites. The maintenance and reconstruction of levees would
 29 improve levee stability over existing conditions due to improved side slopes, erosion control
 30 measures, seepage reduction measures, and overall mass. The impact would be less than significant.
 31 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** 34 **Features**

35 Pile driving and other heavy equipment operations would cause vibrations that could initiate
 36 liquefaction and associated ground movements in places where soil and groundwater conditions are
 37 present to allow liquefaction to occur. The consequences of liquefaction could be manifested in
 38 terms of compaction or settlement, loss of bearing capacity, lateral spreading (horizontal soil
 39 movement), increased lateral soil pressure, and buoyancy within zones of liquefaction. These
 40 consequences could cause loss of property or personal injury and could damage nearby structures
 41 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. In addition to pile driving activities,
6 construction of the water conveyance facilities would require an increased volume of truck and
7 heavy equipment traffic that may occur at some of these locations. Although the trucks and heavy
8 equipment could generate vibrations in the levees, the severity of the vibrations is not expected to
9 be capable of initiating liquefaction. Construction related to conveyance facilities would also require
10 regular access to construction sites, extending the length of the project. Some of the existing public
11 roads would be used as haul routes for the construction of conveyance facilities. Use of the state
12 highway system as haul routes would be maximized where feasible because these roadways are
13 rated for truck traffic and would generally provide the most direct and easily maneuverable routes
14 for large loads. As part of future engineering phases, haul routes needed for the construction of the
15 approved project would be refined. Construction traffic may need to access levee roads at various
16 points along SR 160 and other state routes as shown in Figure 9-7, as well as at locations shown
17 along the West Alignment in Figure 9-8a. Because of the volume of truck traffic that may occur at
18 some of these locations, there is the potential for some effect on levee integrity at various locations
19 depending on the site specific levee conditions along access routes.

20 During project design, site-specific geotechnical and groundwater investigations would be
21 conducted to build upon existing data (e.g., California Department of Water Resources 2009b,
22 2010d, 2010i) to identify and characterize the vertical (depth) and horizontal (spatial) variability in
23 soil bearing capacity and extent of liquefiable soil. Engineering soil parameters that could be used to
24 assess the liquefaction potential, such as SPT blow counts, CPT penetration tip pressure/resistance,
25 and gradation of soil, would also be obtained. SPT blow counts and CPT tip pressure are used to
26 estimate soil resistance to cyclic loadings by using empirical relationships that were developed
27 based on occurrences of liquefaction (or lack of them) during past earthquakes (i.e., the earthquake
28 that is expected to produce the strongest level of ground shaking at a site to which it is appropriate
29 to design a structure to withstand). The resistance then can be compared to cyclic shear stress
30 induced by the design earthquakes. If soil resistance is less than induced stress, the potential of
31 having liquefaction during the design earthquakes is high. It is also known that soil with high “fines”
32 (i.e., silt- and clay-sized particles) content are less susceptible to liquefaction.

33 **NEPA Effects:** The potential effect could be substantial because construction-related ground motions
34 could initiate liquefaction, which could cause failure of structures during construction. Some of the
35 potential levee effects that could occur during the construction in the absence of corrective
36 measures may include rutting, settlement, and slope movement.

37 During design, the facility-specific potential for liquefaction would be investigated by a geotechnical
38 engineer. The potential effects of construction vibrations on nearby structures, levees, and utilities
39 would be evaluated using specific piling information (such as pile type, length, spacing, and pile-
40 driving hammer to be used). In areas determined to have a potential for liquefaction, the engineer
41 would develop design measures and construction methods to ensure that pile driving and heavy
42 equipment operations do not damage facilities under construction and surrounding structures and
43 do not threaten the safety of workers at the site. As shown in Figure 9-6, a majority of Alternative 1C
44 crosses through an area classified as medium to low liquefaction hazard. Alternative 1C also runs
45 through Brannan Island and Twitchell Island, which have medium to medium-high levee

1 liquefaction damage potential. A barge unloading facility is located at the northern end of Brannan
 2 Island in this medium to medium-high levee liquefaction damage potential area. Design strategies
 3 may include predrilling or jetting, using open-ended pipe piles to reduce the energy needed for pile
 4 penetration, using CIDH piles/piers that do not require driving, using pile jacking to press piles into
 5 the ground by means of a hydraulic system, or driving piles during the drier summer months. Field
 6 data collected during design also would be evaluated to determine the need for and extent of
 7 strengthening levees, embankments, and structures to reduce the effect of vibrations. These
 8 construction methods would conform to current seismic design codes and requirements, as
 9 described in Chapter 3, *Description of the Alternatives*. Such design standards include USACE's
 10 *Engineering and Design—Stability Analysis of Concrete Structures and Soil Liquefaction during*
 11 *Earthquakes*, by the Earthquake Engineering Research Institute.

12 As with the effects related to design of conveyance facilities, potential construction traffic effects on
 13 levees would be assessed prior to project construction to determine specific geotechnical issues
 14 related to construction traffic loading. Based on the initial assessment from field reconnaissance,
 15 geotechnical exploration and analyses would be performed for levee sections that need further
 16 evaluations. Should the geotechnical evaluations indicate that certain segments of existing levee
 17 roads need improvements to carry the expected construction truck traffic loads, DWR is committed
 18 to carry out the necessary improvements to the affected levee sections or to find an alternative route
 19 that would avoid the potential deficient levee sections (Mitigation Measures TRANS-2a through 2c).
 20 As discussed in Chapter 19, *Transportation*, Mitigation Measure TRANS-2c, all affected roadways
 21 would be returned to preconstruction condition or better following construction. Implementation of
 22 this measure would ensure that construction activities would not worsen pavement and levee
 23 conditions, relative to existing conditions. Prior to construction, DWR would make a good faith effort
 24 to enter into mitigation agreements with or to obtain encroachment permits from affected agencies
 25 to verify what the location, extent, timing, and fair share cost to be paid by the DWR for any
 26 necessary pre- and post-construction physical improvements. Levee roads that are identified as
 27 potential haul routes and expected to carry significant construction truck traffic would be monitored
 28 to ensure that truck traffic is not adversely affecting the levee and to identify the need for corrective
 29 action.

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

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

- 38 • USACE *Engineering and Design—Design of Pile Foundations*, EM 1110-2-2906, 1991.
- 39 • USACE *Engineering and Design—Earthquake Design and Evaluation for Civil Works Projects*,
 40 ER 1110-2-1806, 1995.
- 41 • 8 CCR Sections 1509 and 3203.

42 Generally, the applicable codes require that facilities be built so that if soil in the foundation or
 43 surrounding area are subject to liquefaction, the removal or densification of the liquefiable material

1 should be considered, along with alternative foundation designs. Additionally, any modification to a
2 federal levee system would require USACE approval under 33 USC 408 (a 408 Permit).

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

10 Conformance to construction methods recommendations and other applicable specifications, as well
11 as implementation of Mitigation Measures TRANS-2a through 2c, would ensure that construction of
12 Alternative 1C would not create an increased likelihood of loss of property, personal injury or death
13 of individuals due to construction- and traffic-related ground motions and resulting potential
14 liquefaction in the work area. Therefore, the effect would not be adverse.

15 **CEQA Conclusion:** Construction-related ground motions and traffic effects could initiate
16 liquefaction, which could cause failure of structures during construction, which could result in injury
17 of workers at the construction sites. The impact could be significant. However, DWR has committed
18 to conform to Cal-OSHA and other state code requirements and conform to applicable design
19 guidelines and standards, such as USACE design measures. Conformance with these requirements
20 and the application of accepted, proven construction engineering practices, in addition to
21 implementation of Mitigation Measures TRANS-2a and TRANS-2b, as well as the maintenance and
22 reconstruction of levees through Mitigation Measure TRANS-2c, would reduce any potential risk
23 such that construction of Alternative 1C would not create an increased likelihood of loss of property,
24 personal injury or death of individuals from construction-related ground motion and resulting
25 potential liquefaction in the work area and the hazard would be controlled to a level that would
26 protect worker safety (see Appendix 3B, *Environmental Commitments, AMMs, and CMs*). The impact
27 would be less than significant.

28 **Mitigation Measure TRANS-2a: Prohibit Construction Activity on Physically Deficient**
29 **Roadway Segments**

30 Please refer to Mitigation Measure TRANS-2a in Alternative 1A, Impact TRANS-2, in Chapter 19,
31 *Transportation*.

32 **Mitigation Measure TRANS-2b: Limit Construction Activity on Physically Deficient**
33 **Roadway Segments**

34 Please refer to Mitigation Measure TRANS-2b in Alternative 1A, Impact TRANS-2, in Chapter 19,
35 *Transportation*.

36 **Mitigation Measure TRANS-2c: Improve Physical Condition of Affected Roadway Segments**
37 **as Stipulated in Mitigation Agreements or Encroachment Permits**

38 Please refer to Mitigation Measure TRANS-2c in Alternative 1A, Impact TRANS-2, in Chapter 19,
39 *Transportation*.

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 According to the available AP Earthquake Fault Zone Maps, none of the Alternative 1C facilities
 4 would cross or be within any known active fault zones. However, numerous AP fault zones have
 5 been mapped west of the conveyance alignment (Figure 9-5). The closest AP fault zone would be the
 6 Greenville fault, located approximately 8.1 miles west of the Alternative 1C conveyance facilities.
 7 The Midway fault is also mapped approximately 3.4 miles west of the Alternative 1C conveyance
 8 facilities, near the cities of Tracy and Livermore. Because none of the Alternative 1C constructed
 9 facilities would be within any of the fault zones (which include the area approximately 200 to 500
 10 feet on each side of the mapped surface trace to account for potential branches of active faults) the
 11 potential that the facilities would be directly subject to fault offsets is negligible.

12 In the Delta, active or potentially active blind thrust faults were identified in the seismic study.
 13 Segment 4 of the Alternative 1C conveyance alignment would cross the Southern Midland fault and
 14 continue through the Montezuma Hills fault zone. Segment 5 and part of Segment 6 would also cross
 15 the Montezuma Hills fault zone. The western part of the proposed Byron Tract Forebay adjacent to
 16 the Clifton Court Forebay is underlain by the West Tracy fault and the southernmost segment of the
 17 Southern Midland fault. Although these blind thrusts are not expected to rupture to the ground
 18 surface under the forebays during earthquake events, they may produce ground or near-ground
 19 shear zones, bulging, or both (California Department of Water Resources 2007a). Assuming that the
 20 West Tracy fault is potentially active, it could cause surface deformation in the western part of the
 21 Clifton Court Forebay. Because the western part of the Byron Tract Forebay is also underlain by the
 22 hanging wall of the fault, this part of the forebay may also experience uplift and resultant surface
 23 deformation (Fugro Consultants 2011). In the seismic study, the South Midland, Montezuma Hills,
 24 and West Tracy blind thrusts were assigned 80%, 50%, and 90% probabilities of being active,
 25 respectively (California Department of Water Resources 2007a).

26 The depth to the Montezuma Hills faults is unknown. The seismic study (California Department of
 27 Water Resources 2007a) indicates that the West Tracy fault dies out as a discernible feature within
 28 approximately 3,000 to 6,000 feet bgs (in the upper 1 to 2 second depth two-way time, estimated to
 29 be approximately 3,000 to 6,000 feet using the general velocity function as published in the
 30 Association of Petroleum Geologists Pacific Section newsletter [Tolmachoff 1993]). This same study
 31 indicates that the tip of the Southern Midway fault is said to extend above the base of the Tertiary
 32 Markley Formation to depths of about 1.5 km or 4,900 feet, and possibly shallower. The minimum
 33 fault depth has not been determined.

34 It appears that the potential of having any shear zones, bulging, or both at the depths of the canal
 35 and the proposed forebay at Clifton Court is low because the depth to the blind thrust faults is
 36 generally deep.

37 **NEPA Effects:** The effect would not be adverse, because no active faults capable of surface rupture
 38 extend into the Alternative 1C alignment. Additionally, although the West Tracy blind thrust occurs
 39 beneath the Alternative 1C alignment, based on available information, it do not present a hazard of
 40 surface rupture.

41 However, because there is limited information regarding the depths of these faults, seismic surveys
 42 would be performed on the South Midland, Montezuma Hills, and West Tracy blind thrusts during
 43 the design phase to determine the depths to the top of the faults. More broadly, design-level
 44 geotechnical studies would be prepared by a geotechnical engineer licensed in the state of California

1 during project design. The studies would further assess site-specific conditions at and near all the
 2 project facility locations, including seismic activity, soil liquefaction, and other potential geologic
 3 and soil-related hazards. This information would be used to verify assumptions and conclusions
 4 included in the EIR/EIS. The geotechnical engineer's recommended measures to address adverse
 5 conditions would conform to applicable design codes, guidelines, and standards. Potential design
 6 strategies or conditions could include avoidance (deliberately positioning structures and lifelines to
 7 avoid crossing identified shear rupture zones), geotechnical engineering (using the inherent
 8 capability of unconsolidated geomaterials to "locally absorb" and distribute distinct bedrock fault
 9 movements) and structural engineering (engineering the facility to undergo some limited amount of
 10 ground deformation without collapse or significant damage).

11 As described in Section 9.3.1, *Methods for Analysis*, such design codes, guidelines, and standards are
 12 environmental commitments by DWR (see also Appendix 3B, *Environmental Commitments, AMMs,*
 13 *and CMs*). For construction of the water conveyance facilities, the codes and standards would
 14 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*
 18 *Evaluation for Civil Works Projects*. These codes and standards include minimum performance
 19 standards for structural design, given site-specific subsurface conditions.

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

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

- 27 ● DWR Division of Engineering *State Water Project—Seismic Loading Criteria Report*, September
 28 2012.
- 29 ● USACE *Engineering and Design—Time-History Dynamic Analysis of Concrete Hydraulic Structures*,
 30 EM 1110-2-6051, 2003.
- 31 ● USACE *Engineering and Design—Response Spectra and Seismic Analysis for Concrete Hydraulic*
 32 *Structures*, EM 1110-2-6050, 1999.
- 33 ● American Society of Civil Engineers *Minimum Design Loads for Buildings and Other Structures*,
 34 ASCE/SEI 7-10, 2010.
- 35 ● 8 CCR 3203.

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

41 The worker safety codes and standards specify protective measures that must be taken at
 42 workplaces to minimize the risk of injury or death from structural or earth failure (e.g., utilizing

1 personal protective equipment). The relevant codes and standards represent performance
 2 standards that must be met by employers and these measures are subject to monitoring by state and
 3 local agencies. Cal-OSHA requirements for an IIPP and the terms of the IIPP to protect worker safety
 4 are the principal measures that would be enforced at workplaces.

5 Conformance to these and other applicable design specifications and standards would ensure that
 6 operation of Alternative 1C would not create an increased likelihood of loss of property, injury or
 7 death of individuals in the event of ground movement in the vicinity of the South Midland,
 8 Montezuma Hills, and West Tracy blind thrusts and would not jeopardize the integrity of the surface
 9 and subsurface facilities along the Alternative 1C conveyance alignment or the proposed forebay
 10 and associated facilities adjacent to the Clifton Court Forebay. Therefore, there would be no adverse
 11 effect.

12 **CEQA Conclusion:** There are no active faults capable of surface rupture that extend into the
 13 Alternative 1C alignment. Although the Montezuma Hills, West Tracy and South Midland blind
 14 thrusts occur beneath the Alternative 1C alignment, based on available information, they do not
 15 present a hazard of surface rupture. Conformance to applicable design specifications and standards
 16 would ensure that operation of Alternative 1C would not create an increased likelihood of loss of
 17 property, personal injury or death of individuals in the event of ground movement in these areas
 18 and would not jeopardize the integrity of the surface and subsurface facilities along the Alternative
 19 1C conveyance alignment or the proposed forebay and associated facilities adjacent to the Clifton
 20 Court Forebay. There would be no impact. No mitigation is required.

21 **Impact GEO-7: Loss of Property, Personal Injury, or Death from Structural Failure Resulting** 22 **from Strong Seismic Shaking during Operation of Water Conveyance Features**

23 Earthquake events may occur on the local and regional seismic sources during operation of the
 24 Alternative 1C water conveyance facilities. The ground shaking could damage the canals, pipelines,
 25 tunnels, culvert siphons, intake facilities, pumping plants, and other facilities, disrupting the water
 26 supply through the conveyance system. In an extreme event of strong seismic shaking, uncontrolled
 27 release of water from the damaged canal, pipelines, tunnel, culvert siphons, intake facilities,
 28 pumping plants, and other facilities could cause flooding, disruption of water supplies to the south,
 29 and inundation of structures. These effects are discussed more fully in Appendix 3E, *Potential*
 30 *Seismicity and Climate Change Risks to SWP/CVP Water Supplies*.

31 The potential of earthquake ground shaking in the early long-term (2025) was estimated using the
 32 results of the seismic study (California Department of Water Resources 2007a). Table 9-25 lists the
 33 expected PGA and 1.0-S_a values in 2025 at selected facility locations for the early long-term.
 34 Earthquake ground shaking for the OBE (144-year return period) and MDE (975-year return period)
 35 was estimated for the stiff soil site, as predicted in the seismic study (California Department of
 36 Water Resources 2007a), and for the anticipated soil conditions at the facility locations. No seismic
 37 study results exist for 2025, so the ground shaking estimated for 2050 was used for the early long-
 38 term (2025).

39 Table 9-25 shows that the proposed facilities would be subject to moderate-to-high earthquake
 40 ground shaking in the early long-term (2025). All facilities would be designed and constructed in
 41 accordance with the requirements of the design measures described earlier in this chapter.
 42 Site-specific geotechnical information would be used to further assess the effect of local soil on the
 43 OBE and MDE ground shaking and to develop design criteria to minimize the potential of damage.

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

7 **Table 9-25. Expected Earthquake Ground Motions at Locations of Selected Major Facilities in the Early**
 8 **Long-Term (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.

9

10 Design-level geotechnical studies would be conducted by a licensed civil engineer who practices in
 11 geotechnical engineering. The studies would assess site-specific conditions at and near all the
 12 project facility locations and provide the basis for designing the conveyance features to withstand
 13 the peak ground acceleration caused by fault movement in the region. The California-registered civil
 14 engineer or California-certified engineering geologist's recommended measures to address this
 15 hazard would conform to applicable design codes, guidelines, and standards. As described in in the
 16 methodology section in this chapter and in Appendix 3B, *Environmental Commitments, AMMs, and*
 17 *CMs*, such design codes, guidelines, and standards include the California Building Code and resource
 18 agency and professional engineering specifications, such as the Division of Safety of Dams' *Guidelines*
 19 *for Use of the Consequence-Hazard Matrix and Selection of Ground Motion Parameters*, DWR's
 20 Division of Flood Management *FloodSAFE Urban Levee Design Criteria*, and USACE's *Engineering and*
 21 *Design—Earthquake Design and Evaluation for Civil Works Projects*. Conformance with these codes
 22 and standards are an environmental commitment by DWR to ensure that ground shaking risks are
 23 minimized as the water conveyance features are operated.

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

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

- 9 • DWR Division of *Engineering State Water Project—Seismic Loading Criteria Report*, September
 10 2012.
- 11 • USACE *Engineering and Design—Time-History Dynamic Analysis of Concrete Hydraulic Structures*,
 12 EM 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/SEI 7-10, 2010.
- 17 • 8 CCR 3203.

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

23 Conformance with these standards and codes are an environmental commitment of the project (see
 24 Appendix 3B, *Environmental Commitments, AMMs, and CMs*). The worker safety codes and standards
 25 specify protective measures that must be taken at workplaces to minimize the risk of injury or death
 26 from structural or earth failure (e.g., utilizing personal protective equipment). The relevant codes
 27 and standards represent performance standards that must be met by employers and these measures
 28 are subject to monitoring by state and local agencies. Cal-OSHA requirements for an IIPP and the
 29 terms of the IIPP to protect worker safety are the principal measures that would be enforced at
 30 workplaces during operations.

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

36 **CEQA Conclusion:** Seismically induced strong ground shaking could damage the canals, pipelines,
 37 culvert siphons, intake facilities, pumping plants, and other facilities. The damage could disrupt the
 38 water supply through the conveyance system. In an extreme event, an uncontrolled release of water
 39 from the damaged conveyance system could cause flooding and inundation of structures. (Please
 40 refer to Chapter 6, *Surface Water*, for a detailed discussion of potential flood impacts.) However,
 41 through the final design process, measures to address this hazard would be required to conform to
 42 applicable design codes, guidelines, and standards. As described in Section 9.3.1, *Methods for*

1 *Analysis*, and in Appendix 3B, *Environmental Commitments, AMMs, and CMs*, such design codes,
 2 guidelines, and standards include the California Building Code and resource agency and professional
 3 engineering specifications, such as the Division of Safety of Dams *Guidelines for Use of the*
 4 *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—*
 6 *Earthquake Design and Evaluation for Civil Works Projects*. Conformance with these codes and
 7 standards is an environmental commitment by DWR to ensure that ground shaking risks are
 8 minimized as the Alternative 1C water conveyance features are operated and there would be no
 9 increased likelihood of loss of property, personal injury or death of individuals. The hazard would be
 10 controlled to a safe level. The impact would be less than significant. No mitigation is required.

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

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

22 The native soils underlying the southern part of the Alternative 1C alignment consist primarily of
 23 alluvial fan and terrace deposits, including clay, silt, sand and gravels of variable density. The
 24 northern part of the alignment is more variable in composition, consisting of natural levee, basin,
 25 and Delta mud deposits. The central portion (Segment 4), through which the tunnel would be
 26 constructed, consists of natural levee, eolian sand, Delta mud, alluvial fans, and dredge spoils. The
 27 more recently deposited, sandy materials would be more prone to liquefaction. Figure 9-6 shows
 28 that the Alternative 1C alignment has no substantial liquefaction damage potential in its northern
 29 part and low to medium-high damage potential in its central and southern parts.

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

37 In the process of preparing final facility designs, site-specific geotechnical and groundwater
 38 investigations would be conducted to identify and characterize the vertical (depth) and horizontal
 39 (spatial) extents of liquefiable soil. Engineering soil parameters that could be used to further assess
 40 the liquefaction potential, such as SPT blow counts, CPT penetration tip pressure/resistance, and
 41 gradation of soil, would also be obtained. SPT blow counts and CPT tip pressure are used to estimate
 42 soil resistance to cyclic loadings by using empirical relationships that were developed based on
 43 occurrences of liquefaction (or lack of them) during past earthquakes. The resistance then can be
 44 compared to cyclic shear stress induced by the design earthquakes. If soil resistance is less than

1 induced stress, the potential of having liquefaction during the design earthquakes is high. It is also
 2 known that soil with high “fines” (i.e., silt- and clay-sized particles) content are less susceptible to
 3 liquefaction.

4 During final design, site-specific potential for liquefaction would be investigated by a geotechnical
 5 engineer. In areas determined to have a potential for liquefaction, a California-registered civil
 6 engineer or California-certified engineering geologist would develop design measures and
 7 construction methods to meet design criteria established by building codes and construction
 8 standards to ensure that design earthquake does not cause damage to or failure of the facility. Such
 9 measures and methods include removing and replacing potentially liquefiable soil, strengthening
 10 foundations (for example, and using post-tensioned slab, reinforced mats, and piles) to resist
 11 excessive total and differential settlements, using *in situ* ground improvement techniques (such as
 12 deep dynamic compaction, vibro-compaction, vibro-replacement, compaction grouting, and other
 13 similar methods). The results of the site-specific evaluation and California-registered civil engineer
 14 or California-certified engineering geologist’s recommendations would be documented in a detailed
 15 geotechnical report prepared in accordance with state guidelines, in particular *Guidelines for*
 16 *Evaluating and Mitigating Seismic Hazards in California* (California Geological Survey 2008). As
 17 described in Section 9.3.1, *Methods for Analysis*, and in Appendix 3B, *Environmental Commitments,*
 18 *AMMs, and CMs*, such design codes, guidelines, and standards include USACE’s *Engineering and*
 19 *Design—Earthquake Design and Evaluation for Civil Works Projects and Liquefaction during*
 20 *Earthquakes*, by the Earthquake Engineering Research Institute. Conformance with these design
 21 requirements is an environmental commitment by DWR to ensure that liquefaction risks are
 22 minimized as the water conveyance features are operated.

23 DWR would ensure that the geotechnical design recommendations are included in the design of
 24 project facilities and construction specifications to minimize the potential effects from liquefaction
 25 and associated hazard. DWR would also ensure that the design specifications are properly executed
 26 during construction.

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

- 30 ● DWR Division of *Engineering State Water Project—Seismic Loading Criteria Report*, September
 31 2012.
- 32 ● USACE *Engineering and Design—Time-History Dynamic Analysis of Concrete Hydraulic Structures*,
 33 EM 1110-2-6051, 2003.
- 34 ● USACE *Engineering and Design—Response Spectra and Seismic Analysis for Concrete Hydraulic*
 35 *Structures*, EM 1110-2-6050, 1999.
- 36 ● American Society of Civil Engineers *Minimum Design Loads for Buildings and Other Structures*,
 37 ASCE/SEI 7-10, 2010.
- 38 ● USACE *Engineering and Design—Design of Pile Foundations*, EM 1110-2-2906, 1991
- 39 ● 8 CCR 3203.

40 Generally, the applicable codes require that facilities be built so that if soil in the foundation or
 41 surrounding area are subject to liquefaction, the removal or densification of the liquefiable material

1 should be considered, along with alternative foundation designs. Additionally, any modification to a
2 federal levee system would require USACE approval under 33 USC 408 (a 408 Permit).

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

9 Conformance to these and other applicable design specifications and standards would ensure that
10 the hazard of liquefaction and associated ground movements would not create an increased
11 likelihood of loss of property, personal injury or death of individuals from structural failure of
12 surface and subsurface facilities resulting from seismic-related ground failure along the Alternative
13 1C conveyance alignment during operation of the water conveyance features. Therefore, the effect
14 would not be adverse.

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

31 **Impact GEO-9: Loss of Property, Personal Injury, or Death from Landslides and Other Slope** 32 **Instability during Operation of Water Conveyance Features**

33 Alternative 1C would involve excavation that creates new cut-and-fill slopes and construction of
34 new embankments and levees. As a result of ground shaking and high soil-water content during
35 heavy rainfall, existing and new slopes that are not properly engineered and natural stream banks
36 could fail and cause damage to facilities. Levees can fail for several reasons: 1) high velocities of
37 water flow can result in high rates of erosion and erode and overtop a levee; 2) the higher velocities
38 of water flow can also lead to higher rates of erosion along the inner parts of levees and lead to
39 undercutting and clumping of the levee into the river. Heavy rainfall or seepage into the levee from
40 the river can increase fluid pressure in the levee and lead to slumping on the outer parts of the levee.
41 If the slumps grow to the top of the levee, large sections of the levee may slump onto the floodplain
42 and lower the elevation of the top of the levee, leading to overtopping; 3) increasing levels of water
43 in the river will cause the water table in the levee to rise which will increase fluid pressure and may

1 result in seepage and eventually lead to internal erosion called piping. Piping will erode the material
2 under the levee, undermining it and causing its collapse and failure.

3 With the exception of levee slopes and natural stream banks, the topography along the Alternative
4 1C conveyance alignment is nearly level to very gently sloping. The areas that may be susceptible to
5 slope failure are along existing levee slopes and at intake, pumping plant, forebay, and certain access
6 road locations. Outside these areas, the land is nearly level and consequently has a negligible
7 potential for slope failure.

8 Based on review of topographic and a landslide map of Alameda County (Roberts et al. 1999), the
9 conveyance facilities would not be constructed on, nor would it be adjacent to, slopes that are
10 subject to mudflows/debris flows from natural slopes.

11 **NEPA Effects:** The effect would be adverse because levee slopes and stream banks may fail, either
12 from high pore-water pressure caused by high rainfall and weak soil, or from seismic shaking.
13 Structures constructed on these slopes could be damaged or fail entirely as a result of slope
14 instability. As discussed in Impact SW-2 in Chapter 6, *Surface Water*, operation of the water
15 conveyance features under Alternative 1C would not result in an increase in potential risk for flood
16 management compared to existing conditions. Peak monthly flows under Alternative 1C in the
17 locations considered were similar to or less than those that would occur under existing conditions.
18 Since flows would not be substantially greater, the potential for increased rates of erosion or
19 seepage are low. For additional discussion on the possible exposure of people or structures to a
20 significant risk from flooding due to levee failure, please refer to Impact SW-6 in Chapter 6, *Surface*
21 *Water*.

22 During project design, a geotechnical engineer would develop slope stability design criteria (such as
23 minimum slope safety factors and allowable slope deformation and settlement) for the various
24 anticipated loading conditions. The design criteria would be documented in a detailed geotechnical
25 report prepared in accordance with the state guidelines, in particular, *Guidelines for Evaluating and*
26 *Mitigating Seismic Hazards in California* (California Geological Survey 2008). As discussed in Chapter
27 3, *Description of the Alternatives*, the foundation soil beneath slopes, embankments, or levees could
28 be improved to increase its strength and to reduce settlement and deformation. Foundation soil
29 improvement could involve excavation and replacement with engineered fill; preloading; ground
30 modifications using jet-grouting, compaction grouting, chemical grouting, shallow soil mixing, deep
31 soil mixing, vibro-compaction, or vibro-replacement; or other methods. Engineered fill also would
32 be used to construct new slopes, embankments, and levees. Surface and internal drainage systems
33 would be installed as necessary to reduce erosion and piping (internal erosion) potential.

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

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

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

- 4 • DWR Division of Engineering *State Water Project—Seismic Loading Criteria Report*, September
 5 2012.
- 6 • DWR Division of Flood Management *FloodSAFE Urban Levee Design Criteria*, May 2012.
- 7 • USACE *Slope Stability*, EM 1110-2-1902, 2003.
- 8 • 8 CCR 3203.

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

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

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

22 **CEQA Conclusion:** Unstable levee slopes and natural stream banks may fail, either from high pore-
 23 water pressure caused by high rainfall and weak soil, or from seismic shaking. Structures
 24 constructed on these slopes could be damaged or fail entirely as a result of slope instability.
 25 However, through the final design process, measures to address this hazard would be required to
 26 conform to applicable design codes, guidelines, and standards. The measures would be described in
 27 a detailed geotechnical report prepared in accordance with the state guidelines, in particular,
 28 *Guidelines for Evaluating and Mitigating Seismic Hazards in California* (California Geological Survey
 29 2008). As described in Section 9.3.1, *Methods for Analysis*, and in Appendix 3B, *Environmental*
 30 *Commitments, AMMs, and CMs*, such design codes, guidelines, and standards include the California
 31 Building Code and resource agency and professional engineering specifications, such as USACE's
 32 *Engineering and Design—Earthquake Design and Evaluation for Civil Works Projects*. Conformance
 33 with these codes and standards is an environmental commitment by DWR to ensure cut and fill
 34 slopes and embankments would be stable as the Alternative 1C water conveyance features are
 35 operated and there would be no increased likelihood of loss of property, personal injury or death of
 36 individuals. The impact would be less than significant. No mitigation is required.

37 **Impact GEO-10: Loss of Property, Personal Injury, or Death from Seiche or Tsunami during** 38 **Operation of Water Conveyance Features**

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

1 the San Francisco Bay. Therefore, the potential hazard of loss of property or personal injury as a
2 result of a tsunami on the water conveyance facilities is low.

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

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

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

21 However, design-level geotechnical studies would be conducted by a licensed civil engineer who
22 practices in geotechnical engineering. The studies would determine the peak ground acceleration
23 caused by movement of the West Tracy fault and the maximum probable seiche wave that could be
24 generated by the ground shaking. The engineer's recommended measures to address this hazard, as
25 well as the hazard of a seiche overtopping the Clifton Court Forebay embankment and subsequent
26 adverse effect on the Byron Tract Forebay embankment, would conform to applicable design codes,
27 guidelines, and standards. As described in Section 9.3.1, *Methods for Analysis*, and in Appendix 3B,
28 *Environmental Commitments, AMMs, and CMs*, such design codes, guidelines, and standards include
29 the Division of Safety of Dams' *Guidelines for Use of the Consequence-Hazard Matrix and Selection of*
30 *Ground Motion Parameters*, DWR's Division of Flood Management *FloodSAFE Urban Levee Design*
31 *Criteria*, and USACE's *Engineering and Design—Earthquake Design and Evaluation for Civil Works*
32 *Projects*. Conformance with these codes and standards is an environmental commitment by DWR to
33 ensure that the adverse effects of a seiche are controlled to an acceptable level while the forebay
34 facility is operated.

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

39 In particular, conformance with the following codes and standards would reduce the potential risk
40 for increased likelihood of loss of property or personal injury tsunami or seiche.

- 41 • U.S. Department of the Interior and USGS, *Climate Change and Water Resources Management: A*
42 *Federal Perspective*, Circular 1331.

- 1 • State of California Sea-Level Rise Task Force of the CO-CAT, Sea-Level Rise Interim Guidance
- 2 Document, 2010.
- 3 • 8 CCR 3203.

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

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

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

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

24 Similarly, the potential for a significant seiche to occur in most parts of the Plan Area is considered
 25 low because the seismic hazard and the geometry of the water bodies (i.e., wide and shallow) near
 26 conveyance facilities are not favorable for a seiche to occur. However, assuming that the West Tracy
 27 fault is potentially active, a potential exists for a seiche to occur in the Clifton Court Forebay and the
 28 Byron Tract Forebay (Fugro Consultants 2011). The impact would not be significant because the
 29 Byron Tract Forebay embankment would be designed and constructed according to applicable
 30 design codes, guidelines, and standards to contain and withstand the anticipated maximum seiche
 31 wave height and potential seiche waver overtopping of the Clifton Court Forebay and Byron Tract
 32 Forebay embankments as the Alternative 1C water conveyance features are operated and there
 33 would be no increased likelihood of loss of property, personal injury or death of individuals. The
 34 impact would 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 If an unlined canal (as opposed to a lined canal) was constructed, seepage from the sideslopes and
 38 bottom of the canal could occur where the normal water level in the canal is higher than the water
 39 surface elevation of the adjacent areas. The seepage could raise the water table on the landside of
 40 the embankments through more permeable lenses of sand and/or gravel in the foundation soil.
 41 Increased water table levels may increase the likelihood of ground settlement and earthquake-
 42 induced liquefaction.

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

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

- 11 • Use of a drainage ditch parallel to the canal to control seepage. Water in the drainage ditch
12 would then be pumped into the sloughs or back into the canal.
- 13 • Installation of pressure-relief wells to collect subsurface water and direct it into the parallel
14 drainage ditch.

15 As indicated above and in Chapter 3, a geotechnical engineer would use site-specific geotechnical
16 and hydrological information to design the canal, and the design would conform to the current
17 standards and construction practices specified by USACE and DWR design standards. As described
18 in Section 9.3.1, *Methods for Analysis*, such design codes, guidelines, and standards are
19 environmental commitments by DWR (see also Appendix 3B, *Environmental Commitments, AMMs,*
20 *and CMs*). For construction of the canal and any required seepage control measures, the codes and
21 standards would include the California Building Code and resource agency and professional
22 engineering specifications, such as USACE's *Engineering and Design—Earthquake Design and*
23 *Evaluation for Civil Works Projects*. These codes and standards include minimum performance
24 standards for structural design, given site-specific subsurface conditions.

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

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

- 31 • USACE *Engineering and Design—Earthquake Design and Evaluation for Civil Works Projects*,
32 ER 1110-2-1806, 1995.
- 33 • USACE *Engineering and Design—Settlement Analysis*, EM 1110-1-1904, 1990.
- 34 • USACE *Slope Stability*, EM 1110-2-1902, 2003.
- 35 • DWR Division of Flood Management *FloodSAFE Urban Levee Design Criteria*, May 2012.
- 36 • 8 CCR 3203.

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

40 The worker safety codes and standards specify protective measures that must be taken at
41 workplaces to minimize the risk of injury or death from structural or earth failure (e.g., utilizing

1 personal protective equipment). The relevant codes and standards represent performance
 2 standards that must be met by employers and these measures are subject to monitoring by state and
 3 local agencies. Cal-OSHA requirements for an IIPP and the terms of the IIPP to protect worker safety
 4 are the principal measures that would be enforced at workplaces during operations.

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

8 **CEQA Conclusion:** Seepage from an unlined canal could raise the water table level along the canal,
 9 thereby increasing the hazard of liquefaction where the water table is not already close to the
 10 surface. The increased hazard of liquefaction could threaten the integrity of the canal in the event
 11 that liquefaction occurs. However, because DWR would conform to applicable design guidelines and
 12 standards, such as USACE design measures there would be no increased likelihood of loss of
 13 property, personal injury or death of individuals from ground failure caused by increased
 14 groundwater surface elevations. The impact would be less than significant. No mitigation is
 15 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 According to the available AP Earthquake Fault Zone Maps, only the Suisun Marsh ROA could be
 19 affected by rupture of an earthquake fault. The active Green Valley fault crosses the southwestern
 20 corner of the ROA. The active Cordelia fault extends approximately one mile into the northwestern
 21 corner of the ROA. Rupture of these faults could damage levees and berms constructed as part of the
 22 restoration, which could result in failure of the levees and flooding of otherwise protected areas.

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

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

39 Because there is limited information regarding the depths of the blind faults mentioned above,
 40 seismic surveys would be performed in the vicinity of the faults as part of final design. These surveys
 41 would be used to verify fault depths where levees and other features would be constructed.

42 Collection of this depth information would be part of broader, design-level geotechnical studies
 43 prepared by a licensed engineer to support all aspects of site-specific project design. The studies

1 would assess site-specific conditions at and near all the project facility locations, including the
 2 nature and engineering properties of all soil horizons and underlying geologic strata, and
 3 groundwater conditions. The engineer's information would be used to develop final engineering
 4 solutions to any hazardous condition, consistent with the code and standards requirements of
 5 federal, state and local oversight agencies. As described in Section 9.3.1, *Methods for Analysis*, and in
 6 Appendix 3B, *Environmental Commitments, AMMs, and CMs*, such design codes, guidelines, and
 7 standards include the California Building Code and resource agency and professional engineering
 8 specifications, such as the Division of Safety of Dams' *Guidelines for Use of the Consequence-Hazard*
 9 *Matrix and Selection of Ground Motion Parameters*, DWR's Division of Flood Management *FloodSAFE*
 10 *Urban Levee Design Criteria*, and USACE's *Engineering and Design—Earthquake Design and*
 11 *Evaluation for Civil Works Projects*. Conformance with these design standards is an environmental
 12 commitment by the BDCP proponents to ensure that risks from a fault rupture are minimized as
 13 levees for habitat restoration areas are constructed and maintained. The hazard would be controlled
 14 to a safe level by following the proper design standards. The BDCP proponents would ensure that
 15 the geotechnical design recommendations are included in the design of project facilities and
 16 construction specifications to minimize the potential effects from seismic events and the presence of
 17 adverse soil conditions. The BDCP proponents would also ensure that the design specifications are
 18 properly executed during implementation.

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

- 22 • DWR Division of Engineering *State Water Project—Seismic Loading Criteria Report*, September
 23 2012.
- 24 • DWR DSOD *Guidelines for Use of the Consequence-Hazard Matrix and Selection of Ground Motion*
 25 *Parameters*, 2002.
- 26 • USACE *Engineering and Design—Earthquake Design and Evaluation for Civil Works Projects*,
 27 ER 1110-2-1806, 1995.
- 28 • USACE *Design and Construction of Levees*, EM 1110-2-1913, 2000.
- 29 • USACE (CESPK-ED-G), *Geotechnical Levee Practice*, SOP EDG-03, 2004.
- 30 • DWR Division of Flood Management *FloodSAFE Urban Levee Design Criteria*, May 2012.
- 31 • 8 CCR Sections 1509 and 3203.

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

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

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

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

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

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

30 Among all the ROAs, the Suisun Marsh ROA would be most subject to ground shaking because of its
 31 proximity to active faults. The Suisun Marsh ROA is subject to a PGA of approximately 0.31 to 0.35 g
 32 for 200-year return interval, while the PGA for the other ROAs ranges from approximately 0.11 to
 33 0.26 g. The ground shaking could damage levees and other structures, and in an extreme event cause
 34 levees to fail such that protected areas flood.

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

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

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

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

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

- 28 • DWR Division of Engineering *State Water Project—Seismic Loading Criteria Report*, September
 29 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*,
 33 ER 1110-2-1806, 1995.
- 34 • USACE *Design and Construction of Levees*, EM 1110-2-1913, 2000.
- 35 • USACE (CESPK-ED-G), *Geotechnical Levee Practice*, SOP EDG-03, 2004.
- 36 • DWR Division of Flood Management *FloodSAFE Urban Levee Design Criteria*, May 2012.
- 37 • 8 CCR Sections 1509 and 3203.

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

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

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

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
 14 to active faults. The Suisun Marsh ROA is subject to a PGA of approximately 0.31 to 0.35 g for 200-
 15 year return interval, while the PGA for the other ROAs ranges from approximately 0.11 to 0.26 g.
 16 Damage to 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, AMMs, and CMs*, design codes, guidelines, and standards, including the California
 19 Building Code and resource agency and professional engineering specifications, such as DWR's
 20 Division of Flood Management *FloodSAFE Urban Levee Design Criteria* and USACE's *Engineering and*
 21 *Design—Earthquake Design and Evaluation for Civil Works Projects* would be used for final design of
 22 conservation features. Conformance with these design standards is an environmental commitment
 23 by the BDCP proponents to ensure that strong seismic shaking risks are minimized as the
 24 conservation measures are operated and there would be no increased likelihood of loss of property,
 25 personal injury or death of individuals in the ROAs. The impact would be less than significant. No
 26 mitigation is required.

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

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

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

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

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

12 During final design, the facility-specific potential for liquefaction would be investigated by a
 13 geotechnical engineer. In areas determined to have a potential for liquefaction, the engineer would
 14 develop design parameters and construction methods to meet the design criteria established to
 15 ensure that design earthquake does not cause damage to or failure of the facility. Such measures and
 16 methods include removing and replacing potentially liquefiable soil, strengthening foundations (for
 17 example, using post-tensioned slab, reinforced mats, and piles) to resist excessive total and
 18 differential settlements, using *in situ* ground improvement techniques (such as deep dynamic
 19 compaction, vibro-compaction, vibro-replacement, compaction grouting, and other similar
 20 methods), and conforming to current seismic design codes and requirements, as described in
 21 Section 9.3.1, *Methods for Analysis*, and in Appendix 3B, *Environmental Commitments, AMMs, and*
 22 *CMS*, 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 the BDCP proponents to ensure that liquefaction risks are minimized as the
 26 conservation measures are implemented. The hazard would be controlled to a safe level.

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

- 30 • USACE *Engineering and Design—Design of Pile Foundations*, EM 1110-2-2906, 1991
- 31 • USACE *Engineering and Design—Stability Analysis of Concrete Structures*, EM 1110-2-2100, 2005
- 32 • USACE *Engineering and Design—Earthquake Design and Evaluation for Civil Works Projects*,
 33 ER 1110-2-1806, 1995
- 34 • 8 CCR Sections 1509 and 3203.

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.

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

1 The BDCP proponents would ensure that the geotechnical design recommendations are included in
 2 the design of levees and construction specifications to minimize the potential effects from
 3 liquefaction and associated hazard. The BDCP proponents would also ensure that the design
 4 specifications are properly executed during implementation and there would be no increased
 5 likelihood of loss of property, personal injury or death of individuals in the ROAs. This effect would
 6 not be adverse.

7 **CEQA Conclusion:** Earthquake-induced ground shaking could cause liquefaction, resulting in
 8 damage to or failure of levees, berms, and other features constructed at the restoration areas.
 9 Failure of levees and other structures could result in flooding of otherwise protected areas.
 10 However, through the final design process, measures to address the liquefaction hazard would be
 11 required to conform to applicable design codes, guidelines, and standards. As described in Section
 12 9.3.1, *Methods for Analysis*, and in Appendix 3B, *Environmental Commitments, AMMs, and CMs*, such
 13 design codes, guidelines, and standards include USACE's *Engineering and Design—Stability Analysis
 14 of Concrete Structures and Soil Liquefaction during Earthquakes*, by the Earthquake Engineering
 15 Research Institute. Conformance with these design standards is an environmental commitment by
 16 the BDCP proponents to ensure that liquefaction risks are minimized as the water conservation
 17 features are implemented. The hazard would be controlled to a safe level and there would be no
 18 increased likelihood of loss of property, personal injury or death of individuals 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 Implementation of CM2–CM7, would involve breaching, modification or removal of existing levees
 23 and construction of new levees and embankments. CM4 which provides for the restoration of up to
 24 65,000 acres of tidal perennial aquatic, tidal mudflat, tidal freshwater emergent wetland, and tidal
 25 brackish emergent wetland natural communities within the ROAs involves the greatest amount of
 26 modifications to levees. Levee modifications, including levee breaching or lowering, may be
 27 performed to reintroduce tidal exchange, reconnect remnant sloughs, restore natural remnant
 28 meandering tidal channels, encourage development of dendritic channel networks, and improve
 29 floodwater conveyance.

30 Levee modifications could involve the removal of vegetation and excavation of levee materials.
 31 Excess earthen materials could be temporarily stockpiled, then re-spread on the surface of the new
 32 levee slopes where applicable or disposed of offsite. Any breaching or other modifications would be
 33 required to be designed and implemented to maintain the integrity of the levee system and to
 34 conform to flood management standards and permitting processes. This would be coordinated with
 35 the appropriate flood management agencies. Those agencies may include USACE, DWR, CVFPB, and
 36 other 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 damage facilities as a result
 39 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
 42 failure are along existing Sacramento and San Joaquin River and Delta island levees and
 43 stream/channel banks, particularly those levees that consist of non-engineered fill and those
 44 streambanks that are steep and consist of low strength soil.

1 The structures associated with conservation measures would not be constructed in, nor would they
2 be 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
4 fail, either from high pore-water pressure caused by high rainfall and weak soil, or from seismic
5 shaking. 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, or other material selected
9 during future evaluations for each location. Aggregate rock could be placed on the remaining levees
10 to provide an access road to the breach location. Erosion protection measures would also be taken
11 where levee lowering is done for the purposes of allowing seasonal or periodic inundation of lands
12 during high flows or high tides to improve habitat or to reduce velocities and elevations of
13 floodwaters. To reduce erosion potential on the new levee crest, a paved or gravel access road could
14 be constructed with short (approximately 1 foot) retaining walls on each edge of the crest to reduce
15 undercutting of the roadway by high tides. Levee modifications could also include excavation of
16 watersides of the slopes to allow placement of slope protection, such as riprap or geotextile fabric,
17 and to modify slopes to provide levee stability. Erosion and scour protection could be placed on the
18 landside of the levee and continued for several feet onto the land area away from the levee toe.
19 Neighboring levees could require modification to accommodate increased flows or to reduce effects
20 of changes in water elevation or velocities along channels following inundation of tidal marshes.
21 Hydraulic modeling would be used during subsequent analyses to determine the need for such
22 measures.

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

29 Additionally, during project design, a geotechnical engineer would develop slope stability design
30 criteria (such as minimum slope safety factors and allowable slope deformation and settlement) for
31 the various anticipated loading conditions. During project design, a geotechnical engineer would
32 develop slope stability design criteria (such as minimum slope safety factors and allowable slope
33 deformation and settlement) for the various anticipated loading conditions. As required by design
34 standards and building codes (see Appendix 3B, *Environmental Commitments, AMMs, and CMs*),
35 foundation soil beneath embankments and levees could be improved to increase its strength and to
36 reduce settlement and deformation. Foundation soil improvement could involve excavation and
37 replacement with engineered fill; preloading; ground modifications using jet-grouting, compaction
38 grouting, chemical grouting, shallow soil mixing, deep soil mixing, vibro-compaction, or
39 vibro-replacement; or other methods. Engineered fill could also be used to construct new
40 embankments and levees.

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

1 The BDCP proponents would ensure that the geotechnical design recommendations are included in
 2 the design of embankments and levees to minimize the potential effects from slope failure. The
 3 BDCP 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
 6 for 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*, September
 9 2012.
- 10 • DWR Division of Flood Management *FloodSAFE Urban Levee Design Criteria*, May 2012.
- 11 • USACE *Slope Stability*, EM 1110-2-1902, 2003.
- 12 • 8 CCR 3203.

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
 15 parameters.

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

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

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

33 **Impact GEO-16: Loss of Property, Personal Injury, or Death from Seiche or Tsunami at** 34 **Restoration Opportunity Areas as a Result of Implementing the Conservation Actions**

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

38 **CEQA Conclusion:** Based on recorded tsunami wave heights at the Golden Gate, the height of a
 39 tsunami wave reaching the ROAs would be small because of the distance from the ocean and
 40 attenuating effect of the San Francisco Bay. Similarly, the potential for a significant seiche to occur in
 41 the Plan Area that would cause loss of property, personal injury, or death at the ROAs is considered

1 low because conditions for a seiche to occur at the ROAs are not favorable. The impact would be less
2 than significant. No mitigation is required.

3 **9.3.3.5 Alternative 2A—Dual Conveyance with Pipeline/Tunnel and Five** 4 **Intakes (15,000 cfs; Operational Scenario B)**

5 **Impact GEO-1: Loss of Property, Personal Injury, or Death from Structural Failure Resulting** 6 **from Strong Seismic Shaking of Water Conveyance Features during Construction**

7 *NEPA Effects:* Alternative 2A would include the same physical/structural components as Alternative
8 1A, but could entail two different intake and intake pumping plant locations. These locations would
9 be where the intakes have a similar hazard of ground shaking and would not substantially change
10 the hazard of loss of property, personal injury, or death during construction. The effects of
11 Alternative 2A would, therefore, be the same as 1A. See the discussion of Impact GEO-1 under
12 Alternative 1A. There would be no adverse effect.

13 *CEQA Conclusion:* Seismically induced ground shaking could cause collapse or other failure of
14 project facilities while under construction. However, DWR would conform to Cal-OSHA and other
15 state code requirements, such as shoring, bracing, lighting, excavation depth restrictions, required
16 slope angles, and other measures, to protect worker safety and there would be no increased
17 likelihood of loss of property, personal injury or death due to construction of Alternative 2A. The
18 impact would be less than significant. No additional mitigation is required.

19 **Impact GEO-2: Loss of Property, Personal Injury, or Death from Settlement or Collapse** 20 **Caused by Dewatering during Construction of Water Conveyance Features**

21 Alternative 2A would include the same physical/structural components as Alternative 1A, but could
22 entail two different intake and intake pumping plant locations. If Intakes 6 and 7, north of Vorden,
23 are chosen, settlement of excavations could occur as a result of dewatering at Alternative 2A
24 construction sites with shallow groundwater. Soil excavation in areas with shallow or perched
25 groundwater levels would require the pumping of groundwater from excavations to allow for
26 construction of facilities. This can be anticipated at all intake locations and pumping plant sites
27 adjacent to the Sacramento River. Similar dewatering may be necessary where intake and forebay
28 pipelines cross waterways and major irrigation canals east of the Sacramento River and north of the
29 proposed intermediate forebay. The conveyance pipeline built between Intake 7 and the
30 intermediate forebay would cross six canals or ditches prior to joining with the conveyance pipeline
31 for Intake 6. All of these crossings occur north of the facility grounds for Intake 7 and range in their
32 distance from the intake site from 0.3 miles to one mile. The combined conveyance pipeline for
33 Intakes 6 and 7 leading to the intermediate forebay would cross four canals or ditches. The northern
34 two crossings would be 0.3 to 0.4 miles west of Lambert Road and the southern two would be 0.5
35 miles west and northwest (respectively) of Russell Road. This pipeline would also cross the
36 Reclamation District 551 borrow canal.

37 *NEPA Effects:* These changes in locations would result in a similar hazard of settlement or collapse
38 and would not substantially change the hazard of loss of property, personal injury, or death during
39 construction. The effects of Alternative 2A would, therefore, be the same as 1A. See the description
40 and findings under Alternative 1A. There would be no adverse effect.

41 *CEQA Conclusion:* Settlement or failure of excavations during construction could result in loss of
42 property or personal injury. However, DWR would conform to Cal-OSHA and other state code

1 requirements, such as using seepage cutoff walls, shoring, and other measures, to protect worker
 2 safety. DWR has made an environmental commitment to use the appropriate code and standard
 3 requirements to minimize potential risks (Appendix 3B, *Environmental Commitments, AMMs, and*
 4 *CMs*) and there would be no increased likelihood of loss of property, personal injury or death due to
 5 construction of Alternative 2A. 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 2A would include the same physical/structural components as Alternative
 9 1A, but could entail two different intake and intake pumping plant locations. These changes in
 10 locations would have no bearing on the hazard of ground settlement of tunnels and would not
 11 change the hazard of loss of property, personal injury, or death during construction. The effects of
 12 Alternative 2A 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
 15 or personal injury during construction. However, DWR would conform to Cal-OSHA, USACE, and
 16 other design requirements to protect worker safety. DWR would also ensure that the design
 17 specifications are properly executed during construction. DWR has made an environmental
 18 commitment to use the appropriate code and standard requirements to minimize potential risks
 19 (Appendix 3B, *Environmental Commitments, AMMs, and CMs*). Hazards to workers and project
 20 structures would be controlled at safe levels and there would be no increased likelihood of loss of
 21 property, personal injury or death due to construction of Alternative 2A. The impact would be less
 22 than significant. No mitigation is required.

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

25 **NEPA Effects:** Alternative 2A would include the same physical/structural components as Alternative
 26 1A, but could entail two different intake and intake pumping plant locations. These changes in
 27 locations would have no bearing on the hazard of slope failure at borrow and storage sites and
 28 would not change the hazard of loss of property, personal injury, or death during construction. The
 29 effects of Alternative 2A 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:** Settlement/failure of cutslopes of borrow sites and failure of soil/RTM fill slopes
 32 could result in loss of property or personal injury during construction. However, because DWR
 33 would conform to Cal-OSHA and other state code requirements and conform to applicable
 34 geotechnical design guidelines and standards, such as USACE design measures, the hazard would be
 35 controlled to a safe level and there would be no increased likelihood of loss of property, personal
 36 injury or death due to construction of Alternative 2A. The impact would be less than significant. No
 37 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**
 40 **Features**

41 **NEPA Effects:** Alternative 2A would include the same physical/structural components as Alternative
 42 1A, but could entail two different intake and intake pumping plant locations. These changes in

1 locations would have no bearing on the hazard of structural failure from construction-related
 2 ground motions and would not change the hazard of loss of property, personal injury, or death
 3 during operation of the water conveyance features. The effects of Alternative 2A would, therefore,
 4 be the same as 1A. See the description and findings under Alternative 1A. There would be no
 5 adverse effect.

6 **CEQA Conclusion:** Construction-related ground motions and traffic effects could initiate
 7 liquefaction, which could cause failure of structures during construction. The impact could be
 8 significant. However, because DWR would conform to Cal-OSHA and other state code requirements
 9 and conform to applicable design guidelines and standards, such as USACE design measures, in
 10 addition to implementation of Mitigation Measures TRANS-2a and TRANS-2b, as well as the
 11 maintenance and reconstruction of levees through Mitigation Measure TRANS-2c, the hazard would
 12 be controlled to a level that would protect worker safety (see Appendix 3B, *Environmental*
 13 *Commitments, AMMs, and CMs*) and there would be no increased likelihood of loss of property,
 14 personal injury or death due to construction of Alternative 2A. The impact would be less than
 15 significant.

16 **Mitigation Measure TRANS-2a: Prohibit Construction Activity on Physically Deficient**
 17 **Roadway Segments**

18 Please refer to Mitigation Measure TRANS-2a in Alternative 1A, Impact TRANS-2, in Chapter 19,
 19 *Transportation*.

20 **Mitigation Measure TRANS-2b: Limit Construction Activity on Physically Deficient**
 21 **Roadway Segments**

22 Please refer to Mitigation Measure TRANS-2b in Alternative 1A, Impact TRANS-2, in Chapter 19,
 23 *Transportation*.

24 **Mitigation Measure TRANS-2c: Improve Physical Condition of Affected Roadway Segments**
 25 **as Stipulated in Mitigation Agreements or Encroachment Permits**

26 Please refer to Mitigation Measure TRANS-2c in Alternative 1A, Impact TRANS-2, in Chapter 19,
 27 *Transportation*.

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 **NEPA Effects:** Alternative 2A would include the same physical/structural components as Alternative
 31 1A, but could entail two different intake and intake pumping plant locations. These changes in
 32 locations would have no bearing on the hazard of fault rupture and would not change the hazard of
 33 loss of property, personal injury, or death during operation of the water conveyance features. The
 34 effects of Alternative 2A would, therefore, be the same as 1A. See the description and findings under
 35 Alternative 1A. There would be no adverse effect.

36 **CEQA Conclusion:** There are no active faults capable of surface rupture that extend into the
 37 Alternative 2A alignment. Although the Thornton Arch and West Tracy blind thrusts occur beneath
 38 the Alternative 2A alignment, based on available information, they do not present a hazard of
 39 surface rupture and there would be no increased likelihood of loss of property, personal injury or
 40 death due to operation of Alternative 2A. There would be no impact. No mitigation is 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 **NEPA Effects:** Alternative 2A would include the same physical/structural components as Alternative
 4 1A, but could entail two different intake and intake pumping plant locations. These changes in
 5 locations would have no bearing on the hazard of structural failure from seismic shaking and would
 6 not change the hazard of loss of property, personal injury, or death during operation of the water
 7 conveyance features. The effects of Alternative 2A would, therefore, be the same as 1A. See the
 8 description and findings under Alternative 1A. There would be no adverse effect.

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

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

29 **NEPA Effects:** Alternative 2A would include the same physical/structural components as Alternative
 30 1A, but could entail two different intake and intake pumping plant locations. These changes in
 31 locations would have no bearing on the hazard of structural failure from ground failure and would
 32 not change the hazard of loss of property, personal injury, or death during operation of the water
 33 conveyance features. The effects of Alternative 2A would, therefore, be the same as 1A. See the
 34 description and findings under Alternative 1A. There would be no adverse effect.

35 **CEQA Conclusion:** Seismically induced ground shaking could cause liquefaction. Liquefaction could
 36 damage pipelines, tunnels, intake facilities, pumping plants, and other facilities, and thereby disrupt
 37 the water supply through the conveyance system. In an extreme event, an uncontrolled release of
 38 water from the damaged conveyance system could cause flooding and inundation of structures.
 39 (Please refer to Chapter 6, *Surface Water*, for a detailed discussion of potential flood impacts.)
 40 However, through the final design process, measures to address the liquefaction hazard would be
 41 required to conform to applicable design codes, guidelines, and standards. As described in Section
 42 9.3.1, *Methods for Analysis*, and in Appendix 3B, *Environmental Commitments, AMMs, and CMs*, such
 43 design codes, guidelines, and standards include USACE's *Engineering and Design—Stability Analysis*
 44 *of Concrete Structures and Soil Liquefaction during Earthquakes*, by the Earthquake Engineering

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

6 **Impact GEO-9: Loss of Property, Personal Injury, or Death from Landslides and Other Slope** 7 **Instability during Operation of Water Conveyance Features**

8 **NEPA Effects:** Alternative 2A would include the same physical/structural components as Alternative
9 1A, but could entail two different intake and intake pumping plant locations. These changes in
10 locations would have no bearing on the hazard of landslides and other slope instability and would
11 not change the hazard of loss of property, personal injury, or death during operation of the water
12 conveyance features. The effects of Alternative 2A would, therefore, be the same as 1A. See the
13 description and findings under Alternative 1A. There would be no adverse effect.

14 **CEQA Conclusion:** Unstable levee slopes and natural stream banks may fail, either from high pore-
15 water pressure caused by high rainfall and weak soil, or from seismic shaking. Structures
16 constructed on these slopes could be damaged or fail entirely as a result of slope instability.
17 However, through the final design process, measures to address this hazard would be required to
18 conform to applicable design codes, guidelines, and standards. As described in Section 9.3.1,
19 *Methods for Analysis*, and in Appendix 3B, *Environmental Commitments, AMMs, and CMs*, such design
20 codes, guidelines, and standards include the California Building Code and resource agency and
21 professional engineering specifications, such as USACE's *Engineering and Design—Earthquake*
22 *Design and Evaluation for Civil Works Projects*. Conformance with these codes and standards is an
23 environmental commitment by DWR to ensure cut and fill slopes and embankments would be stable
24 as the water conveyance features are operated and there would be no increased likelihood of loss of
25 property, personal injury or death due to operation of Alternative 2A. The impact would be less than
26 significant. No mitigation is required.

27 **Impact GEO-10: Loss of Property, Personal Injury, or Death from Seiche or Tsunami during** 28 **Operation of Water Conveyance Features**

29 **NEPA Effects:** Alternative 2A would include the same physical/structural components as Alternative
30 1A, but could entail two different intake and intake pumping plant locations. These changes in
31 locations would have no bearing on the hazard of seiche or tsunami and would not change the
32 hazard of loss of property, personal injury, or death during operation of the water conveyance
33 features. The effects of Alternative 2A would, therefore, be the same as 1A. See the description and
34 findings under Alternative 1A. There would be no adverse effect.

35 **CEQA Conclusion:** Based on recorded tsunami wave heights at the Golden Gate (Contra Costa
36 Transportation Agency 2009) and in the interior of the San Francisco Bay and on tsunami
37 inundation maps prepared by the California Department of Conservation (2009), the height of a
38 tsunami wave reaching the Suisun Marsh and the Delta would be small because of the distance from
39 the ocean and attenuating effect of the San Francisco Bay. Similarly, the potential for a significant
40 seiche to occur in most parts of the Plan Area is considered low because the seismic hazard and the
41 geometry of the water bodies (i.e., wide and shallow) near conveyance facilities are not favorable for
42 a seiche to occur. However, assuming the West Tracy fault is potentially active, a potential exists for
43 a seiche to occur in the Clifton Court Forebay and the Byron Tract Forebay (Fugro Consultants

2011). The impact would not be significant because the Byron Tract Forebay embankment would be designed and constructed according to applicable design codes, guidelines, and standards to contain and withstand the anticipated maximum seiche wave height. There would be no increased likelihood of loss of property, personal injury or death from seiche or tsunami due to operation of Alternative 2A. The impact would be less than significant. No mitigation is required.

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

NEPA Effects: Alternative 2A would not involve construction of unlined canals; therefore, there would be no increase in groundwater surface elevations and consequently no effect caused by canal seepage. There would be no effect.

CEQA Conclusion: Alternative 2A would not involve construction of unlined canals; therefore, there would be no increase in groundwater surface elevations and consequently no impact caused by canal seepage and there would be no increased likelihood of loss of property, personal injury or death due to operation of Alternative 2A. There would be no impact. No mitigation is required.

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

NEPA Effects: Conservation measures would be the same under Alternative 2A as under 1A. See description and findings under Alternative 1A. There would be no adverse effect.

CEQA Conclusion: Rupture of the Cordelia and Green Valley faults could occur at the Suisun Marsh ROA and damage ROA facilities, such as levees and berms. Damage to these features could result in their failure, causing flooding of otherwise protected areas. However, through the final design process for conservation measures in the ROAs, measures to address the fault rupture 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, AMMs, and CMs*, 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 would not create an 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-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 2A 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.

1 Damage to these features could result in their failure, causing flooding of otherwise protected areas.
 2 However, as described in Section 9.3.1, *Methods for Analysis*, and in Appendix 3B, *Environmental*
 3 *Commitments, AMMs, and CMs*, design codes, guidelines, and standards, including the California
 4 Building Code and resource agency and professional engineering specifications, such as DWR's
 5 Division of Flood Management *FloodSAFE Urban Levee Design Criteria* and USACE's *Engineering and*
 6 *Design—Earthquake Design and Evaluation for Civil Works Projects* would be used for final design of
 7 conservation features. Conformance with these design standards is an environmental commitment
 8 by the BDCP proponents to ensure that strong seismic shaking risks are minimized as the
 9 conservation measures are operated and would not create an increased likelihood of loss of
 10 property, personal injury or death of individuals in the ROAs. The impact would be less than
 11 significant. No mitigation is required.

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

15 **NEPA Effects:** Conservation measures would be the same under Alternative 2A as under 1A. See
 16 description and findings under Alternative 1A. There would be no adverse effect.

17 **CEQA Conclusion:** Earthquake-induced ground shaking could cause liquefaction, resulting in
 18 damage to or failure of levees, berms, and other features constructed at the restoration areas.
 19 Failure of levees and other structures could result in flooding of otherwise protected areas.
 20 However, through the final design process, measures to address the liquefaction hazard would be
 21 required to conform to applicable design codes, guidelines, and standards. As described in Section
 22 9.3.1, *Methods for Analysis*, and in Appendix 3B, *Environmental Commitments, AMMs, and CMs*, such
 23 design codes, guidelines, and standards include USACE's *Engineering and Design—Stability Analysis*
 24 *of Concrete Structures and Soil Liquefaction during Earthquakes*, by the Earthquake Engineering
 25 Research Institute. Conformance with these design standards is an environmental commitment by
 26 the BDCP proponents to ensure that liquefaction risks are minimized as the water conservation
 27 features are implemented. The hazard would be controlled to a safe level and would not create an
 28 increased likelihood of loss of property, personal injury or death of individuals in the ROAs. The
 29 impact would be less than significant. No mitigation is required.

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

32 **NEPA Effects:** Conservation measures would be the same under Alternative 2A as under 1A. See
 33 description and findings under Alternative 1A. There would be no adverse effect.

34 **CEQA Conclusion:** Unstable new and existing levee and embankment slopes could fail as a result of
 35 seismic shaking and as a result of high soil-water content during heavy rainfall and cause flooding of
 36 otherwise protected areas. However, because BDCP proponents would conform to applicable design
 37 guidelines and standards, such as USACE design measures, the hazard would be controlled to a safe
 38 level and would not create an increased likelihood of loss of property, personal injury or death of
 39 individuals in the 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 2A would be similar to that as under
 4 Alternative 1A. See description and findings under Alternative 1A. The distance from the ocean and
 5 attenuating effect of the San Francisco Bay would likely allow only a low tsunami wave height to
 6 reach the Suisun Marsh and the Delta. Conditions for a seiche to occur at the ROAs are not favorable.
 7 There would be no adverse effect.

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

14 **9.3.3.6 Alternative 2B—Dual Conveyance with East Alignment and Five**
 15 **Intakes (15,000 cfs; Operational Scenario B)**

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

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
 20 locations would result in a similar hazard of ground shaking and would not substantially change the
 21 hazard of loss of property, personal injury, or death during construction. The effects of Alternative
 22 2B would, therefore, be the same as 1B. See the description and findings under Alternative 1B. There
 23 would be no adverse effect.

24 **CEQA Conclusion:** Seismically induced ground shaking could cause collapse or other failure of
 25 project facilities while under construction. However, DWR would conform to Cal-OSHA and other
 26 state code requirements, such as shoring, bracing, lighting, excavation depth restrictions, required
 27 slope angles, and other measures, to protect worker safety. Conformance with these standards and
 28 codes is an environmental commitment of the project (see Appendix 3B, *Environmental*
 29 *Commitments, AMMs, and CMs*). Conformance with these health and safety requirements and the
 30 application of accepted, proven construction engineering practices would reduce this risk and there
 31 would be no increased likelihood of loss of property, personal injury or death due to construction of
 32 Alternative 2B. This impact is less than significant. No mitigation is required.

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

35 Alternative 2B would include the same physical/structural components as Alternative 1B, but could
 36 entail two different intake and intake pumping plant locations. If Intakes 6 and 7, north of Vorden,
 37 are chosen, settlement of excavations could occur as a result of dewatering at Alternative 2B
 38 construction sites with shallow groundwater. Soil excavation in areas with shallow or perched
 39 groundwater levels would require the pumping of groundwater from excavations to allow for
 40 construction of facilities. This can be anticipated at all intake locations and pumping plant sites
 41 adjacent to the Sacramento River. Similar dewatering may be necessary where intake and forebay
 42 pipelines cross waterways and major irrigation canals east of the Sacramento River and north of the

1 proposed intermediate forebay. The conveyance pipeline built between Intake 6 and the canal
 2 would cross Snodgrass Slough, an adjacent body of water, and seven irrigation canals or drainage
 3 ditches prior to joining with the canal. The crossings closest to the intake would occur
 4 approximately 0.25 miles to 0.5 miles southeast of Russell Road. Snodgrass Slough would be crossed
 5 approximately 0.5 miles north of Alfalfa Plant Road. Intersections with three canals or ditches would
 6 then be located west of Snodgrass Slough and east of the proposed canal. The conveyance pipeline
 7 built between Intake 7 and the canal would cross Snodgrass Slough, an adjacent body of water, and
 8 eleven irrigation canals or drainage ditches prior to joining with the canal. The five crossings closest
 9 to the intake would occur approximately 0.3 miles to 1.1 miles northeast of the facility grounds
 10 proposed for Intake 7. Three crossings would be located 0.1 to 0.2 miles south of Alfalfa Plant Road,
 11 in addition to the crossing with Snodgrass Slough and an associated waterway. Intersections with
 12 four canals or ditches would then be located west of Snodgrass Slough and east of the proposed
 13 canal.

14 **NEPA Effects:** These changes in locations would result in a similar hazard of settlement or collapse
 15 and would not substantially change the hazard of loss of property, personal injury, or death during
 16 construction. The effects of Alternative 2B would, therefore, be the same as 1B. See the description
 17 and findings under Alternative 1B. There would be no adverse effect.

18 **CEQA Conclusion:** Settlement or failure of excavations during construction could result in loss of
 19 property or personal injury. However, DWR would conform to Cal-OSHA and other state code
 20 requirements, such as seepage cutoff walls, shoring, and other measures, to protect worker safety.
 21 DWR would also ensure that the design specifications are properly executed during construction.
 22 DWR has made an environmental commitment to use the appropriate code and standard
 23 requirements to minimize potential risks (Appendix 3B, *Environmental Commitments, AMMs, and*
 24 *CMs*) and there would be no increased likelihood of loss of property, personal injury or death due to
 25 construction of Alternative 2B. The impact would be less than significant. No mitigation is required.

26 **Impact GEO-3: Loss of Property, Personal Injury, or Death from Ground Settlement during** 27 **Construction of Water Conveyance Features**

28 **NEPA Effects:** Alternative 2B would include the same physical/structural components as Alternative
 29 1B, but could entail two different intake and intake pumping plant locations. These changes in
 30 locations would have no bearing on the hazard of ground settlement of tunnel siphons and would
 31 not change the hazard of loss of property, personal injury, or death during construction. The effects
 32 of Alternative 2B would, therefore, be the same as 1B. See the description and findings under
 33 Alternative 1B. There would be no adverse effect.

34 **CEQA Conclusion:** Ground settlement above the tunneling operation could result in loss of property
 35 or personal injury during construction. However, DWR would conform to Cal-OSHA, USACE, and
 36 other design requirements to protect worker safety. DWR would also ensure that the design
 37 specifications are properly executed during construction. DWR has made an environmental
 38 commitment to use the appropriate code and standard requirements to minimize potential risks
 39 (Appendix 3B, *Environmental Commitments, AMMs, and CMs*) and there would be no increased
 40 likelihood of loss of property, personal injury or death due to construction of Alternative 2B.
 41 Hazards to workers and project structures would be controlled at safe levels and the impact would
 42 be less than significant. No mitigation is required.

1 **Impact GEO-4: Loss of Property, Personal Injury, or Death from Slope Failure during**
 2 **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
 5 locations would have no bearing on the hazard of slope failure at borrow and storage sites and
 6 would not change the hazard of loss of property, personal injury, or death during construction. The
 7 effects of Alternative 2B would, therefore, be the same as 1B. See the description and findings under
 8 Alternative 1B. There would be no adverse effect.

9 **CEQA Conclusion:** Settlement/failure of cutslopes of borrow sites and failure of soil/RTM fill slopes
 10 could result in loss of property or personal injury during construction. However, because DWR
 11 would conform to Cal-OSHA and other state code requirements and conform to applicable
 12 geotechnical design guidelines and standards, such as USACE design measures, the hazard would be
 13 controlled to a safe level and there would be no increased likelihood of loss of property, personal
 14 injury or death due to construction of Alternative 2B. The impact would be less than significant. No
 15 mitigation is required.

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

19 **NEPA Effects:** Alternative 2B would include the same physical/structural components as Alternative
 20 1B, but could entail two different intake and intake pumping plant locations. These changes in
 21 locations would have no bearing on the hazard of structural failure from construction-related
 22 ground motions and would not change the hazard of loss of property, personal injury, or death
 23 during operation of the water conveyance features. The effects of Alternative 2B would, therefore,
 24 be the same as 1B. See the description and findings under Alternative 1B. There would be no
 25 adverse effect.

26 **CEQA Conclusion:** Construction-related ground motions and traffic effects could initiate
 27 liquefaction, which could cause failure of structures during construction. The impact could be
 28 significant. However, because DWR would conform to Cal-OSHA and other state code requirements
 29 and conform to applicable design guidelines and standards, such as USACE design measures, in
 30 addition to implementation of Mitigation Measures TRANS-2a and TRANS-2b, as well as the
 31 maintenance and reconstruction of levees through Mitigation Measure TRANS-2c, the hazard would
 32 be controlled to a level that would protect worker safety (see Appendix 3B, *Environmental*
 33 *Commitments, AMMs, and CMs*) and there would be no increased likelihood of loss of property,
 34 personal injury or death due to construction of Alternative 2B. The impact would be less than
 35 significant.

36 **Mitigation Measure TRANS-2a: Prohibit Construction Activity on Physically Deficient**
 37 **Roadway Segments**

38 Please refer to Mitigation Measure TRANS-2a in Alternative 1A, Impact TRANS-2, in Chapter 19,
 39 *Transportation*.

1 **Mitigation Measure TRANS-2b: Limit Construction Activity on Physically Deficient**
 2 **Roadway Segments**

3 Please refer to Mitigation Measure TRANS-2b in Alternative 1A, Impact TRANS-2, in Chapter 19,
 4 *Transportation*.

5 **Mitigation Measure TRANS-2c: Improve Physical Condition of Affected Roadway Segments**
 6 **as Stipulated in Mitigation Agreements or Encroachment Permits**

7 Please refer to Mitigation Measure TRANS-2c in Alternative 1A, Impact TRANS-2, in Chapter 19,
 8 *Transportation*.

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 2B would include the same physical/structural components as Alternative
 12 1B, but could entail two different intake and intake pumping plant locations. These changes in
 13 locations would have no bearing on the hazard of fault rupture and would not change the hazard of
 14 loss of property, personal injury, or death during operation of the water conveyance features. The
 15 effects of Alternative 2B would, therefore, be the same as 1B. See the description and findings under
 16 Alternative 1B. There would be no adverse effect

17 **CEQA Conclusion:** There are no active faults capable of surface rupture that extend into the East
 18 alignment. Although the Thornton Arch and West Tracy blind thrusts occur beneath the East
 19 alignment, based on available information, they do not present a hazard of surface rupture and there
 20 would be no increased likelihood of loss of property, personal injury or death due to operation of
 21 Alternative 2B. 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 2B would include the same physical/structural components as Alternative
 25 1B, but could entail two different intake and intake pumping plant locations. These changes in
 26 locations would have no bearing on the hazard of structural failure from seismic shaking and would
 27 not change the hazard of loss of property, personal injury, or death during operation of the water
 28 conveyance features. The effects of Alternative 2B would, therefore, be the same as 1B. See the
 29 description and findings under Alternative 1B. There would be no adverse effect.

30 **CEQA Conclusion:** Seismically induced strong ground shaking could damage the canals, pipelines,
 31 tunnel 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
 34 refer to Chapter 6, *Surface Water*, for a detailed discussion of potential flood impacts.) However,
 35 through the final design process, measures to address this hazard would be required to conform to
 36 applicable design codes, guidelines, and standards. As described in Section 9.3.1, *Methods for*
 37 *Analysis*, and in Appendix 3B, *Environmental Commitments, AMMs, and CMs*, such design codes,
 38 guidelines, and standards include the California Building Code and resource agency and professional
 39 engineering specifications, such as the Division of Safety of Dams *Guidelines for Use of the*
 40 *Consequence-Hazard Matrix and Selection of Ground Motion Parameters*, DWR's Division of Flood
 41 Management *FloodSAFE Urban Levee Design Criteria*, and USACE's *Engineering and Design*—

1 *Earthquake Design and Evaluation for Civil Works Projects.* Conformance with these codes and
 2 standards is an environmental commitment by DWR to ensure that ground shaking risks are
 3 minimized as the water conveyance features are operated. The hazard would be controlled to a safe
 4 level and there would be no increased likelihood of loss of property, personal injury or death due to
 5 operation of Alternative 2B. The impact would be less than significant. No mitigation is required.

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

9 **NEPA Effects:** Alternative 2B would include the same physical/structural components as Alternative
 10 1B, but could entail two different intake and intake pumping plant locations. These changes in
 11 locations would have no bearing on the hazard of structural failure from ground failure and would
 12 not change the hazard of loss of property, personal injury, or death during operation of the water
 13 conveyance features. The effects of Alternative 2B would, therefore, be the same as 1B. See the
 14 description and findings under Alternative 1B. There would be no adverse effect.

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

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

32 **NEPA Effects:** Alternative 2B would include the same physical/structural components as Alternative
 33 1B, but could entail two different intake and intake pumping plant locations. These changes in
 34 locations would have no bearing on the hazard of landslides and other slope instability and would
 35 not change the hazard of loss of property, personal injury, or death during operation of the water
 36 conveyance features. The effects of Alternative 2B would, therefore, be the same as 1B. See the
 37 description and findings under Alternative 1B. There would be no adverse effect.

38 **CEQA Conclusion:** Unstable levee slopes and natural stream banks may fail, either from high pore-
 39 water pressure caused by high rainfall and weak soil, or from seismic shaking. Structures
 40 constructed on these slopes could be damaged or fail entirely as a result of slope instability.
 41 However, through the final design process, measures to address this hazard would be required to
 42 conform to applicable design codes, guidelines, and standards. As described in Section 9.3.1,
 43 *Methods for Analysis*, and in Appendix 3B, *Environmental Commitments, AMMs, and CMs*, such design

1 codes, guidelines, and standards include the California Building Code and resource agency and
 2 professional engineering specifications, such as USACE's *Engineering and Design—Earthquake*
 3 *Design and Evaluation for Civil Works Projects*. Conformance with these codes and standards is an
 4 environmental commitment by DWR to ensure cut and fill slopes and embankments would be stable
 5 as the water conveyance features are operated and there would be no increased likelihood of loss of
 6 property, personal injury or death due to operation of Alternative 2B. The impact would be less than
 7 significant. No mitigation is required.

8 **Impact GEO-10: Loss of Property, Personal Injury, or Death from Seiche or Tsunami during** 9 **Operation of Water Conveyance Features**

10 **NEPA Effects:** Alternative 2B would include the same physical/structural components as Alternative
 11 1B, but could entail two different intake and intake pumping plant locations. These changes in
 12 locations would have no bearing on the hazard of seiche or tsunami and would not change the
 13 hazard of loss of property, personal injury, or death during operation of the water conveyance
 14 features. The effects of Alternative 2B would, therefore, be the same as 1B. See the description and
 15 findings under Alternative 1B. There would be no adverse effect.

16 **CEQA Conclusion:** Based on recorded tsunami wave heights at the Golden Gate (Contra Costa
 17 Transportation Agency 2009) and in the interior of the San Francisco Bay and on tsunami
 18 inundation maps prepared by the California Department of Conservation (2009), the height of a
 19 tsunami wave reaching the Suisun Marsh and the Delta would be small because of the distance from
 20 the ocean and attenuating effect of the San Francisco Bay. Similarly, the potential for a significant
 21 seiche to occur in most parts of the Plan Area is considered low because the seismic hazard and the
 22 geometry of the water bodies (i.e., wide and shallow) near conveyance facilities are not favorable for
 23 a seiche to occur. However, assuming that the West Tracy fault is potentially active, a potential exists
 24 for a seiche to occur in the Clifton Court Forebay and the Byron Tract Forebay (Fugro Consultants
 25 2011). The impact would not be significant because the Byron Tract Forebay embankment would be
 26 designed and constructed according to applicable design codes, guidelines, and standards to contain
 27 and withstand the anticipated maximum seiche wave height. There would be no increased likelihood
 28 of loss of property, personal injury or death due to operation of Alternative 2B from seiche or
 29 tsunami. The impact would be less than significant. No mitigation is required.

30 **Impact GEO-11: Ground Failure Caused by Increased Groundwater Surface Elevations from** 31 **Unlined Canal Seepage as a Result of Operating the Water Conveyance Facilities**

32 **NEPA Effects:** Alternative 2B would include the same physical/structural components as Alternative
 33 1B, but could entail two different intake and intake pumping plant locations. These changes in
 34 locations would result in a similar hazard of ground shaking and would not substantially change the
 35 hazard of loss of property, personal injury, or death during construction. The effects of Alternative
 36 2B would, therefore, be the same as 1B. See the description and findings under Alternative 1B. There
 37 would be no adverse effect.

38 **CEQA Conclusion:** Seepage from an unlined canal could raise the water table level along the canal,
 39 thereby increasing the hazard of liquefaction where the water table is not already close to the
 40 surface. The increased hazard of liquefaction could threaten the integrity of the canal in the event
 41 that liquefaction occurs. However, because DWR would conform to applicable design guidelines and
 42 standards, such as USACE design measures, the hazard would be controlled to a safe level and there

1 would be no increased likelihood of loss of property, personal injury or death due to operation of
2 Alternative 2B. The impact would be less than significant. No mitigation is required.

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

5 **NEPA Effects:** Conservation measures would be the same under Alternative 2B as under 1A. See
6 description and findings under Alternative 1A. There would be no adverse effect.

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

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

23 **NEPA Effects:** Conservation measures would be the same under Alternative 2B as under 1A. See
24 description and findings under Alternative 1A. There would be no adverse effect.

25 **CEQA Conclusion:** Ground shaking could damage levees, berms, and other structures. Among all the
26 ROAs, the Suisun Marsh ROA would be the most subject to ground shaking because of its proximity
27 to active faults. The Suisun Marsh ROA is subject to a PGA of approximately 0.31 to 0.35 g for 200-
28 year return interval, while the PGA for the other ROAs ranges from approximately 0.11 to 0.26 g.
29 Damage to these features could result in their failure, causing flooding of otherwise protected areas.
30 However, as described in Section 9.3.1, *Methods for Analysis*, and in Appendix 3B, *Environmental*
31 *Commitments, AMMs, and CMs*, design codes, guidelines, and standards, including the California
32 Building Code and resource agency and professional engineering specifications, such as DWR's
33 Division of Flood Management *FloodSAFE Urban Levee Design Criteria* and USACE's *Engineering and*
34 *Design—Earthquake Design and Evaluation for Civil Works Projects* would be used for final design of
35 conservation features. Conformance with these design standards is an environmental commitment
36 by the BDCP proponents to ensure that strong seismic shaking risks are minimized as the
37 conservation measures are operated and there would be no increased likelihood of loss of property,
38 personal injury or death in the ROAs. The impact would be less than significant. No mitigation is
39 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**
 3 **Opportunity 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
 7 damage to or failure of levees, berms, and other features constructed at the restoration areas.
 8 Failure of levees and 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, AMMs, and CMs*, such
 12 design codes, guidelines, and standards include USACE's *Engineering and Design—Stability Analysis*
 13 *of Concrete Structures* and *Soil Liquefaction during Earthquakes*, by the Earthquake Engineering
 14 Research Institute. Conformance with these design standards is an environmental commitment by
 15 the BDCP proponents to ensure that liquefaction risks are minimized as the water conservation
 16 features are implemented. The hazard would be controlled to a safe level and there would be no
 17 increased likelihood of loss of property, personal injury or death in the ROAs. The impact would be
 18 less than significant. 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 *NEPA Effects:* Conservation measures would be the same under Alternative 2B as under 1A. See
 22 description and findings under Alternative 1A. There would be no adverse effect.

23 *CEQA Conclusion:* Unstable new and existing levee and embankment slopes could fail as a result of
 24 seismic shaking and as a result of high soil-water content during heavy rainfall and cause flooding of
 25 otherwise protected areas. However, because the BDCP proponents would conform to applicable
 26 design guidelines and standards, such as USACE design measures, the hazard would be controlled to
 27 a safe level and there would be no increased likelihood of loss of property, personal injury or death
 28 in the ROAs. The impact 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
 35 effect of the San Francisco Bay. The impact would be less than significant. No mitigation is required.
 36 Similarly, the potential for a significant seiche to occur in the Plan Area that would cause loss of
 37 property, personal injury, or death at the ROAs is considered low because conditions for a seiche to
 38 occur at the ROAs are not favorable. The impact would be less than significant. No mitigation is
 39 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 to 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, AMMs, and CMs*). 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 to 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, AMMs, and CMs*) 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.

1 The effects of Alternative 2C 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:** Ground settlement above the tunneling operation could result in loss of property
4 or personal injury during construction. However, DWR would conform to Cal-OSHA, USACE and
5 other design requirements to protect worker safety. DWR would also ensure that the design
6 specifications are properly executed during construction. DWR has made an environmental
7 commitment to use the appropriate code and standard requirements to minimize potential risks
8 (Appendix 3B, *Environmental Commitments, AMMs, and CMs*). Hazards to workers and project
9 structures would be controlled at safe levels and there would be no increased likelihood of loss of
10 property, personal injury or death due to construction of Alternative 2C. The impact would be less
11 than 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:** Alternative 2C would include the same physical/structural components as Alternative
15 1C, but could entail two different intake and intake pumping plant locations. These changes in
16 locations would have no bearing on the hazard of slope failure at borrow sites and storage sites and
17 would not change the hazard of loss of property, personal injury, or death during construction. The
18 effects of Alternative 2C would, therefore, be the same as 1C. See the description and findings under
19 Alternative 1C. There would be no adverse effect.

20 **CEQA Conclusion:** Settlement/failure of cutslopes of borrow sites and failure of soil/RTM fill slopes
21 could result in loss of property or personal injury during construction. However, because DWR
22 would conform to Cal-OSHA requirements and conform to applicable geotechnical design guidelines
23 and standards, such as USACE design measures, the hazard would be controlled to a safe level and
24 there would be no increased likelihood of loss of property, personal injury or death due to
25 construction of Alternative 2C. The 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**
28 **Features**

29 **NEPA Effects:** Alternative 2C would include the same physical/structural components as Alternative
30 1C, but could entail two different intake and intake pumping plant locations. These changes in
31 locations would have no bearing on the hazard of structural failure from construction-related
32 ground motions and would not change the hazard of loss of property, personal injury, or death
33 during operation of the water conveyance features. The effects of Alternative 2C would, therefore, be
34 the same as 1C. See the description and findings under Alternative 1C. There would be no adverse
35 effect.

36 **CEQA Conclusion:** Construction-related ground motions and traffic effects could initiate
37 liquefaction, which could cause failure of structures during construction. The impact could be
38 significant. However, because DWR has committed to conform to Cal-OSHA and other state code
39 requirements and conform to applicable design guidelines and standards, such as USACE design
40 measures, in addition to implementation of Mitigation Measures TRANS-2a and TRANS-2b, as well
41 as the maintenance and reconstruction of levees through Mitigation Measure TRANS-2c, the hazard
42 would be controlled to a level that would protect worker safety (see Appendix 3B, *Environmental*
43 *Commitments, AMMs, and CMs*) and there would be no increased likelihood of loss of property,

1 personal injury or death due to construction of Alternative 2C. The impact would be less than
2 significant.

3 **Mitigation Measure TRANS-2a: Prohibit Construction Activity on Physically Deficient**
4 **Roadway Segments**

5 Please refer to Mitigation Measure TRANS-2a in Alternative 1A, Impact TRANS-2, in Chapter 19,
6 *Transportation*.

7 **Mitigation Measure TRANS-2b: Limit Construction Activity on Physically Deficient**
8 **Roadway Segments**

9 Please refer to Mitigation Measure TRANS-2b in Alternative 1A, Impact TRANS-2, in Chapter 19,
10 *Transportation*.

11 **Mitigation Measure TRANS-2c: Improve Physical Condition of Affected Roadway Segments**
12 **as Stipulated in Mitigation Agreements or Encroachment Permits**

13 Please refer to Mitigation Measure TRANS-2c in Alternative 1A, Impact TRANS-2, in Chapter 19,
14 *Transportation*.

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

17 **NEPA Effects:** Alternative 2C would include the same physical/structural components as Alternative
18 1C, but could entail two different intake and intake pumping plant locations. These changes in
19 locations would have no bearing on the hazard of fault rupture and would not change the hazard of
20 loss of property, personal injury, or death during operation of the water conveyance features. The
21 effects of Alternative 2C would, therefore, be the same as 1C. See the description and findings under
22 Alternative 1C. There would be no adverse effect.

23 **CEQA Conclusion:** There are no active faults capable of surface rupture that extend into the West
24 alignment. Although the Thornton Arch and West Tracy blind thrusts occur beneath the West
25 alignment, based on available information, they do not present a hazard of surface rupture and there
26 would be no increased likelihood of loss of property, personal injury or death due to operation of
27 Alternative 2C. There would be no impact. No mitigation is required.

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

30 **NEPA Effects:** Alternative 2C would include the same physical/structural components as Alternative
31 1C, but could entail two different intake and intake pumping plant locations. These changes in
32 locations would have no bearing on the hazard of structural failure from seismic shaking and would
33 not change the hazard of loss of property, personal injury, or death during operation of the water
34 conveyance features. The effects of Alternative 2C would, therefore, be the same as 1C. See the
35 description and findings under Alternative 1C. There would be no adverse effect.

36 **CEQA Conclusion:** Seismically induced strong ground shaking could damage the canal, pipelines,
37 tunnels, culvert siphons, intake facilities, pumping plants, and other facilities. The damage could
38 disrupt the water supply through the conveyance system. In an extreme event, an uncontrolled
39 release of water from the damaged conveyance system could cause flooding and inundation of

1 structures. (Please refer to Chapter 6, *Surface Water*, for a detailed discussion of potential flood
 2 impacts.) However, through the final design process, measures to address this hazard would be
 3 required to conform to applicable design codes, guidelines, and standards. As described in Section
 4 9.3.1, *Methods for Analysis*, and in Appendix 3B, *Environmental Commitments, AMMs, and CMs*, such
 5 design codes, guidelines, and standards include the California Building Code and resource agency
 6 and professional engineering specifications, such as the Division of Safety of Dams *Guidelines for Use*
 7 *of the Consequence-Hazard Matrix and Selection of Ground Motion Parameters*, DWR's Division of
 8 Flood Management *FloodSAFE Urban Levee Design Criteria*, and USACE's *Engineering and Design—*
 9 *Earthquake Design and Evaluation for Civil Works Projects*. Conformance with these codes and
 10 standards is an environmental commitment by DWR to ensure that ground shaking risks are
 11 minimized as the water conveyance features are operated. The hazard would be controlled to a safe
 12 level and there would be no increased likelihood of loss of property, personal injury or death due to
 13 operation of Alternative 2C. The impact would be less than significant. No mitigation is required.

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

17 **NEPA Effects:** Alternative 2C would include the same physical/structural components as Alternative
 18 1C, but could entail two different intake and intake pumping plant locations. These changes in
 19 locations would have no bearing on the hazard of structural failure from ground failure and would
 20 not change the hazard of loss of property, personal injury, or death during operation of the water
 21 conveyance features. The effects of Alternative 2C would, therefore, be the same as 1C. See the
 22 description and findings under Alternative 1C. There would be no adverse effect.

23 **CEQA Conclusion:** Seismically induced ground shaking could cause liquefaction. Liquefaction could
 24 damage pipelines, tunnels, culvert siphons, intake facilities, pumping plants, and other facilities, and
 25 thereby disrupt the water supply through the conveyance system. In an extreme event, flooding and
 26 inundation of structures could result from an uncontrolled release of water from the damaged
 27 conveyance system. (Please refer to Chapter 6, *Surface Water*, for a detailed discussion of potential
 28 flood impacts.) However, through the final design process, measures to address the liquefaction
 29 hazard would be required to conform to applicable design codes, guidelines, and standards. As
 30 described in Section 9.3.1, *Methods for Analysis*, and in Appendix 3B, *Environmental Commitments,*
 31 *AMMs, and CMs*, such design codes, guidelines, and standards include USACE's *Engineering and*
 32 *Design—Stability Analysis of Concrete Structures and Soil Liquefaction during Earthquakes*, by the
 33 Earthquake Engineering Research Institute. Conformance with these design standards is an
 34 environmental commitment by DWR to ensure that liquefaction risks are minimized as the water
 35 conveyance features are operated. The hazard would be controlled to a safe level and there would
 36 be no increased likelihood of loss of property, personal injury or death due to operation of
 37 Alternative 2C. The impact would be less than significant. No mitigation is required.

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

40 **NEPA Effects:** Alternative 2C would include the same physical/structural components as Alternative
 41 1C, but could entail two different intake and intake pumping plant locations. These changes in
 42 locations would have no bearing on the hazard of landslides and other slope instability and would
 43 not change the hazard of loss of property, personal injury, or death during operation of the water

1 conveyance features. The effects of Alternative 2C would, therefore, be the same as 1C. See the
2 description and findings under Alternative 1C. There would be no adverse effect.

3 **CEQA Conclusion:** Unstable levee slopes and natural stream banks may fail, either from high pore-
4 water pressure caused by high rainfall and weak soil, or from seismic shaking. Structures
5 constructed on these slopes could be damaged or fail entirely as a result of slope instability.
6 However, through the final design process, measures to address this hazard would be required to
7 conform to applicable design codes, guidelines, and standards. As described in Section 9.3.1,
8 *Methods for Analysis*, and in Appendix 3B, *Environmental Commitments, AMMs, and CMs*, such design
9 codes, guidelines, and standards include the California Building Code and resource agency and
10 professional engineering specifications, such as USACE's *Engineering and Design—Earthquake*
11 *Design and Evaluation for Civil Works Projects*. Conformance with these codes and standards is an
12 environmental commitment by DWR to ensure cut and fill slopes and embankments would be stable
13 as the water conveyance features are operated and there would be no increased likelihood of loss of
14 property, personal injury or death due to operation of Alternative 2C. The impact would be less than
15 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 2C would include the same physical/structural components as Alternative
19 1C, but could entail two different intake and intake pumping plant locations. These changes in
20 locations would have no bearing on the hazard of seiche or tsunami and would not change the
21 hazard of loss of property, personal injury, or death during operation of the water conveyance
22 features. The effects of Alternative 2C would, therefore, be the same as 1C. See the description and
23 findings under Alternative 1C. 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
26 inundation maps prepared by the California Department of Conservation (2009), the height of a
27 tsunami wave reaching the Suisun Marsh and the Delta would be small because of the distance from
28 the ocean and attenuating effect of the San Francisco Bay. Similarly, the potential for a significant
29 seiche to occur in most parts of the Plan Area is considered low because the seismic hazard and the
30 geometry of the water bodies (i.e., wide and shallow) near conveyance facilities are not favorable for
31 a seiche to occur. However, assuming that the West Tracy fault is potentially active, a potential exists
32 for a seiche to occur in the Clifton Court Forebay and the Byron Tract Forebay (Fugro Consultants
33 2011). The impact would not be significant because the Byron Tract Forebay embankment would be
34 designed and constructed according to applicable design codes, guidelines, and standards to contain
35 and withstand the anticipated maximum seiche wave height. There would be no increased likelihood
36 of loss of property, personal injury or death due to operation of Alternative 2C from seiche or
37 tsunami. The impact would be 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 2C would include the same physical/structural components as Alternative
41 1C, but could entail two different intake and intake pumping plant locations. These changes in
42 locations would result in a similar hazard of ground shaking and would not substantially change the
43 hazard of loss of property, personal injury, or death during construction. The effects of Alternative

1 2C would, therefore, be the same as 1C. See the description and findings under Alternative 1C. There
2 would be no adverse effect.

3 **CEQA Conclusion:** Seepage from an unlined canal could raise the water table level along the canal,
4 thereby increasing the hazard of liquefaction where the water table is not already close to the
5 surface. The increased hazard of liquefaction could threaten the integrity of the canal in the event
6 that liquefaction occurs. However, because DWR would conform to applicable design guidelines and
7 standards, such as USACE design measures, the hazard would be controlled to a safe level and there
8 would be no increased likelihood of loss of property, personal injury or death due to operation of
9 Alternative 2C. The impact would be less than significant. No mitigation is required.

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

12 **NEPA Effects:** Conservation measures would be the same under Alternative 2C as under 1A. See
13 description and findings under Alternative 1A. There would be no adverse effect.

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

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

30 **NEPA Effects:** Conservation measures would be the same under Alternative 2C as under 1A. See
31 description and findings under Alternative 1A. There would be no adverse effect.

32 **CEQA Conclusion:** Ground shaking could damage levees, berms, and other structures. Among all the
33 ROAs, the Suisun Marsh ROA would be the most subject to ground shaking because of its proximity
34 to active faults. The Suisun Marsh ROA is subject to a PGA of approximately 0.31 to 0.35 g for 200-
35 year return interval, while the PGA for the other ROAs ranges from approximately 0.11 to 0.26 g.
36 Damage to these features could result in their failure, causing flooding of otherwise protected areas.

37 However, as described in Section 9.3.1, *Methods for Analysis*, and in Appendix 3B, *Environmental*
38 *Commitments, AMMs, and CMs*, design codes, guidelines, and standards, including the California
39 Building Code and resource agency and professional engineering specifications, such as DWR's
40 Division of Flood Management *FloodSAFE Urban Levee Design Criteria* and USACE's *Engineering and*
41 *Design—Earthquake Design and Evaluation for Civil Works Projects* would be used for final design of
42 conservation features. Conformance with these design standards is an environmental commitment

1 by the BDCP proponents to ensure that strong seismic shaking risks are minimized as the
 2 conservation measures are operated and there would be no increased likelihood of loss of property,
 3 personal injury or death in the ROAs. The impact would be less than significant. No mitigation is
 4 required.

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

8 *NEPA Effects:* Conservation measures would be the same under Alternative 2C as under 1A. See
 9 description and findings under Alternative 1A. There would be no adverse effect.

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

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

25 *NEPA Effects:* Conservation measures would be the same under Alternative 2C as under 1A. See
 26 description and findings under Alternative 1A. There would be no adverse impact.

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

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

35 *NEPA Effects:* Conservation measures under Alternative 2C would be similar to that as under
 36 Alternative 1A. See description and findings under Alternative 1A. There would be no adverse
 37 impact.

38 *CEQA Conclusion:* Based on recorded tsunami wave heights at the Golden Gate, the height of a
 39 tsunami wave reaching the ROAs would be small because of the distance from the ocean and
 40 attenuating effect of the San Francisco Bay. Similarly, the potential for a significant seiche to occur in
 41 the Plan Area is considered low because conditions for a seiche to occur near conveyance facilities

1 are not favorable. There would be no increased likelihood of loss of property, personal injury or
 2 death in the ROAs from seiche or tsunami. The impact would be less than significant. No mitigation
 3 is required.

4 **9.3.3.8 Alternative 3—Dual Conveyance with Pipeline/Tunnel and** 5 **Intakes 1 and 2 (6,000 cfs; Operational Scenario A)**

6 **Impact GEO-1: Loss of Property, Personal Injury, or Death from Structural Failure Resulting** 7 **from Strong Seismic Shaking of Water Conveyance Features during Construction**

8 **NEPA Effects:** Alternative 3 would include the same physical/structural components as Alternative
 9 1A, but would entail three less intakes and three less pumping plants. These differences would
 10 present a slightly lower hazard of structural failure from seismic shaking and would not
 11 substantially change the hazard of loss of property, personal injury, or death during construction
 12 compared to Alternative 1A. The effects of Alternative 3 would, therefore, be the same as 1A. See the
 13 description and findings under Alternative 1A. There would be no adverse effect.

14 **CEQA Conclusion:** Seismically induced ground shaking could cause collapse or other failure of
 15 project facilities while under construction. However, DWR would conform to Cal-OSHA and other
 16 state code requirements, such as shoring, bracing, lighting, excavation depth restrictions, required
 17 slope angles, and other measures, to protect worker safety. Conformance with these standards and
 18 codes is an environmental commitment of the project (see Appendix 3B, *Environmental*
 19 *Commitments, AMMs, and CMs*). Conformance with these health and safety requirements and the
 20 application of accepted, proven construction engineering practices would reduce this risk and there
 21 would be no increased likelihood of loss of property, personal injury or death due to construction of
 22 Alternative 3. This impact would be less than significant. No additional mitigation is required.

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

25 **NEPA Effects:** Alternative 3 would include the same physical/structural components as Alternative
 26 1A, but would entail three less intakes and three less pumping plants. These differences would
 27 present a slightly lower hazard of settlement or collapse caused by dewatering and would not
 28 substantially change the hazard of loss of property, personal injury, or death during construction
 29 compared to Alternative 1A. The effects of Alternative 3 would, therefore, be the same as 1A. See the
 30 description and findings under Alternative 1A. There would be no adverse effect.

31 **CEQA Conclusion:** Settlement or failure of excavations during construction could result in loss of
 32 property or personal injury. However, DWR would conform to Cal-OSHA and other state code
 33 requirements, such as using seepage cutoff walls, shoring, and other measures, to protect worker
 34 safety. DWR would also ensure that the design specifications are properly executed during
 35 construction. DWR has made an environmental commitment to use the appropriate code and
 36 standard requirements to minimize potential risks (Appendix 3B, *Environmental Commitments,*
 37 *AMMs, and CMs*) and there would be no increased likelihood of loss of property, personal injury or
 38 death due to construction of Alternative 3. The impact would be less than significant. No mitigation
 39 is required.

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

3 **NEPA Effects:** Alternative 3 would include the same physical/structural components as Alternative
4 1A, but would entail three less intakes and three less pumping plants. These differences would
5 present a slightly lower hazard of ground settlement hazard on the tunnel and would not
6 substantially change the hazard of loss of property, personal injury, or death during construction
7 compared to Alternative 1A. The effects of Alternative 3 would, therefore, be the same as 1A. See the
8 description and findings under Alternative 1A. There would be no adverse effect.

9 **CEQA Conclusion:** Ground settlement above the tunneling operation could result in loss of property
10 or personal injury during construction. However, DWR would conform to Cal-OSHA, USACE, and
11 other design requirements to protect worker safety. DWR would also ensure that the design
12 specifications are properly executed during construction. DWR has made an environmental
13 commitment to use the appropriate code and standard requirements to minimize potential risks
14 (Appendix 3B, *Environmental Commitments, AMMs, and CMs*). Hazards to workers and project
15 structures would be controlled at safe levels and there would be no increased likelihood of loss of
16 property, personal injury or death due to construction of Alternative 3. The impact would be less
17 than significant. No mitigation is required.

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

20 **NEPA Effects:** Alternative 3 would include the same physical/structural components as Alternative
21 1A, but would entail three less intakes and three less pumping plants. These differences would
22 present a slightly lower hazard of slope failure at borrow and spoils storage sites and would not
23 substantially change the hazard of loss of property, personal injury, or death during construction
24 compared to Alternative 1A. The effects of Alternative 3 would, therefore, be the same as 1A. See the
25 description and findings under Alternative 1A. 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
28 would conform to Cal-OSHA and other state code requirements and conform to applicable
29 geotechnical design guidelines and standards, such as USACE design measures, the hazard would be
30 controlled to a safe level and there would be no increased likelihood of loss of property, personal
31 injury or death due to construction of Alternative 3. The impact would be less than significant. No
32 mitigation is required.

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

36 **NEPA Effects:** Alternative 3 would include the same physical/structural components as Alternative
37 1A, but would entail three less intakes and three less pumping plants. These differences would
38 present a slightly lower hazard of structural failure from construction-related ground motions and
39 would not substantially change the hazard of loss of property, personal injury, or death during
40 construction compared to Alternative 1A. The effects of Alternative 3 would, therefore, be the same
41 as 1A. See the description and findings under Alternative 1A. There would be no adverse effect.

1 **CEQA Conclusion:** Construction-related ground motions and traffic effects could initiate
 2 liquefaction, which could cause failure of structures during construction, which could result in injury
 3 of workers at the construction sites. The impact could be significant. However, because DWR would
 4 conform to Cal-OSHA and other state code requirements and conform to applicable design
 5 guidelines and standards, such as USACE design measures, in addition to implementation of
 6 Mitigation Measures TRANS-2a and TRANS-2b, as well as the maintenance and reconstruction of
 7 levees through Mitigation Measure TRANS-2c, the hazard would be controlled to a level that would
 8 protect worker safety (see Appendix 3B, *Environmental Commitments, AMMs, and CMs*) and there
 9 would be no increased likelihood of loss of property, personal injury or death due to construction of
 10 Alternative 3. The impact would be less than significant.

11 **Mitigation Measure TRANS-2a: Prohibit Construction Activity on Physically Deficient**
 12 **Roadway Segments**

13 Please refer to Mitigation Measure TRANS-2a in Alternative 1A, Impact TRANS-2, in Chapter 19,
 14 *Transportation*.

15 **Mitigation Measure TRANS-2b: Limit Construction Activity on Physically Deficient**
 16 **Roadway Segments**

17 Please refer to Mitigation Measure TRANS-2b in Alternative 1A, Impact TRANS-2, in Chapter 19,
 18 *Transportation*.

19 **Mitigation Measure TRANS-2c: Improve Physical Condition of Affected Roadway Segments**
 20 **as Stipulated in Mitigation Agreements or Encroachment Permits**

21 Please refer to Mitigation Measure TRANS-2c in Alternative 1A, Impact TRANS-2, in Chapter 19,
 22 *Transportation*.

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

25 **NEPA Effects:** Alternative 3 would include the same physical/structural components as Alternative
 26 1A, but would entail three less intakes and three less pumping plants. These differences would not
 27 present a difference in the hazard of an earthquake fault 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
 30 under Alternative 1A. There would be no adverse effect.

31 **CEQA Conclusion:** There are no active faults capable of surface rupture that extend into the
 32 pipeline/tunnel alignment. Although the Thornton Arch and West Tracy blind thrusts occur beneath
 33 the pipeline/tunnel alignment, based on available information, they do not present a hazard of
 34 surface rupture and there would be no increased likelihood of loss of property, personal injury or
 35 death due to operation of Alternative 3. There would be no impact. No mitigation is required.

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

38 **NEPA Effects:** Alternative 3 would include the same physical/structural components as Alternative
 39 1A, but would entail three less intakes and three less pumping plants. These differences would

1 present a slightly lower hazard of seismic shaking but would not substantially change the hazard of
 2 loss of property, personal injury, or death during construction compared to Alternative 1A. The
 3 effects of Alternative 3 would, therefore, be the same as 1A. See the description and findings under
 4 Alternative 1A. There would be no adverse effect.

5 **CEQA Conclusion:** Seismically induced strong ground shaking could damage pipelines, tunnels,
 6 intake facilities, pumping plants, and other facilities. The damage could disrupt the water supply
 7 through the conveyance system. In an extreme event, flooding and inundation of structures could
 8 result from an uncontrolled release of water from the damaged conveyance system. (Please refer to
 9 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, AMMs, and CMs*, such design codes, guidelines, and
 13 standards include the California Building Code and resource agency and professional engineering
 14 specifications, such as the Division of Safety of Dams' *Guidelines for Use of the Consequence-Hazard*
 15 *Matrix and Selection of Ground Motion Parameters*, DWR's Division of Flood Management *FloodSAFE*
 16 *Urban Levee Design Criteria*, and USACE's *Engineering and Design—Earthquake Design and*
 17 *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
 19 water conveyance features are operated. The hazard would be controlled to a safe level and there
 20 would be no increased likelihood of loss of property, personal injury or death due to operation of
 21 Alternative 3. 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 3 would include the same physical/structural components as Alternative
 26 1A, but would entail three less intakes and three less pumping plants. These differences would
 27 present a slightly lower hazard of structural failure from liquefaction but would not substantially
 28 change the hazard of loss of property or personal injury during construction compared to
 29 Alternative 1A. The effects of Alternative 3 would, therefore, be the same as 1A. See the description
 30 and findings under Alternative 1A. There would be no adverse effect.

31 **CEQA Conclusion:** Seismically induced ground shaking could cause liquefaction. Liquefaction could
 32 damage pipelines, tunnels, intake facilities, pumping plants, and other facilities, and thereby disrupt
 33 the water supply through the conveyance system. In an extreme event, flooding and inundation of
 34 structures could result from an uncontrolled release of water from the damaged conveyance system.
 35 (Please refer to Chapter 6, *Surface Water*, for a detailed discussion of potential flood impacts.)
 36 However, through the final design process, measures to address the liquefaction hazard would be
 37 required to conform to applicable design codes, guidelines, and standards. As described in Section
 38 9.3.1, *Methods for Analysis*, and in Appendix 3B, *Environmental Commitments, AMMs, and CMs*, such
 39 design codes, guidelines, and standards include USACE's *Engineering and Design—Stability Analysis*
 40 *of Concrete Structures and Soil Liquefaction during Earthquakes*, by the Earthquake Engineering
 41 Research Institute. Conformance with these design standards is an environmental commitment by
 42 DWR to ensure that liquefaction risks are minimized as the water conveyance features are operated.
 43 The hazard would be controlled to a safe level and there would be no increased likelihood of loss of
 44 property, personal injury or death due to operation of Alternative 3. The impact would be less than
 45 significant. No mitigation is 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 3 would include the same physical/structural components as Alternative
 4 1A, but would entail three less intakes and three less pumping plants. These differences would
 5 present a slightly lower hazard of landslides and other slope instability but 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
 8 and findings under Alternative 1A. There 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
 11 constructed on these slopes could be damaged or fail entirely as a result of slope instability.
 12 However, through the final design process, measures to address this hazard would be required to
 13 conform to applicable design codes, guidelines, and standards. As described in Section 9.3.1,
 14 *Methods for Analysis*, and in Appendix 3B, *Environmental Commitments, AMMs, and CMs*, such design
 15 codes, guidelines, and standards include the California Building Code and resource agency and
 16 professional engineering specifications, such as 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 cut and fill slopes and embankments would be stable
 19 as the water conveyance features are operated and there would be no increased likelihood of loss of
 20 property, personal injury or death due to operation of Alternative 3. The impact would be less than
 21 significant. No mitigation is required.

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

24 **NEPA Effects:** Alternative 3 would include the same physical/structural components as Alternative
 25 1A, but would entail three less intakes and three less pumping plants. These differences would
 26 present a slightly lower hazard of a seiche or tsunami but would not substantially change the hazard
 27 of loss of property, personal injury, or death during construction compared to Alternative 1A. The
 28 effects of Alternative 3 would, therefore, be the same as 1A. See the description and findings under
 29 Alternative 1A. There would be no adverse effect.

30 **CEQA Conclusion:** Based on recorded tsunami wave heights at the Golden Gate (Contra Costa
 31 Transportation Agency 2009) and in the interior of the San Francisco Bay and on tsunami
 32 inundation maps prepared by the California Department of Conservation (2009), the height of a
 33 tsunami wave reaching the Suisun Marsh and the Delta would be small because of the distance from
 34 the ocean and attenuating effect of the San Francisco Bay. Similarly, the potential for a significant
 35 seiche to occur in most parts of the Plan Area is considered low because the seismic hazard and the
 36 geometry of the water bodies (i.e., wide and shallow) near conveyance facilities are not favorable for
 37 a seiche to occur. However, assuming the West Tracy fault is potentially active, a potential exists for
 38 a seiche to occur in the Clifton Court Forebay and the Byron Tract Forebay (Fugro Consultants
 39 2011). The impact would not be significant because the Byron Tract Forebay embankment would be
 40 designed and constructed according to applicable design codes, guidelines, and standards to contain
 41 and withstand the anticipated maximum seiche wave height. There would be no increased likelihood
 42 of loss of property, personal injury or death due to operation of Alternative 3 from seiche or
 43 tsunami. The impact would be less than significant. No additional 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 3 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
 5 seepage. There would be no effect.

6 **CEQA Conclusion:** Alternative 3 would not involve construction of unlined canals; therefore, there
 7 would be no increase in groundwater surface elevations and consequently no impact caused by
 8 canal seepage. There would be no impact. 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 3 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
 14 ROA and damage ROA facilities, such as levees and berms. Damage to these features could result in
 15 their failure, causing flooding of otherwise protected areas. However, through the final design
 16 process for conservation measures in the ROAs, measures to address the fault rupture hazard would
 17 be required to conform to applicable design codes, guidelines, and standards. As described in
 18 Section 9.3.1, *Methods for Analysis*, and in Appendix 3B, *Environmental Commitments, AMMs, and*
 19 *CMs*, such design codes, guidelines, and standards include the Division of Safety of Dams' *Guidelines*
 20 *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
 24 risks are minimized as the conservation measures are implemented. The hazard would be controlled
 25 to a safe level and there would be no increased likelihood of loss of property, personal injury or
 26 death in the 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 **NEPA Effects:** Conservation measures would be the same under Alternative 3 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
 33 to active faults. The Suisun Marsh ROA is subject to a PGA of approximately 0.31 to 0.35 g for 200-
 34 year return interval, while the PGA for the other ROAs ranges from approximately 0.11 to 0.26 g.
 35 Damage to 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, AMMs, and CMs*, design codes, guidelines, and standards, including the California
 38 Building Code and resource agency and professional engineering specifications, such as DWR's
 39 Division of Flood Management *FloodSAFE Urban Levee Design Criteria* and USACE's *Engineering and*
 40 *Design—Earthquake Design and Evaluation for Civil Works Projects* would be used for final design of
 41 conservation features. Conformance with these design standards is an environmental commitment
 42 by the BDCP proponents to ensure that strong seismic shaking risks are minimized as the

1 conservation measures are operated and there would be no increased likelihood of loss of property,
 2 personal injury or death in the ROAs. The impact would be less than significant. No mitigation is
 3 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**
 6 **Opportunity Areas**

7 **NEPA Effects:** Conservation measures would be the same under Alternative 3 as under 1A. See
 8 description and findings under Alternative 1A. There would be no adverse effect.

9 **CEQA Conclusion:** Earthquake-induced ground shaking could cause liquefaction, resulting in
 10 damage to or failure of levees, berms, and other features constructed at the restoration areas.
 11 Failure of levees and other structures could result in flooding of otherwise protected areas.

12 However, through the final design process, measures to address the liquefaction hazard would be
 13 required to conform to applicable design codes, guidelines, and standards. As described in Section
 14 9.3.1, *Methods for Analysis*, and in Appendix 3B, *Environmental Commitments, AMMs, and CMs*, such
 15 design codes, guidelines, and standards include USACE's *Engineering and Design—Stability Analysis*
 16 *of Concrete Structures and Soil Liquefaction during Earthquakes*, by the Earthquake Engineering
 17 Research Institute. Conformance with these design standards is an environmental commitment by
 18 the BDCP proponents to ensure that liquefaction risks are minimized as the water conservation
 19 features are implemented and there would be no increased likelihood of loss of property, personal
 20 injury or death in the ROAs. The impact would be less than 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 **NEPA Effects:** Conservation measures would be the same under Alternative 3 as under 1A. See
 24 description and findings under Alternative 1A. There would be no adverse effect.

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

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

33 **NEPA Effects:** Conservation measures under Alternative 3 would be similar to that as under
 34 Alternative 1A. See description and findings under Alternative 1A. There would be no adverse effect.

35 **CEQA Conclusion:** Based on recorded tsunami heights at the Golden Gate, the height of a tsunami
 36 wave reaching the construction areas would be small because of the distance from the ocean and
 37 attenuating effect of the San Francisco Bay. Similarly, the potential for a significant seiche to occur in
 38 the Plan Area that would cause loss of property, personal injury, or death at the ROAs is considered
 39 low because conditions for a seiche to occur near conveyance facilities are not favorable. The impact
 40 would be less 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 five 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 tunnels, the pumping plant, 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.

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

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

- 8 • DWR Division of Engineering *State Water Project—Seismic Loading Criteria Report*, September
 9 2012.
- 10 • USACE *Engineering and Design—Earthquake Design and Evaluation for Civil Works Projects*,
 11 ER 1110-2-1806, 1995.
- 12 • USACE *Engineering and Design—Earthquake Design and Evaluation of Concrete Hydraulic*
 13 *Structures*, EM 1110-2-6053, 2007.
- 14 • USACE *Engineering and Design—Response Spectra and Seismic Analysis for Concrete Hydraulic*
 15 *Structures*, EM 1110-2-6050, 1999.
- 16 • USACE *Engineering and Design—Stability Analysis of Concrete Structures*, EM 1110-2-2100, 2005.
- 17 • 8 CCR Sections 1509 and 3203.

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

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

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

37 **CEQA Conclusion:** Seismically induced ground shaking that is estimated to occur and the resultant
 38 ground motion anticipated at Alternative 4 construction sites, including the intake locations, the
 39 tunnels, the pipelines and the forebays, could cause collapse or other failure of project facilities
 40 while under construction. For example, facilities lying directly on or near active blind faults, such as
 41 the concrete batch plants and fuel stations near Twin Cities Road and Interstate 5 and at the
 42 expanded Clifton Court Forebay, as well as the expanded Forebay itself for Alternative 4, may have

1 an increased likelihood of loss of property or personal injury at these sites in the event of seismically
 2 induced ground shaking. However, DWR would conform to Cal-OSHA and other state code
 3 requirements, such as shoring, bracing, lighting, excavation depth restrictions, required slope
 4 angles, and other measures, to protect worker safety. Conformance with these standards and codes
 5 is an environmental commitment of the project (see Appendix 3B, *Environmental Commitments,*
 6 *AMMs, and CMs*). Conformance with these health and safety requirements and the application of
 7 accepted, proven construction engineering practices would reduce this risk and there would be no
 8 increased likelihood of loss of property, personal injury or death due to construction of Alternative
 9 4. This impact would be less than significant. No mitigation is required.

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

12 Settlement of excavations could occur as a result of dewatering at Alternative 4 construction sites
 13 with shallow groundwater. Soil excavation in areas with shallow or perched groundwater levels
 14 would require the pumping of groundwater from excavations to allow for construction of facilities.
 15 This can be anticipated at all intake locations (Sites 2, 3, and 5) and the pumping plant site, where
 16 60% of the dewatering for Alternative 4 would take place. All of the intake locations and the
 17 pumping plant for Alternative 4 are located on alluvial floodbasin deposits, alluvial floodplain
 18 deposits and natural levee deposits. Unlike the pipeline/tunnel alternatives, the conveyance tunnels
 19 constructed between the three intakes and the intermediate forebay would not be anticipated to
 20 require dewatering prior to construction and would not have any associated impact.

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

23 **NEPA Effects:** This potential effect could be substantial because settlement or collapse during
 24 dewatering could cause injury of workers at the construction sites as a result of collapse of
 25 excavations.

26 The hazard of settlement and subsequent collapse of excavations would be evaluated by assessing
 27 site-specific geotechnical and hydrological conditions at intake locations, as well as where intake
 28 and forebay pipelines cross waterways and major irrigation canals. A California-registered civil
 29 engineer or California-certified engineering geologist would recommend measures in a geotechnical
 30 report to address these hazards, such as seepage cutoff walls and barriers, shoring, grouting of the
 31 bottom of the excavation, and strengthening of nearby structures, existing utilities, or buried
 32 structures. As described in Section 9.3.1, *Methods for Analysis*, the measures would conform to
 33 applicable design and building codes, guidelines, and standards, such as the California Building Code
 34 and USACE's *Engineering and Design—Structural Design and Evaluation of Outlet Works*. See
 35 Appendix 3B, *Environmental Commitments, AMMs, and CMs*.

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

- 39 ● DWR Division of Flood Management *FloodSAFE Urban Levee Design Criteria*, May 2012.
- 40 ● USACE *Engineering and Design—Settlement Analysis*, EM 1110-1-1904, 1990.
- 41 ● 8 CCR Sections 1509 and 3203.

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

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

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

19 **CEQA Conclusion:** Settlement or failure of excavations during construction could result in loss of
 20 property or personal injury. However, DWR would conform to Cal-OSHA and other state code
 21 requirements, such as using seepage cutoff walls, shoring, and other measures, to protect worker
 22 safety. DWR has made an environmental commitment to conform to appropriate codes and
 23 standards to minimize potential risks (Appendix 3B, *Environmental Commitments, AMMs, and CMs*).
 24 Additionally, DWR has made an environmental commitment that a geotechnical report be completed
 25 by a California-certified engineering geologist, that the report's geotechnical design
 26 recommendations be included in the design of project facilities, and that the report's design
 27 specifications are properly executed during construction to minimize the potential effects from
 28 settlement and failure of excavations. on. Proper execution of these environmental commitments to
 29 minimize potential risks would result in no increased likelihood of loss of property, personal injury
 30 or death due to construction of Alternative 4. The impact would be less than significant. No
 31 mitigation is required.

32 **Impact GEO-3: Loss of Property, Personal Injury, or Death from Ground Settlement during** 33 **Construction of Water Conveyance Features**

34 Two types of ground settlement could be induced during tunneling operations: large settlement and
 35 systematic settlement. Large settlement occurs primarily as a result of over-excavation by the
 36 tunneling shield. The over-excavation is caused by failure of the tunnel boring machine to control
 37 unexpected or adverse ground conditions (for example, running, raveling, squeezing, and flowing
 38 ground) or operator error. Large settlement can lead to the creation of voids and/or sinkholes above
 39 the tunnel. In extreme circumstances, this settlement can affect the ground surface, potentially
 40 causing loss of property or personal injury above the tunneling operation.

41 Systematic settlement usually results from ground movements that occur before tunnel supports
 42 can exit the shield and the tunnel to make full contact with the ground. Soil with higher silt and clay
 43 content tend to experience less settlement than sandy soil. Additional ground movements can occur
 44 with the deflection of the tunnel supports and over-excavation caused by steering/plowing of the

1 tunnel boring machine at horizontal and vertical curves. A deeper tunnel induces less ground
 2 surface settlement because a greater volume of soil material is available above the tunnel to fill any
 3 systematic void space.

4 The geologic units in the area of the Alternative 4 modified pipeline/tunnel alignment are shown on
 5 Figure 9-3 and summarized in Table 9-26. The characteristics of each unit would affect the potential
 6 for settlement during tunneling operations. Segments 1 and 3, located in the Clarksburg area and the
 7 area west of Locke, respectively, contain higher amounts of sand than the other segments, so they
 8 pose a greater risk of settlement.

9 **Table 9-26. Surficial Geology Underlying Alternative 4/Modified Pipeline/Tunnel Alignment by**
 10 **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; Atwater 1982.

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

11
 12 Operator errors or highly unfavorable/unexpected ground conditions could result in larger
 13 settlement. Large ground settlements caused by tunnel construction are almost always the result of
 14 using inappropriate tunneling equipment (incompatible with the ground conditions), improperly
 15 operating the machine, or encountering sudden or unexpected changes in ground conditions.

16 Given the likely design depth of the tunnel, the amount of settlement beneath developed areas and
 17 critical infrastructure (i.e., the village of Hood, SR 4 and SR 12, the EBMUD aqueduct, and a
 18 potentially sensitive satellite dish facility) would be minor. At the evaluated infrastructure, the
 19 predicted maximum ground surface settlement would range from 0.0 to 2.9 inches, with a change in
 20 ground slope ratio ranging from 0 to 1:714 (the higher value corresponding to a 0.14% slope). The
 21 width of the settlement “trough,” as a cross-section oriented perpendicular to the tunnel alignment,

1 would be 328 to 525 feet among the evaluated facilities. Other facilities that may be determined to
 2 be critical infrastructure include natural gas pipelines, the proposed EBMUD tunnel, levees, and local
 3 electrical distribution and communication lines.

4 **NEPA Effects:** Although the potential effect is expected to be minor, during detailed project design, a
 5 site-specific subsurface geotechnical evaluation would be conducted along the modified
 6 pipeline/tunnel alignment to verify or refine the findings of the preliminary geotechnical
 7 investigations. The tunneling equipment and drilling methods would be reevaluated and refined
 8 based on the results of the investigations, and field procedures for sudden changes in ground
 9 conditions would be implemented to minimize or avoid ground settlement. The primary exploration
 10 methods for these investigations include soil borings and CPTs (California Department of Water
 11 Resources 2014), which could potentially result in the settlement of dewatered sediments or
 12 liquefaction, respectively. However, these effects would be reduced with implementation of DWR's
 13 environmental commitments and avoidance and minimization measures (see Appendix 3B,
 14 *Environmental Commitments, AMMs, and CMs*). A California-registered civil engineer or California-
 15 certified engineering geologist would recommend measures to address these hazards, such as
 16 specifying the type of tunnel boring machine to be used in a given segment. The results of the site-
 17 specific evaluation and the engineer's recommendations would be documented in a detailed
 18 geotechnical report, which will contain site-specific evaluations of the settlement hazard associated
 19 with the site-specific soil conditions overlying the tunnel throughout the alignment. The report will
 20 also contain recommendations for the type of tunnel boring machine to be used and the tunneling
 21 techniques to be applied to avoid excessive settlement for specific critical assets, such as buildings,
 22 major roads, natural gas pipelines, electrical and communication lines, aqueducts, bridges, levees,
 23 and sensitive satellite dish facilities. Also included in the report will be recommendations for
 24 geotechnical and structural instrumentation for monitoring of settlement.

25 As described in Section 9.3.1, *Methods for Analysis*, the measures would conform to applicable design
 26 guidelines and standards, such as USACE design measures. See Appendix 3B, *Environmental*
 27 *Commitments, AMMs, and CMs*. In particular, conformance with the following federal design manuals
 28 and professional society and geotechnical literature would be used to predict the maximum amount
 29 of settlement that could occur for site-specific conditions, to identify the maximum allowable
 30 settlement for individual critical assets, and to develop recommendations for tunneling to avoid
 31 excessive settlement, all to minimize the likelihood of loss of property or personal injury from
 32 ground settlement above the tunneling operation during construction.

- 33 • *Technical Design Manual for Design and Construction of Road Tunnels* (U.S. Department of
 34 Transportation, Federal Highway Administration 2009).
- 35 • *A Method of Estimating Surface Settlement above Tunnels Constructed in Soft Ground* (National
 36 Research Council of Canada 1983).
- 37 • *Predicting the Dynamics of Ground Settlement and its Derivatives Caused by Tunnelling in Soil*
 38 (Attewell and Woodman 1982).
- 39 • *Predicting the Settlements above Twin Tunnels Constructed in Soft Ground* (Chapman et al. 2004).
- 40 • *Report on Settlements Induced by Tunneling in Soft Ground* (International Tunneling Association
 41 2007).
- 42 • *Closed-Face Tunnelling Machines and Ground Stability: A Guideline for Best Practice* (British
 43 Tunnelling Society 2005).

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
 4 specifications are properly executed during construction. DWR has made this conformance and
 5 monitoring process an environmental commitment of the BDCP (Appendix 3B, *Environmental*
 6 *Commitments, AMMs, and CMs*).

7 Generally, the applicable codes require that facilities be built so that they are designed for slope
 8 stability and seepage/underseepage factors of safety greater than 1.0 (i.e., stable) and would
 9 therefore be less impacted in the event of ground settlement. The worker safety codes and
 10 standards specify protective measures that must be taken at construction sites to minimize the risk
 11 of injury or death from structural or earth failure. The relevant codes and standards represent
 12 performance standards that must be met by contractors and these measures are subject to
 13 monitoring by state and local agencies. Cal-OSHA requirements for an IIPP and the terms of the IIPP
 14 to protect worker safety are the principal 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 4 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 tunneling operation could result in loss of property
 19 or personal injury during construction. However, DWR would conform to Cal-OSHA, USACE, and
 20 other design requirements to protect worker safety. DWR would also ensure that the design
 21 specifications are properly executed during construction. DWR would ensure that the geotechnical
 22 design recommendations are included in the design of project facilities and construction
 23 specifications and are properly executed during construction to minimize the potential effects from
 24 settlement. DWR has made this conformance and monitoring process an environmental
 25 commitment of the BDCP (see Appendix 3B, *Environmental Commitments, AMMs, and CMs*). Hazards
 26 to workers and project structures would be controlled at safe levels and there would be no
 27 increased likelihood of loss of property, personal injury or death due to construction of Alternative
 28 4. The impact would be less than significant. No mitigation is required.

29 **Impact GEO-4: Loss of Property, Personal Injury, or Death from Slope Failure during** 30 **Construction of Water Conveyance Features**

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

37 While specific borrow sources have not yet been secured near the Alternative 4 alignment, several
 38 potential locations within the project area have been identified based on geologic data presented
 39 through the DRMS study. Borrow site locations identified outside the project area were based on
 40 reviews of published geologic maps, specifically the California Geological Survey Map No. 1A
 41 Sacramento Quadrangle (1981) and Map No. 5A San Francisco-San Jose Quadrangle (1991).
 42 Borrow areas for construction of intake facilities, pumping plant, intermediate forebay, and other
 43 supporting facilities would be sited near the locations of these structures (generally within
 44 10 miles). Along the modified pipeline/tunnel alignment, selected areas would also be used for

1 disposing of the byproduct (RTM) of tunneling operations. Table 9-27 describes the geology of these
2 areas as mapped by Atwater (1982) (Figure 9-3).

3 **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
Segment 2 Reusable Tunnel Material Area	Qch	Alluvial fans and terraces from non-glaciated drainage basins: clay, silt, sand, and gravel
	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 Reusable Tunnel Material Area	Qry	Riverbank Formation: alluvial fans from glaciated basins that consist of moderately sorted to well-sorted sand, gravel, silt, and minor clay
	Qry	Riverbank Formation: alluvial fans from glaciated basins that consist of moderately sorted to well-sorted sand, gravel, silt, and minor clay
Segment 5 Reusable Tunnel Material Area	Qpm	Delta mud: mud and peat with minor silt or sand
Segment 10 Reusable Tunnel Material Area	Qymc	Alluvial fans and terraces from non-glaciated drainage basins: sand, silt and gravel

Sources: Hansen et al. 2001; Atwater 1982.

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

4
5 Some borrow areas and pre-cast tunnel segment plants would be in areas already proposed for
6 disturbance and therefore are evaluated by this EIR/EIS; others would be at new locations outside
7 the Plan Area. Areas outside of the Plan Area would likely occur at existing permitted facilities. Any
8 new locations would undergo additional technical and environmental review, including that for
9 Geology and Seismicity impacts.

10 **NEPA Effects:** The potential effect could be substantial because excavation of borrow material and
11 the resultant cutslopes and potential failure of spoils/RTM fill slopes could cause injury of workers
12 at the 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
15 be placed in 12-inch lifts with proper compaction and stored no higher than 12 feet above
16 preconstruction ground elevation with maximum side slopes of 5H:1V. During design, the potential
17 for native ground settlement below the spoils would be evaluated by a geotechnical engineer using
18 site-specific geotechnical and hydrological information. The use of shoring, seepage cutoff walls, and

1 ground modifications to prevent slope instability, soil boiling, or excessive settlement would be
2 considered in the design. As described in Section 9.3.1, *Methods for Analysis*, the measures would
3 conform to applicable design and building codes, guidelines, and standards, such as the California
4 Building Code and USACE's *Engineering and Design—Structural Design and Evaluation of Outlet*
5 *Works*.

6 In addition to the risk of slope failure at borrow sites and spoils and RTM sites, there are also
7 potential impacts on levee stability resulting from construction of Alternative 4 water conveyance
8 facilities. The intake facilities would be sited along the existing Sacramento River levee system,
9 requiring reconstruction of levees and construction of a perimeter levee/building pad to provide
10 continued flood management.

11 As discussed in Chapter 3, *Description of the Alternatives*, the new perimeter levee/building pad
12 would be designed to provide an adequate Sacramento River channel cross section and to provide
13 the same level of flood protection as the existing levee and would be constructed to geometries that
14 exceed PL 84-99 standards. The design of the levee/building pad height would consider potential
15 wind and wave erosion. The elevation of the levee/building pad crest would provide adequate
16 freeboard above anticipated water surface elevations. Depending on the foundation material at each
17 intake facility, foundation improvements would entail excavation and replacement of soil below the
18 new levee/building pad footprint and potential ground improvement. The levee/building pad
19 height, as measured from the adjacent ground surface on the landside vertically up to the elevation
20 of the berm crest, would range from approximately 20 to 45 feet to provide adequate freeboard
21 above anticipated water surface elevations. The width of the perimeter levee/berm (toe of berm to
22 toe of berm) would range from approximately 180 to 360 feet. The minimum crest width of the
23 berm would be 20 feet; however, in some places it would be larger to accommodate roadways and
24 other features. A cut-off wall would be constructed along the perimeter of the forebay part of the
25 intake facility to avoid seepage, and the minimum slope of the levee walls/building pad would be
26 three units horizontal to one unit vertical. All levee reconstruction/building pad construction would
27 conform to applicable state and federal flood management engineering and permitting
28 requirements.

29 The levees would be armored with riprap—small to large angular boulders—on the waterside.
30 Intakes would be constructed using a sheetpile cofferdam in the river to create a dewatered
31 construction area that would encompass the intake site. The cofferdam would lie approximately 10–
32 35 feet from the footprint of the intake and would be built from upstream to downstream, with the
33 downstream end closed last. The distance between the face of the intake and the face of the
34 cofferdam would be dependent on the foundation design and overall dimensions. The length of each
35 temporary cofferdam would vary by intake location, but would range from 740 to 2,440 feet. The
36 cofferdams would be supported by steel sheet piles and/or king piles (heavy H-section steel piles).
37 Installation of these piles may require both impact and vibratory pile drivers. Some clearing and
38 grubbing of levees would be required prior to installation of the sheet pile cofferdam, depending on
39 site conditions. Additionally, if stone bank protection, riprap, or mature vegetation is present at
40 intake construction site, it would be removed prior to sheet pile installation. DWR would ensure that
41 the geotechnical design recommendations are included in the design of project facilities and
42 construction specifications and are properly executed during construction to minimize the potential
43 effects from failure of excavations. DWR has made this conformance and monitoring process an
44 environmental commitment of the BDCP (see Appendix 3B, *Environmental Commitments, AMMs, and*
45 *CMs*).

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

- 4 • DWR Division of Engineering *State Water Project—Seismic Loading Criteria Report*, September
 5 2012.
- 6 • DWR Division of Flood Management *FloodSAFE Urban Levee Design Criteria*, May 2012.
- 7 • 8 CCR Sections 1509 and 3203.

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

17 Conformance to these and other applicable design specifications and standards would ensure that
 18 construction of Alternative 4 would not create an increased likelihood of loss of property, personal
 19 injury or death of individuals from slope failure at borrow sites and spoils and RTM storage sites.
 20 The maintenance and reconstruction of levees would improve levee stability over existing
 21 conditions due to improved side slopes, erosion control measures (geotextile fabrics, rock
 22 revetments, or other material), seepage reduction measures, and overall mass. Therefore, there
 23 would be no adverse effect.

24 **CEQA Conclusion:** Settlement/failure of cutslopes of borrow sites and failure of soil/RTM fill slopes
 25 could result in loss of property or personal injury during construction. However, because DWR
 26 would conform to Cal-OSHA and other state code requirements and conform to applicable
 27 geotechnical design guidelines and standards, such as USACE design measures, the hazard would be
 28 controlled to a safe level and there would be no increased likelihood of loss of property, personal
 29 injury or death due to construction of Alternative 4 at borrow sites and spoils and RTM storage sites.
 30 The maintenance and reconstruction of levees would improve levee stability over existing
 31 conditions due to improved side slopes, erosion control measures, seepage reduction measures, and
 32 overall mass. The impact would be less than significant. No mitigation is required.

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

36 Pile driving and other heavy equipment operations would cause vibrations that could initiate
 37 liquefaction and associated ground movements in places where soil and groundwater conditions are
 38 present to allow liquefaction to occur. The consequences of liquefaction could be manifested in
 39 terms of compaction or settlement, loss of bearing capacity, lateral spreading (horizontal soil
 40 movement), increased lateral soil pressure, and buoyancy within zones of liquefaction. These
 41 consequences could 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. In addition to pile driving activities,
6 construction of the water conveyance facilities would require an increased volume of truck and
7 heavy equipment traffic that may occur at some of these locations. Although the trucks and heavy
8 equipment could generate vibrations in the levees, the severity of the vibrations is not expected to
9 be capable of initiating liquefaction. Construction related to conveyance facilities would also require
10 regular access to construction sites, extending the length of the project. Some of the existing public
11 roads would be used as haul routes for the construction of conveyance facilities. Use of the state
12 highway system as haul routes would be maximized where feasible because these roadways are
13 rated for truck traffic and would generally provide the most direct and easily maneuverable routes
14 for large loads. As part of future engineering phases, haul routes needed for the construction of the
15 approved project would be refined. Construction traffic may need to access levee roads at various
16 points along SR 160 and other state routes as shown in Figure 9-7, as well as at locations shown
17 along the Modified Pipeline/Tunnel Alignment in Figure 9-8b. Because of the volume of truck traffic
18 that may occur at some of these locations, there is the potential for some effect on levee integrity at
19 various locations depending on the site specific levee conditions along access routes.

20 During project design, site-specific geotechnical and groundwater investigations would be
21 conducted to build upon existing data (e.g., California Department of Water Resources 2010a,
22 2010b, 2011) to identify and characterize the vertical (depth) and horizontal (spatial) variability in
23 soil bearing capacity and extent of liquefiable soil. Engineering soil parameters that could be used to
24 assess the liquefaction potential, such as (SPT) blow counts, (CPT) penetration tip
25 pressure/resistance, and gradation of soil, would also be obtained. SPT blow counts and CPT tip
26 pressure are used to estimate soil resistance to cyclic loadings by using empirical relationships that
27 were developed based on occurrences of liquefaction (or lack of them) during past earthquakes.
28 The resistance then can be compared to cyclic shear stress induced by the design earthquake (i.e.,
29 the earthquake that is expected to produce the strongest level of ground shaking at a site to which it
30 is appropriate to design a structure to withstand). If soil resistance is less than induced stress, the
31 potential of having liquefaction during the design earthquakes is high. It is also known that soil with
32 high "fines" (i.e., silt- and clay-sized particles) content are less susceptible to liquefaction.

33 **NEPA Effects:** The potential effect could be substantial because construction-related ground motions
34 could initiate liquefaction, which could cause failure of structures during construction, which could
35 result in injury of workers at the construction sites. Some of the potential levee effects that could
36 occur during the construction in the absence of corrective measures may include rutting, settlement,
37 and slope movement.

38 During design, the facility-specific potential for liquefaction would be investigated by a geotechnical
39 engineer. The investigations are an environmental commitment of the BDCP (see Appendix 3B,
40 *Environmental Commitments, AMMs, and CMs*). The potential effects of construction vibrations on
41 nearby structures, levees, and utilities would be evaluated using specific piling information (such as
42 pile type, length, spacing, and pile-driving hammer to be used). In areas determined to have a
43 potential for liquefaction, the California-registered civil engineer or California-certified engineering
44 geologist would develop design strategies and construction methods to ensure that pile driving and

1 heavy equipment operations do not cause liquefaction which otherwise could damage facilities
2 under construction and surrounding structures, and could threaten the safety of workers at the site.

3 As shown in Figure 9-6, the Alternative 4 alignment extends through areas that generally have a
4 medium or high vulnerability for seismically induced levee failure, with a high risk of liquefaction at
5 intakes 2 and 5 (California Department of Water Resources 2015). Figure 9-6 shows that four of the
6 five barge unloading facilities would be located on levees with a high vulnerability to seismically
7 induced failure; the fifth (the northernmost) has a low vulnerability. Design measures to avoid pile-
8 driving induced levee failure may include predrilling or jetting, using open-ended pipe piles to
9 reduce the energy needed for pile penetration, using CIDH piles/piers that do not require driving,
10 using pile jacking to press piles into the ground by means of a hydraulic system, or driving piles
11 during the drier summer months. Field data collected during design also would be evaluated to
12 determine the need for and extent of strengthening levees, embankments, and structures to reduce
13 the effect of vibrations. These construction methods would conform to current seismic design codes
14 and requirements, as described in Appendix 3B, *Environmental Commitments, AMMs, and CMs*. Such
15 design standards include USACE's *Engineering and Design—Stability Analysis of Concrete Structures*
16 and *Soil Liquefaction during Earthquakes*, by the Earthquake Engineering Research Institute.

17 As with the effects related to design of conveyance facilities, potential construction traffic effects on
18 levees would be assessed prior to project construction to determine specific geotechnical issues
19 related to construction traffic loading. Based on the initial assessment from field reconnaissance,
20 geotechnical exploration and analyses would be performed for levee sections that need further
21 evaluations. Should the geotechnical evaluations indicate that certain segments of existing levee
22 roads need improvements to carry the expected construction truck traffic loads, DWR is committed
23 to carry out the necessary improvements to the affected levee sections or to find an alternative route
24 that would avoid the potential deficient levee sections (Mitigation Measures TRANS-2a through 2c).
25 As discussed in Chapter 19, *Transportation*, Mitigation Measure TRANS-2c, all affected roadways
26 would be returned to preconstruction condition or better following construction. Implementation of
27 this measure would ensure that construction activities would not worsen pavement and levee
28 conditions, relative to existing conditions. Prior to construction, DWR would make a good faith effort
29 to enter into mitigation agreements with or to obtain encroachment permits from affected agencies
30 to verify what the location, extent, timing, and fair share cost to be paid by the DWR for any
31 necessary pre- and post-construction physical improvements. Levee roads that are identified as
32 potential haul routes and expected to carry significant construction truck traffic would be monitored
33 to ensure that truck traffic is not adversely affecting the levee and to identify the need for corrective
34 action.

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

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

- 43 • 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*,
2 ER 1110-2-1806, 1995.
- 3 • 8 CCR Sections 1509 and 3203.

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).

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

15 Conformance to construction method recommendations and other applicable specifications, as well
16 as implementation of Mitigation Measures TRANS-2a through 2c, would ensure that construction of
17 Alternative 4 would not create an increased likelihood of loss of property, personal injury or death
18 of individuals due to construction- and traffic-related ground motions and resulting potential
19 liquefaction in the work area. Therefore, there would be no adverse effect.

20 **CEQA Conclusion:** Construction-related ground motions and traffic effects could initiate
21 liquefaction, which could cause failure of structures during construction. The impact could be
22 significant. However, because DWR would conform to Cal-OSHA and other state code requirements
23 and conform to applicable design guidelines and standards, such as USACE design measures, in
24 addition to implementation of Mitigation Measures TRANS-2a and TRANS-2b, as well as the
25 maintenance and reconstruction of levees through Mitigation Measure TRANS-2c, the hazard would
26 be controlled to a level that would protect worker safety (see Appendix 3B, *Environmental*
27 *Commitments, AMMs, and CMs*). Further, DWR has made an environmental commitment (see
28 Appendix 3B) that the construction methods recommended by the geotechnical engineer are
29 included in the design of project facilities and construction specifications to minimize the potential
30 for construction-induced liquefaction. DWR also has committed to ensure that these methods are
31 followed during construction. Proper execution of these environmental commitments would result
32 in no increased likelihood of loss of property, personal injury or death due to construction of
33 Alternative 4. The impact would be less than significant.

34 **Mitigation Measure TRANS-2a: Prohibit Construction Activity on Physically Deficient** 35 **Roadway Segments**

36 Please refer to Mitigation Measure TRANS-2a in Alternative 1A, Impact TRANS-2, in Chapter 19,
37 *Transportation*.

38 **Mitigation Measure TRANS-2b: Limit Construction Activity on Physically Deficient** 39 **Roadway Segments**

40 Please refer to Mitigation Measure TRANS-2b in Alternative 1A, Impact TRANS-2, in Chapter 19,
41 *Transportation*.

1 **Mitigation Measure TRANS-2c: Improve Physical Condition of Affected Roadway Segments**
 2 **as Stipulated in Mitigation Agreements or Encroachment Permits**

3 Please refer to Mitigation Measure TRANS-2c in Alternative 1A, Impact TRANS-2, in Chapter 19,
 4 *Transportation*.

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

7 According to the available AP Fault Zone Maps, none of the Alternative 4 facilities would cross or be
 8 within any known active fault zones. However, numerous AP fault zones have been mapped west of
 9 the conveyance alignment (Figure 9-5). The closest AP fault zone would be the Greenville fault,
 10 located approximately 7.6 miles west of the conveyance facilities. Because none of the Alternative 4
 11 constructed facilities would be within any of the fault zones (which include the area approximately
 12 200 to 500 feet on each side of the mapped surface trace to account for potential branches of active
 13 faults), the potential that the facilities would be directly subject to fault offsets is negligible.

14 In the Delta, active or potentially active blind thrust faults were identified in the seismic study.
 15 Segments 3 and 4 of the Alternative 4 conveyance alignment (which is the same as the Modified
 16 Pipeline/Tunnel Alignment in Figure 9-3) would cross the Thornton Arch fault zone. The western
 17 part of the proposed expanded Clifton Court Forebay is underlain by the West Tracy fault. Although
 18 these blind thrusts are not expected to rupture to the ground surface under the forebays during
 19 earthquake events, they may produce ground or near-ground shear zones, bulging, or both
 20 (California Department of Water Resources 2007a). If the West Tracy fault is potentially active, it
 21 could cause surface deformation in the western part of the existing Clifton Court Forebay. Because
 22 the western part of the expanded Clifton Court Forebay is also underlain by the hanging wall of the
 23 fault, this part of the forebay may also experience uplift and resultant surface deformation (Fugro
 24 Consultants 2011). In the seismic study (California Department of Water Resources 2007a), the
 25 Thornton Arch and West Tracy blind thrusts have been assigned 20% and 90% probabilities of
 26 being active, respectively. The depth to the Thornton Arch blind thrust is unknown. The seismic
 27 study indicates that the West Tracy fault dies out as a discernible feature within approximately
 28 3,000 to 6,000 feet bgs [in the upper 1- to 2-second depth two-way time, estimated to be
 29 approximately 3,000 to 6,000 feet using the general velocity function as published in the Association
 30 of Petroleum Geologists Pacific Section newsletter (Tolmachoff 1993)].

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

35 **NEPA Effects:** The effect would not be adverse because no active faults extend into the Alternative 4
 36 alignment. Additionally, although the Thornton Arch and West Tracy blind thrusts occur beneath the
 37 Alternative 4 alignment, they do not present a hazard of surface rupture based on available
 38 information, including the AP Earthquake Fault Zone Map showing faults capable of surface rupture
 39 (Figure 9-5).

40 However, because there is limited information regarding the depths of the Thornton Arch and West
 41 Tracy blind thrusts, seismic surveys would be performed on the blind thrust during the design phase
 42 to determine the depths to the top of the faults. More broadly, design-level geotechnical studies
 43 would be prepared by a geotechnical engineer licensed in the state of California during project

1 design. The studies would further assess site-specific conditions at and near all the project facility
 2 locations, including seismic activity, soil liquefaction, and other potential geologic and soil-related
 3 hazards. This information would be used to verify assumptions and conclusions included in the
 4 EIR/EIS. Consistent with the BDCP's environmental commitments (see Appendix 3B, *Environmental*
 5 *Commitments, AMMs, and CMs*), DWR would ensure that the geotechnical engineer's recommended
 6 measures to address adverse conditions would conform to applicable design codes, guidelines, and
 7 standards, would be included in the project design and construction specifications, and would be
 8 properly executed during construction. Potential design strategies or conditions could include
 9 avoidance (deliberately positioning structures and lifelines to avoid crossing identified shear
 10 rupture zones), geotechnical engineering (using the inherent capability of unconsolidated
 11 geomaterials to "locally absorb" and distribute distinct bedrock fault movements) and structural
 12 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*, such conformance with design codes, guidelines,
 15 and standards are environmental commitments by DWR (see Appendix 3B, *Environmental*
 16 *Commitments, AMMs, and CMs*). For construction of the water conveyance facilities, the codes and
 17 standards would include the California Building Code and resource agency and professional
 18 engineering specifications, such as the Division of Safety of Dams' *Guidelines for Use of the*
 19 *Consequence-Hazard Matrix and Selection of Ground Motion Parameters*, DWR's Division of Flood
 20 Management *FloodSAFE Urban Levee Design Criteria*, and USACE's *Engineering and Design—*
 21 *Earthquake Design and Evaluation for Civil Works Projects*. These codes and standards include
 22 minimum performance standards for structural design, given site-specific subsurface conditions.

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

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

- 30 ● DWR Division of Engineering *State Water Project—Seismic Loading Criteria Report*, September
 31 2012.
- 32 ● USACE *Engineering and Design—Time-History Dynamic Analysis of Concrete Hydraulic Structures*,
 33 EM 1110-2-6051, 2003.
- 34 ● USACE *Engineering and Design—Response Spectra and Seismic Analysis for Concrete Hydraulic*
 35 *Structures*, EM 1110-2-6050, 1999.
- 36 ● American Society of Civil Engineers *Minimum Design Loads for Buildings and Other Structures*,
 37 ASCE/SEI 7-10, 2010.
- 38 ● 8 CCR 3203.

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

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

7 Conformance to these and other applicable design specifications and standards would ensure that
 8 operation of Alternative 4 would not create an increased likelihood of loss of property, personal
 9 injury or death of individuals in the event of ground movement in the vicinity of the Thornton Arch
 10 fault zone and West Tracy blind thrust. Therefore, such ground movements would not jeopardize
 11 the integrity of the surface and subsurface facilities along the Alternative 4 conveyance alignment or
 12 the proposed expanded Clifton Court Forebay and associated facilities adjacent to the existing
 13 Clifton Court Forebay. Therefore, there would be no adverse effect.

14 **CEQA Conclusion:** There are no active faults capable of surface rupture that extend into the
 15 Alternative 4 modified pipeline/tunnel alignment. Although the Thornton Arch and West Tracy
 16 blind thrusts occur beneath the Alternative 4 modified pipeline/tunnel alignment, based on
 17 available information, they do not present a hazard of surface rupture and there would be no
 18 increased likelihood of loss of property, personal injury or death due to operation of Alternative 4.
 19 However, because there is limited information regarding the depths of the Thornton Arch and West
 20 Tracy blind thrusts, seismic surveys would be performed on the blind thrust during the design phase
 21 to determine the depths to the top of the faults. More broadly, design-level geotechnical studies
 22 would be prepared by a geotechnical engineer licensed in the state of California during project
 23 design. The studies would further assess site-specific conditions at and near all the project facility
 24 locations, including seismic activity, soil liquefaction, and other potential geologic and soil-related
 25 hazards. This information would be used to verify assumptions and conclusions included in the
 26 EIR/EIS. Consistent with the BDCP's environmental commitments (see Appendix 3B, *Environmental*
 27 *Commitments, AMMs, and CMs*), DWR would ensure that the geotechnical engineer's recommended
 28 measures to address adverse conditions would conform to applicable design codes, guidelines, and
 29 standards, would be included in the project design and construction specifications, and would be
 30 properly executed during construction. Potential design strategies or conditions could include
 31 avoidance (deliberately positioning structures and lifelines to avoid crossing identified shear
 32 rupture zones), geotechnical engineering (using the inherent capability of unconsolidated
 33 geomaterials to "locally absorb" and distribute distinct bedrock fault movements), and structural
 34 engineering (engineering the facility to undergo some limited amount of ground deformation
 35 without collapse or significant damage).

36 As described in Section 9.3.1, *Methods for Analysis*, such conformance with design codes, guidelines,
 37 and standards are environmental commitments by DWR (see Appendix 3B, *Environmental*
 38 *Commitments, AMMs, and CMs*). For construction of the water conveyance facilities, the codes and
 39 standards would include the California Building Code and resource agency and professional
 40 engineering specifications, such as the Division of Safety of Dams *Guidelines for Use of the*
 41 *Consequence-Hazard Matrix and Selection of Ground Motion Parameters*, DWR's Division of Flood
 42 Management *FloodSAFE Urban Levee Design Criteria*, and USACE's *Engineering and Design—*
 43 *Earthquake Design and Evaluation for Civil Works Projects*. These codes and standards include
 44 minimum performance standards for structural design, given site-specific subsurface conditions.
 45 Conformance to these and other applicable design specifications and standards would ensure that
 46 operation of Alternative 4 would not create an increased likelihood of loss of property, personal

1 injury or death of individuals in the event of ground movement in the vicinity of the Thornton Arch
 2 fault zone and West Tracy blind thrust. Therefore, such ground movements would not jeopardize
 3 the integrity of the surface and subsurface facilities along the Alternative 4 conveyance alignment or
 4 the proposed expanded Clifton Court Forebay and associated facilities adjacent to the existing
 5 Clifton Court Forebay. There would be no 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 4 water conveyance facilities. The ground shaking could damage pipelines, tunnels,
 10 intake facilities, pumping plants, and other facilities, disrupting the water supply through the
 11 conveyance system. In an extreme event of strong seismic shaking, uncontrolled release of water
 12 from damaged pipelines, tunnels, intake facilities, pumping plant, and other facilities could cause
 13 flooding, disruption of water supplies to the south, and inundation of structures. These effects are
 14 discussed more fully in Appendix 3E, *Potential Seismicity and Climate Change Risks to SWP/CVP*
 15 *Water Supplies*.

16 Table 9-17 lists the expected PGA and 1.0-S_a values in 2025 at selected facility locations along the
 17 pipeline/tunnel alignment. Alternative 4 would include the same physical/structural components as
 18 Alternative 1A, but would entail two less intakes and five less pumping plants. These differences
 19 would present a slightly lower hazard of seismic shaking but would not substantially change the
 20 hazard of loss of property or personal injury during construction compared to Alternative 1A.

21 For early long-term, earthquake ground motions with return periods of 144 years and 975 years
 22 were estimated from the results presented in the seismic study (California Department of Water
 23 Resources 2007a). The 144-year and 975-year ground motions correspond to the OBE (i.e., an
 24 earthquake that has a 50% probability of exceedance in a 100-year period (which is equivalent to a
 25 144-year return period event) and the MDE (i.e., an earthquake that causes ground motions that
 26 have a 10% chance of being exceeded in 100 years) design ground motions, respectively. Values
 27 were estimated for a stiff soil site (as predicted in the seismic study), and for the anticipated soil
 28 conditions at the facility locations. No seismic study results exist for 2025, so the ground shaking
 29 estimated for the 2050 were used for Early Long-term (2025).

30 Table 9-17 shows that the proposed facilities would be subject to moderate-to-high earthquake
 31 ground shaking through 2025. All facilities would be designed and constructed in accordance with
 32 the requirements of the design guidelines and building codes described in Appendix 3B,
 33 *Environmental Commitments, AMMs, and CMs*. Site-specific geotechnical information would be used
 34 to further assess the effects of local soil on the OBE and MDE ground shaking and to develop design
 35 criteria that minimize damage potential.

36 **NEPA Effects:** This potential effect could be substantial because strong ground shaking could
 37 damage pipelines, tunnels, intake facilities, pumping plant, and other facilities and result in loss of
 38 property or personal injury. The damage could disrupt the water supply through the conveyance
 39 system. In an extreme event, an uncontrolled release of water from the conveyance system could
 40 cause flooding and inundation of structures. Please refer to Chapter 6, *Surface Water*, and Appendix
 41 3E, *Potential Seismicity and Climate Change Risks to SWP/CVP Water Supplies*, for a detailed
 42 discussion of potential flood effects.

1 The structure of the underground conveyance facility would decrease the likelihood of loss of
 2 property or personal injury of individuals from structural shaking of surface and subsurface
 3 facilities along the Alternative 4 conveyance alignment in the event of strong seismic shaking. The
 4 conveyance pipeline would be lined with precast concrete which would be installed continuously
 5 following the advancement of a pressurized tunnel boring machine. The lining consists of precast
 6 concrete segments inter-connected to maintain alignment and structural stability during
 7 construction. Reinforced concrete segments are precast to comply with strict quality control. High
 8 performance gasket maintains water tightness at the concrete joints, while allowing the joint to
 9 rotate and accommodate movements during intense ground shaking. PCTL has been used
 10 extensively in seismically active locations such as Japan, Puerto Rico, Taiwan, Turkey, Italy and
 11 Greece. The adoption of PCTL in the United States started about 20 years ago, including many
 12 installations in seismically active areas such as Los Angeles, San Diego, Portland and Seattle. PCTL
 13 provides better seismic performance than conventional tunnels for several reasons:

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

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

25 In accordance with the DWR's environmental commitments (see Appendix 3B, *Environmental*
 26 *Commitments, AMMs, and CMs*), design-level geotechnical studies would be conducted by a licensed
 27 civil engineer who practices in geotechnical engineering. The studies would assess site-specific
 28 conditions at and near all the project facility locations and provide the basis for designing the
 29 conveyance features to withstand the peak ground acceleration caused by fault movement in the
 30 region. The California-registered civil engineer or California-certified engineering geologist's
 31 recommended measures to address this hazard would conform to applicable design codes,
 32 guidelines, and standards. As described in Section 9.3.1, *Methods for Analysis*, and in Appendix 3B,
 33 such design codes, guidelines, and standards include the California Building Code and resource
 34 agency and professional engineering specifications, such as the Division of Safety of Dams *Guidelines*
 35 *for Use of the Consequence-Hazard Matrix and Selection of Ground Motion Parameters*, DWR's
 36 Division of Flood Management *FloodSAFE Urban Levee Design Criteria*, and USACE's *Engineering and*
 37 *Design—Earthquake Design and Evaluation for Civil Works Projects*. Conformance with these codes
 38 and standards are an environmental commitment by DWR to ensure that ground shaking risks are
 39 minimized as the water conveyance features are operated.

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

1 specifications are properly executed during construction. See Appendix 3B, *Environmental*
2 *Commitments, AMMs, and CMs*.

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

- 6 • DWR Division of Engineering *State Water Project—Seismic Loading Criteria Report*, September
7 2012.
- 8 • USACE *Engineering and Design—Time-History Dynamic Analysis of Concrete Hydraulic Structures*,
9 EM 1110-2-6051, 2003.
- 10 • USACE *Engineering and Design—Response Spectra and Seismic Analysis for Concrete Hydraulic*
11 *Structures*, EM 1110-2-6050, 1999.
- 12 • American Society of Civil Engineers *Minimum Design Loads for Buildings and Other Structures*,
13 ASCE/SEI 7-10, 2010.
- 14 • 8 CCR 3203.

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

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

26 Conformance to these and other applicable design specifications and standards would ensure that
27 operation of Alternative 4 would not create an increased likelihood of loss of property, personal
28 injury or death of individuals from structural shaking of surface and subsurface facilities along the
29 Alternative 4 conveyance alignment in the event of strong seismic shaking. Therefore, there would
30 be no adverse effect.

31 **CEQA Conclusion:** Seismically induced strong ground shaking could damage pipelines, tunnels,
32 intake facilities, pumping plant, and other facilities. The damage could disrupt the water supply
33 through the conveyance system. In an extreme event, an uncontrolled release of water from the
34 damaged conveyance system could cause flooding and inundation of structures. (Please refer to
35 Chapter 6, *Surface Water*, for a detailed discussion of potential flood impacts.) However, through the
36 final design process, which would be supported by geotechnical investigations required by DWR's
37 environmental commitments (see Appendix 3B, *Environmental Commitments, AMMs, and CMs*),
38 measures to address this hazard would be required to conform to applicable design codes,
39 guidelines, and standards. As described in Section 9.3.1, *Methods for Analysis*, and in Appendix 3B,
40 such design codes, guidelines, and standards include the California Building Code and resource
41 agency and professional engineering specifications, such as the Division of Safety of Dams' *Guidelines*
42 *for Use of the Consequence-Hazard Matrix and Selection of Ground Motion Parameters*, DWR's

1 Division of Flood Management *FloodSAFE Urban Levee Design Criteria*, and USACE's *Engineering and*
 2 *Design—Earthquake Design and Evaluation for Civil Works Projects*. Conformance with these codes
 3 and standards is an environmental commitment by DWR to ensure that ground shaking risks are
 4 minimized as the water conveyance features are operated. The hazard would be controlled to a safe
 5 level and there would be no increased likelihood of loss of property, personal injury or death due to
 6 operation of Alternative 4. The impact would be less than significant. No mitigation is required.

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

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

18 The native soil underlying Alternative 4 facilities consist of various channel deposits and recent silty
 19 and sandy alluvium at shallow depths. The available data along the southern portion of the
 20 conveyance (from approximately Potato Slough to Clifton Court Forebay) show that the recent
 21 alluvium overlies peaty or organic soils, which in turn is underlain by layers of mostly sandy and
 22 silty soil (Real and Knudsen 2009). Soil borings advanced by DWR along the northern portion of the
 23 conveyance (from approximately Potato Slough to Intake 1) show the surface soil as being similar to
 24 the range reported for the southern portion, but locally containing strata of clayey silt and lean clay.
 25 Because the borings were made over water, peat was usually absent from the boring logs (California
 26 Department of Water Resources 2011).

27 The silty and sandy soil deposits underlying the peaty and organic soil over parts of the Delta are
 28 late-Pleistocene age dune sand, which are liquefiable during major earthquakes. The tops of these
 29 materials are exposed in some areas, but generally lie beneath the peaty soil at depths of about 10–
 30 40 feet bgs along the modified pipeline/tunnel alignment (Real and Knudsen 2009). Liquefaction
 31 hazard mapping by Real and Knudsen (2009), which covers only the southwestern part of the Plan
 32 Area, including the part of the alignment from near Isleton to the Palm Tract, indicates that the
 33 lateral ground deformation potential would range from <0.1 to 6.0 feet. Liquefaction-induced
 34 ground settlement during the 1906 San Francisco earthquake was also reported near Alternative 4
 35 facilities at a bridge crossing over Middle River just north of Woodward Island (Youd and Hoose
 36 1978). Local variations in thickness and lateral extent of liquefiable soil may exist, and they may
 37 have important influence on liquefaction-induced ground deformations.

38 Figure 9-6 shows that the northern part of the Alternative 4 alignment is outside the area (i.e.,
 39 outside the mean higher high water floodplain) within which levees were evaluated by DWR
 40 (California Department of Water Resources 2008b) for their vulnerability to seismically induced
 41 levee failure. The remainder of the alignment, extending south from approximately Courtland,
 42 extends through areas in which the levees generally have a high or medium vulnerability to
 43 seismically induced failure.

1 Because the tunnel invert would be at depths of 100–160 feet bgs, the potential effect on these
2 facilities due to liquefaction is judged to be low. However, certain surface and near-surface facilities,
3 such as the pumping plant and Clifton Court forebay expansion area, would be constructed in areas
4 with medium or high vulnerability to failure from seismic shaking, as inferred from the levee seismic
5 vulnerability map (Figure 9-6).

6 **NEPA Effects:** The potential effect could be substantial because seismically induced ground shaking
7 could cause liquefaction, and damage pipelines, tunnels, intake facilities, pumping plant, and other
8 facilities. The damage could disrupt the water supply through the conveyance system. In an extreme
9 event, an uncontrolled release of water from the damaged conveyance system could cause flooding
10 and inundation of structures. Please refer to Appendix 3E, *Potential Seismicity and Climate Change*
11 *Risks to SWP/CVP Water Supplies*, for a detailed discussion of potential flooding effects.

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

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

42 DWR would ensure that the geotechnical design recommendations are included in the design of
43 project facilities and construction specifications to minimize the potential effects from liquefaction
44 and associated hazards. DWR would also ensure that the design specifications are properly executed
45 during construction.

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

- 4 • DWR Division of Engineering *State Water Project—Seismic Loading Criteria Report*, September
 5 2012.
- 6 • USACE *Engineering and Design—Time-History Dynamic Analysis of Concrete Hydraulic Structures*,
 7 EM 1110-2-6051, 2003
- 8 • USACE *Engineering and Design—Response Spectra and Seismic Analysis for Concrete Hydraulic*
 9 *Structures*, EM 1110-2-6050, 1999.
- 10 • American Society of Civil Engineers *Minimum Design Loads for Buildings and Other Structures*,
 11 ASCE/SEI 7-10, 2010.
- 12 • USACE *Engineering and Design—Design of Pile Foundations*, EM 1110-2-2906, 1991
- 13 • 8 CCR 3203.

14 Generally, the applicable codes require that facilities be built so that if soil in the foundation or
 15 surrounding area are subject to liquefaction, the removal or densification of the liquefiable material
 16 should be considered, along with alternative foundation designs. Additionally, any modification to a
 17 federal levee system would require USACE approval under 33 USC 408 (a 408 Permit).

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

24 Conformance to these and other applicable design specifications and standards would ensure that
 25 the hazard of liquefaction and associated ground movements would not create an increased
 26 likelihood of loss of property, personal injury or death of individuals from structural failure
 27 resulting from seismic-related ground failure along the Alternative 4 conveyance alignment during
 28 operation of the water conveyance features. Therefore, the effect would not be adverse.

29 **CEQA Conclusion:** Seismically induced ground shaking could cause liquefaction. Liquefaction could
 30 damage pipelines, tunnels, intake facilities, pumping plant, and other facilities, and thereby disrupt
 31 the water supply through the conveyance system. In an extreme event, flooding and inundation of
 32 structures could result from an uncontrolled release of water from the damaged conveyance system.
 33 (Please refer to Chapter 6, *Surface Water*, for a detailed discussion of potential flood impacts.)
 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, AMMs, and CMs*, such
 37 design codes, guidelines, and standards include USACE's *Engineering and Design—Stability Analysis*
 38 *of Concrete Structures and Soil Liquefaction during Earthquakes*, by the Earthquake Engineering
 39 Research Institute. Conformance with these design standards is an environmental commitment by
 40 DWR to ensure that liquefaction risks are minimized as the water conveyance features are operated.
 41 The hazard would be controlled to a safe level and there would be no increased likelihood of loss of

1 property, personal injury or death due to operation of Alternative 4. The impact would be less than
2 significant. No mitigation is required.

3 **Impact GEO-9: Loss of Property, Personal Injury, or Death from Landslides and Other Slope** 4 **Instability during Operation of Water Conveyance Features**

5 Alternative 4 would involve excavation that creates new cut-and-fill slopes and construction of new
6 embankments and levees. As a result of ground shaking and high soil-water content during heavy
7 rainfall, existing and new slopes that are not properly engineered and natural stream banks could
8 fail and cause damage to facilities. Levees can fail for several reasons: 1) high velocities of water
9 flow can result in high rates of erosion and erode and overtop a levee; 2) the higher velocities of
10 water flow can also lead to higher rates of erosion along the inner parts of levees and lead to
11 undercutting and clumping of the levee into the river. Heavy rainfall or seepage into the levee from
12 the river can increase fluid pressure in the levee and lead to slumping on the outer parts of the levee.
13 If the slumps grow to the top of the levee, large sections of the levee may slump onto the floodplain
14 and lower the elevation of the top of the levee, leading to overtopping; 3) increasing levels of water
15 in the river will cause the water table in the levee to rise which will increase fluid pressure and may
16 result in seepage and eventually lead to internal erosion called piping. Piping will erode the material
17 under the levee, undermining it and causing its collapse and failure.

18 With the exception of levee slopes and natural stream banks, the topography along the Alternative 4
19 conveyance alignment is nearly level to very gently sloping. The areas that may be susceptible to
20 slope failure are along existing levee slopes, and at intakes, pumping plant, forebay, and certain
21 access road locations. Outside these areas, the land is nearly level and consequently has a negligible
22 potential for slope failure. Based on review of topographic maps and a landslide map of Alameda
23 County (Roberts et al. 1999), the conveyance facilities would not be constructed on, nor would it be
24 adjacent to, slopes that are subject to mudflows/debris flows from natural slopes.

25 **NEPA Effects:** The potential effect could be substantial because levee slopes and stream banks may
26 fail, either from high pore-water pressure caused by high rainfall and weak soil, or from seismic
27 shaking. Structures built on these slopes could be damaged or fail entirely as a result of slope
28 instability. As discussed in Impact SW-2 in Chapter 6, *Surface Water*, operation of the water
29 conveyance features under Alternative 4 would not result in an increase in potential risk for flood
30 management compared to existing conditions. Peak monthly flows under Alternative 4 in the
31 locations considered were similar to or less than those that would occur under existing conditions.
32 Since flows would not be substantially greater, the potential for increased rates of erosion or
33 seepage are low. For additional discussion on the possible exposure of people or structures to
34 impacts from flooding due to levee failure, please refer to Impact SW-6 in Chapter 6.

35 During project design, a geotechnical engineer would develop slope stability design criteria (such as
36 minimum slope safety factors and allowable slope deformation and settlement) for the various
37 anticipated loading conditions. The design criteria would be documented in a detailed geotechnical
38 report prepared in accordance with state guidelines, in particular *Guidelines for Evaluating and*
39 *Mitigating Seismic Hazards in California* (California Geological Survey 2008). As discussed in Chapter
40 3, *Description of the Alternatives*, the foundation soil beneath slopes, embankments, or levees could
41 be 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
44 soil mixing, vibro-compaction, or vibro-replacement; or other methods. Engineered fill also would

1 be used to construct new slopes, embankments, and levees. Surface and internal drainage systems
2 would be installed as necessary to reduce erosion and piping (internal erosion) potential.

3 Site-specific geotechnical and hydrological information would be used, and the design would
4 conform to the current standards and construction practices, as described in Section 9.3.1, *Methods*
5 *for Analysis*, such as USACE's *Design and Construction of Levees* and USACE's EM 1110-2-1902, *Slope*
6 *Stability*. The design requirements would be presented in a detailed geotechnical report.

7 Conformance with these design requirements is an environmental commitment by DWR to ensure
8 that slope stability hazards would be avoided as the water conveyance features are operated. DWR
9 would ensure that the geotechnical design recommendations are included in the design of cut and
10 fill slopes, embankments, and levees to minimize the potential effects from slope failure. DWR would
11 also ensure that the design specifications are properly executed during construction.

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

- 15 • DWR Division of Engineering *State Water Project—Seismic Loading Criteria Report*, September
16 2012.
- 17 • DWR Division of Flood Management *FloodSAFE Urban Levee Design Criteria*, May 2012.
- 18 • USACE *Slope Stability*, EM 1110-2-1902, 2003.
- 19 • 8 CCR 3203.

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

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

29 Conformance to the above and other applicable design specifications and standards would ensure
30 that the hazard of slope instability would not create an increased likelihood of loss of property,
31 personal injury of individuals along the Alternative 4 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
35 constructed on these slopes could be damaged or fail entirely as a result of slope instability.

36 However, during the final project design process, as required by DWR's environmental
37 commitments (see Appendix 3B, *Environmental Commitments, AMMs, and CMs*), a geotechnical
38 engineer would develop slope stability design criteria (such as minimum slope safety factors and
39 allowable slope deformation and settlement) for the various anticipated loading conditions during
40 facility operations. The design criteria would be documented in a detailed geotechnical report
41 prepared in accordance with state guidelines, in particular Guidelines for Evaluating and Mitigating
42 Seismic Hazards in California (California Geological Survey 2008).

1 DWR would also ensure that measures to address this hazard would be required to conform to
 2 applicable design codes, guidelines, and standards. As described in Section 9.3.1, *Methods for*
 3 *Analysis*, and in Appendix 3B, *Environmental Commitments, AMMs, and CMs*, such design codes,
 4 guidelines, and standards include the California Building Code and resource agency and professional
 5 engineering specifications, such as USACE's *Engineering and Design—Earthquake Design and*
 6 *Evaluation for Civil Works Projects*. Conformance with these codes and standards is an
 7 environmental commitment by DWR to ensure cut and fill slopes and embankments would be stable
 8 as the water conveyance features are operated and there would be no increased likelihood of loss of
 9 property, personal injury or death due to operation of Alternative 4. The impact would be less than
 10 significant. No mitigation is required.

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

13 Based on recorded tsunami wave heights at the Golden Gate (Contra Costa Transportation Agency
 14 2009) and in the interior of the San Francisco Bay and on tsunami inundation maps prepared by the
 15 California Department of Conservation (2009), the height of a tsunami wave reaching the Suisun
 16 Marsh and the Delta would be small because of the distance from the ocean and attenuating effect of
 17 the San Francisco Bay. Therefore, the potential hazard of loss of property or personal injury as a
 18 result of a tsunami on the water conveyance facilities is low.

19 Similarly, with the exception of the expanded Clifton Court Forebay, the potential for a substantial
 20 seiche to take place in the Plan Area is considered low because seismic and water body geometry
 21 conditions for a seiche to occur near conveyance facilities are not favorable. Fugro Consultants, Inc.
 22 (2011) identified the potential for a seiche of an unspecified wave height to occur in the Clifton
 23 Court Forebay, caused by strong ground motions along the underlying West Tracy fault, assuming
 24 that this fault is potentially active. Since the fault also exists in the immediate vicinity of the
 25 expanded Clifton Court Forebay, a seiche could also occur in the expanded Clifton Court Forebay.

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

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

36 However, design-level geotechnical studies would be conducted by a licensed civil engineer who
 37 practices in geotechnical engineering. The studies would determine the peak ground acceleration
 38 caused by movement of the West Tracy fault and the maximum probable seiche wave that could be
 39 generated by the ground shaking. The California-registered civil engineer or California-certified
 40 engineering geologist's recommended measures to address this hazard, as well as the hazard of a
 41 seiche overtopping the expanded Clifton Court Forebay embankment, would conform to applicable
 42 design codes, guidelines, and standards. As described in Section 9.3.1, *Methods for Analysis*, and in
 43 Appendix 3B, *Environmental Commitments, AMMs, and CMs*, such design codes, guidelines, and
 44 standards include the Division of Safety of Dams' *Guidelines for Use of the Consequence-Hazard*

1 *Matrix and Selection of Ground Motion Parameters*, DWR's Division of Flood Management *FloodSAFE*
 2 *Urban Levee Design Criteria*, and USACE's *Engineering and Design—Earthquake Design and*
 3 *Evaluation for Civil Works Projects*. Conformance with these codes and standards is an
 4 environmental commitment by DWR to ensure that the adverse effects of a seiche are controlled to
 5 an acceptable level while the forebay facility is operated.

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

10 In particular, conformance with the following codes and standards would reduce the potential risk
 11 for increased likelihood of loss of property or personal injury tsunami or seiche.

- 12 • U.S. Department of the Interior and USGS *Climate Change and Water Resources Management: A*
 13 *Federal Perspective*, Circular 1331.
- 14 • State of California Sea-Level Rise Task Force of the CO-CAT, *Sea-Level Rise Interim Guidance*
 15 *Document*, 2010.
- 16 • 8 CCR 3203.

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

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

26 Conformance to these and other applicable design specifications and standards would ensure that
 27 the embankment for the expanded portion of the Clifton Court Forebay would be designed and
 28 constructed to contain and withstand the anticipated maximum seiche wave height and would not
 29 create an increased likelihood of loss of property, personal injury or death of individuals along the
 30 Alternative 4 conveyance alignment during operation of the water conveyance features. Therefore,
 31 the effect would not be adverse.

32 **CEQA Conclusion:** Based on recorded tsunami wave heights at the Golden Gate (Contra Costa
 33 Transportation Agency 2009) and in the interior of the San Francisco Bay and on tsunami
 34 inundation maps prepared by the California Department of Conservation (2009), the height of a
 35 tsunami wave reaching the Suisun Marsh and the Delta would be small because of the distance from
 36 the ocean and attenuating effect of the San Francisco Bay. Similarly, the potential for a significant
 37 seiche to occur in most parts of the Plan Area is considered low because the seismic hazard and the
 38 geometry of the water bodies (i.e., wide and shallow) near conveyance facilities are not favorable for
 39 a seiche to occur. However, assuming the West Tracy fault is potentially active, a potential exists for
 40 a seiche to occur in the expanded Clifton Court Forebay (Fugro Consultants 2011).

41 However, design-level geotechnical studies would be conducted by a licensed civil engineer who
 42 practices in geotechnical engineering. The studies would determine the peak ground acceleration

1 caused by movement of the West Tracy fault and the maximum probable seiche wave that could be
 2 generated by the ground shaking. The California-registered civil engineer or California-certified
 3 engineering geologist's recommended measures to address this hazard, as well as the hazard of a
 4 seiche overtopping the expanded Clifton Court Forebay embankment, would 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, AMMs, and CMs*, such design codes, guidelines, and
 7 standards include the Division of Safety of Dams' *Guidelines for Use of the Consequence-Hazard*
 8 *Matrix and Selection of Ground Motion Parameters*, DWR's *Division of Flood Management FloodSAFE*
 9 *Urban Levee Design Criteria*, and USACE's *Engineering and Design—Earthquake Design and*
 10 *Evaluation for Civil Works Projects*. Conformance with these codes and standards is an
 11 environmental commitment by DWR to ensure that the adverse effects of a seiche are controlled to
 12 an acceptable level while the forebay facility is operated. DWR would ensure that the geotechnical
 13 design recommendations are included in the design of project facilities and construction
 14 specifications to minimize the potential effects from seismic events and consequent seiche waves.
 15 DWR would also ensure that the design specifications are properly executed during construction.

16 The effect would not be adverse because the expanded Clifton Court Forebay embankment would be
 17 designed and constructed according to applicable design codes, guidelines, and standards to contain
 18 and withstand the anticipated maximum seiche wave height, as required by DWR's environmental
 19 commitments (see Appendix 3B, *Environmental Commitments, AMMs, and CMs*). There would be no
 20 increased likelihood of loss of property, personal injury or death due to operation of Alternative 4
 21 from seiche or tsunami. The impact would be less than significant. No additional mitigation is
 22 required.

23 **Impact GEO-11: Ground Failure Caused by Increased Groundwater Surface Elevations from** 24 **Unlined Canal Seepage as a Result of Operating the Water Conveyance Facilities**

25 **NEPA Effects:** Alternative 4 would not involve construction of unlined canals; therefore, there would
 26 be no increase in groundwater surface elevations and consequently no effect caused by canal
 27 seepage. There would be no effect.

28 **CEQA Conclusion:** Alternative 4 would not involve construction of unlined canals; therefore, there
 29 would be no increase in groundwater surface elevations and consequently no impact caused by
 30 canal seepage. There would be no impact. No mitigation is required.

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

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

38 Within the Delta, active or potentially active blind thrust faults were identified in the seismic study
 39 (California Department of Water Resources 2007a). The extreme southeastern corner of the Suisun
 40 Marsh is underlain by the Montezuma blind thrust zone. Parts of the Cache Slough and Yolo Bypass
 41 ROAs are underlain by part of the North Midland blind thrust zone. The Cosumnes/Mokelumne
 42 River and East Delta ROAs are underlain by the Thornton Arch fault zone. Although these blind
 43 thrusts are not expected to rupture to the ground surface during earthquake events, they may

1 produce ground or near-ground shear zones, bulging, or both. In the seismic study (California
 2 Department of Water Resources 2007a), the Thornton Arch blind thrust was assigned a 20%
 3 probability of being active. The depth to the Thornton Arch blind thrust is unknown. Based on
 4 limited geologic and seismic survey information, it appears that the potential of having any shear
 5 zones, bulging, or both at the sites of the habitat levees is low because the depth to the blind thrust
 6 faults is generally deep.

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

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

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

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

- 37 ● DWR Division of Engineering *State Water Project—Seismic Loading Criteria Report*, September
 38 2012.
- 39 ● DWR DSOD *Guidelines for Use of the Consequence-Hazard Matrix and Selection of Ground Motion*
 40 *Parameters*, 2002.
- 41 ● USACE *Engineering and Design—Earthquake Design and Evaluation for Civil Works Projects*,
 42 ER 1110-2-1806, 1995.
- 43 ● USACE *Design and Construction of Levees*, EM 1110-2-1913, 2000.

- 1 • USACE (CESPK-ED-G), Geotechnical Levee Practice, SOP EDG-03, 2004.
- 2 • DWR Division of Flood Management *FloodSAFE Urban Levee Design Criteria*, May 2012.
- 3 • 8 CCR Sections 1509 and 3203.

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

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

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

21 **CEQA Conclusion:** Rupture of the Cordelia and Green Valley faults could occur at the Suisun Marsh
 22 ROA and damage ROA facilities, such as levees and berms. Damage to these features could result in
 23 their failure, causing flooding of otherwise protected areas.

24 However, through the final design process for conservation measures in the ROAs and because there
 25 is limited information regarding the depths of the blind faults mentioned above, seismic surveys
 26 would be performed in the vicinity of the faults as part of final designs. These surveys would be used
 27 to verify fault depths where levees and other features would be constructed. Collection of this depth
 28 information would be part of broader, design-level geotechnical studies conducted by a geotechnical
 29 engineer licensed in the state of California to support all aspects of site-specific project design. The
 30 studies would assess site-specific conditions at and near all the project facility locations, including
 31 the nature and engineering properties of all soils and underlying geologic strata, and groundwater
 32 conditions. The geotechnical engineer's information would be used to develop final engineering
 33 solutions and project designs to any hazardous condition, consistent with DWR's environmental
 34 commitments (see Appendix 3B, *Environmental Commitments, AMMs, and CMs*).

35 Additionally, measures to address the fault rupture hazard would be required to conform to
 36 applicable design codes, guidelines, and standards. As described in Section 9.3.1, *Methods for*
 37 *Analysis*, and in Appendix 3B, *Environmental Commitments, AMMs, and CMs*, such design codes,
 38 guidelines, and standards include the Division of Safety of Dams' *Guidelines for Use of the*
 39 *Consequence-Hazard Matrix and Selection of Ground Motion Parameters*, DWR's Division of Flood
 40 Management *FloodSAFE Urban Levee Design Criteria*, and USACE's *Engineering and Design—*
 41 *Earthquake Design and Evaluation for Civil Works Projects*. Conformance with these design codes,
 42 guidelines, and standards is an environmental commitment by the BDCP proponents to ensure that
 43 fault rupture risks are minimized as the conservation measures are implemented. The hazard would

1 be controlled to a safe level and there would be no increased likelihood of loss of property, personal
2 injury or death in the ROAs. The impact would be 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
6 of 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
8 the Northern Midland fault zone, which underlies the ROA. Although more distant from these
9 sources, the other ROAs would be subject to shaking from the San Andreas, Hayward-Rodgers
10 Creek, Calaveras, Concord-Green Valley, San Gregorio, Greenville, and Mt. Diablo Thrust faults and
11 the more proximate 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 0.31–0.35 g
14 for 200-year return interval, while the PGA for the other ROAs ranges from approximately 0.11–0.26
15 g. The ground shaking could damage levees and other structures, and in an extreme event cause
16 levees to 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. Design-level geotechnical studies would be prepared
24 by a geotechnical engineer licensed in the state of California during project design. The studies
25 would assess site-specific conditions at and near all the project facility locations and provide the
26 basis for designing the levees and other features to withstand the peak ground acceleration caused
27 by fault movement in the region. The geotechnical engineer's recommended measures to address
28 this hazard would conform to applicable design codes, guidelines, and standards. Potential design
29 strategies or conditions could include avoidance (deliberately positioning structures and lifelines to
30 avoid crossing identified shear rupture zones), geotechnical engineering (using the inherent
31 capability of unconsolidated geomaterials to "locally absorb" and distribute distinct bedrock fault
32 movements) and structural engineering (engineering the facility to undergo some limited amount of
33 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 *AMMs, and CMs*, such design codes, guidelines, and standards include the California Building Code
36 and resource agency and professional engineering specifications, such as the Division of Safety of
37 Dams' *Guidelines for Use of the Consequence-Hazard Matrix and Selection of Ground Motion*
38 *Parameters*, DWR's Division of Flood Management *FloodSAFE Urban Levee Design Criteria*, and
39 USACE's *Engineering and Design—Earthquake Design and Evaluation for Civil Works Projects*.
40 Conformance with these design standards is an environmental commitment by the BDCP
41 proponents to ensure that strong seismic shaking risks are minimized as the conservation measures
42 are implemented.

43 The BDCP proponents would ensure that the geotechnical design recommendations are included in
44 the design of project features and construction specifications to minimize the potential effects from

1 seismic events and the presence of adverse soil conditions. The BDCP proponents would also ensure
2 that the design specifications are properly executed during implementation.

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

- 6 • DWR Division of Engineering *State Water Project—Seismic Loading Criteria Report*, September
7 2012.
- 8 • DWR DSOD *Guidelines for Use of the Consequence-Hazard Matrix and Selection of Ground Motion*
9 *Parameters*, 2002.
- 10 • USACE *Engineering and Design—Earthquake Design and Evaluation for Civil Works Projects*,
11 ER 1110-2-1806, 1995.
- 12 • USACE *Design and Construction of Levees*, EM 1110-2-1913, 2000.
- 13 • USACE (CESPK-ED-G), *Geotechnical Levee Practice*, SOP EDG-03, 2004.
- 14 • DWR Division of Flood Management *FloodSAFE Urban Levee Design Criteria*, May 2012.
- 15 • 8 CCR Sections 1509 and 3203.

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

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

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

32 **CEQA Conclusion:** Ground shaking could damage levees, berms, and other structures. Among all the
33 ROAs, the Suisun Marsh ROA would be the most subject to ground shaking because of its proximity
34 to active faults. The Suisun Marsh ROA is subject to a PGA of approximately 0.31 to 0.35 g for 200-
35 year return interval, while the PGA for the other ROAs ranges from approximately 0.11 to 0.26 g.
36 Damage to these features could result in their failure, causing flooding of otherwise protected areas.
37 However, as described in Section 9.3.1, *Methods for Analysis*, and in Appendix 3B, *Environmental*
38 *Commitments, AMMs, and CMs*, design codes, guidelines, and standards, including the California
39 Building Code and resource agency and professional engineering specifications, such as DWR's
40 Division of Flood Management *FloodSAFE Urban Levee Design Criteria* and USACE's *Engineering and*
41 *Design—Earthquake Design and Evaluation for Civil Works Projects* would be used for final design of

1 conservation features. Conformance with these design standards is an environmental commitment
 2 by the BDCP proponents to ensure that strong seismic shaking risks are minimized as the
 3 conservation measures are operated and there would be no increased likelihood of loss of property,
 4 personal injury or death in the ROAs. The impact would be less than significant. No mitigation is
 5 required.

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

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

17 The ROAs vary with respect to their liquefaction hazard (Figure 9-6). All of the levees in the Suisun
 18 Marsh ROA have a medium vulnerability to failure from seismic shaking and resultant liquefaction.
 19 The liquefaction vulnerability among the other ROAs in which seismically induced levee failure
 20 vulnerability has been assessed (Figure 9-6) (i.e., in parts or all the Cache Slough Complex and South
 21 Delta ROAs) is medium or high.

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

25 During final design of conservation facilities, site-specific geotechnical and groundwater
 26 investigations would be conducted to identify and characterize the vertical (depth) and horizontal
 27 (spatial) extent of liquefiable soil. Engineering soil parameters that could be used to assess the
 28 liquefaction potential, such as SPT blow counts, CPT penetration tip pressure/resistance, and
 29 gradation of soil, would also be obtained. SPT blow counts and CPT tip pressure are used to estimate
 30 soil 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 is less susceptible to
 35 liquefaction.

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

1 Section 9.3.1, *Methods for Analysis*, and in Appendix 3B, *Environmental Commitments, AMMs, and*
 2 *CMs*, such design codes, guidelines, and standards include USACE's *Engineering and Design—*
 3 *Stability Analysis of Concrete Structures* and *Soil Liquefaction during Earthquakes*, by the Earthquake
 4 Engineering Research Institute. Conformance with these design standards is an environmental
 5 commitment by the BDCP proponents to ensure that liquefaction risks are minimized as the
 6 conservation measures are implemented. The hazard would be controlled to a safe level.

7 In particular, conformance with the following codes and standards would reduce the potential risk
 8 for increased likelihood of loss of property or personal injury from structural failure resulting from
 9 seismic-related ground failure.

- 10 • USACE *Engineering and Design—Design of Pile Foundations*, EM 1110-2-2906, 1991.
- 11 • USACE *Engineering and Design—Stability Analysis of Concrete Structures*, EM 1110-2-2100, 2005.
- 12 • USACE *Engineering and Design—Earthquake Design and Evaluation for Civil Works Projects*,
 13 ER 1110-2-1806, 1995.
- 14 • 8 CCR Sections 1509 and 3203.

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

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

25 As required by the environmental commitments (see Appendix 3B, *Environmental Commitments,*
 26 *AMMs, and CMs*), the BDCP proponents would ensure that the geotechnical design recommendations
 27 are included in the design of levees and construction specifications to minimize the potential effects
 28 from liquefaction and associated hazard. The BDCP proponents would also ensure that the design
 29 specifications are properly executed during implementation and would not create an increased
 30 likelihood of loss of property, personal injury or death of individuals in the ROAs. This effect would
 31 not be adverse.

32 **CEQA Conclusion:** Earthquake-induced ground shaking could cause liquefaction, resulting in
 33 damage to or failure of levees, berms, and other features constructed at the restoration areas.
 34 Failure of levees and other structures could result in flooding of otherwise protected areas. As
 35 required by the environmental commitments (see Appendix 3B, *Environmental Commitments, AMMs,*
 36 *and CMs*), site-specific geotechnical and groundwater investigations would be conducted to identify
 37 and characterize the vertical (depth) and horizontal (spatial) extent of liquefiable soil. The BDCP
 38 proponents would ensure that the geotechnical design recommendations are included in the design
 39 of levees and construction specifications to minimize the potential effects from liquefaction and
 40 associated hazard. The BDCP proponents would also ensure that the design specifications are
 41 properly executed during implementation and would not create an increased likelihood of loss of
 42 property, personal injury or death of individuals in the ROAs. Further, through the final design
 43 process, measures to address the liquefaction 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, such design codes, guidelines, and standards include USACE's *Engineering and*
 3 *Design—Stability Analysis of Concrete Structures* and *Soil Liquefaction during Earthquakes*, by the
 4 Earthquake Engineering Research Institute. Conformance with these design standards is an
 5 environmental commitment by the BDCP proponents to ensure that liquefaction risks are minimized
 6 as the water conservation features are implemented and there would be no increased likelihood of
 7 loss of property, personal injury or death in the ROAs. The impact would be less than significant. No
 8 mitigation is required.

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

11 Implementation of CM2–CM7, would involve breaching, modification or removal of existing levees
 12 and construction of new levees and embankments. CM4 which provides for the restoration of up to
 13 65,000 acres of tidal perennial aquatic, tidal mudflat, tidal freshwater emergent wetland, and tidal
 14 brackish emergent wetland natural communities within the ROAs involves the greatest amount of
 15 modifications to levees. Levee modifications, including levee breaching or lowering, may be
 16 performed to reintroduce tidal exchange, reconnect remnant sloughs, restore natural remnant
 17 meandering tidal channels, encourage development of dendritic channel networks, and improve
 18 floodwater conveyance.

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

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

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

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

36 **NEPA Effects:** The potential effect could be substantial because levee slopes and embankments may
 37 fail, either from high pore-water pressure caused by high rainfall and weak soil, or from seismic
 38 shaking. Failure of these features could result in loss, injury, and death as well as flooding of
 39 otherwise protected areas.

40 As outlined in Chapter 3, *Description of Alternatives*, erosion protection measures and protection
 41 against related failure of adjacent levees would be taken where levee breaches were developed.
 42 Erosion protection could include geotextile fabrics, rock revetments, or other material selected

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

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

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

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

34 The BDCP proponents would ensure that the geotechnical design recommendations are included in
35 the design of embankments and levees to minimize the potential effects from slope failure. The
36 BDCP proponents would also ensure that the design specifications are properly executed during
37 implementation.

38 In particular, conformance with the following codes and standards would reduce the potential risk
39 for increased likelihood of loss of property or personal injury from structural failure resulting from
40 landslides or other slope instability.

- 41 ● DWR Division of Engineering *State Water Project – Seismic Loading Criteria Report*, September
42 2012.
- 43 ● DWR Division of Flood Management *FloodSAFE Urban Levee Design Criteria*, May 2012.

- 1 • USACE *Slope Stability*, EM 1110-2-1902, 2003.
- 2 • 8 CCR 3203.

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

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

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

16 **CEQA Conclusion:** Unstable new and existing levee and embankment slopes could fail as a result of
 17 seismic shaking and as a result of high soil-water content during heavy rainfall and cause flooding of
 18 otherwise protected areas. However, during project design and as required by the BDCP
 19 proponents' environmental commitments (see Appendix 3B, *Environmental Commitments, AMMs,*
 20 *and CMs*), a geotechnical engineer would develop slope stability design criteria (such as minimum
 21 slope safety factors and allowable slope deformation and settlement) for the various anticipated
 22 loading conditions. The BDCP proponents would ensure that the geotechnical design
 23 recommendations are included in the design of embankments and levees to minimize the potential
 24 effects from slope failure. The BDCP proponents would also ensure that the design specifications are
 25 properly executed during implementation.

26 Additionally, as required by the BDCP proponents' environmental commitments (see Appendix 3B,
 27 *Environmental Commitments, AMMs, and CMs*), site-specific geotechnical and hydrological
 28 information would be used to ensure conformance with applicable design guidelines and standards,
 29 such as USACE design measures. Through implementation of these environmental commitments, the
 30 hazard would be controlled to a safe level and there would be no increased likelihood of loss of
 31 property, personal injury or death in the ROAs. The impact would be less than significant. Therefore,
 32 no mitigation is required.

33 **Impact GEO-16: Loss of Property, Personal Injury, or Death from Seiche or Tsunami at** 34 **Restoration Opportunity Areas as a Result of Implementing the Conservation Actions**

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

38 **CEQA Conclusion:** Based on recorded tsunami heights at the Golden Gate, the height of a tsunami
 39 wave reaching the ROAs would be small because of the distance from the ocean and attenuating
 40 effect of the San Francisco Bay. Similarly, the potential for a significant seiche to occur in the Plan
 41 Area that would cause loss of property, personal injury, or death at the ROAs is considered low

1 because conditions for a seiche to occur at the ROAs are not favorable. The impact would be less
2 than significant. No mitigation is required.

3 **9.3.3.10 Alternative 5—Dual Conveyance with Pipeline/Tunnel and** 4 **Intake 1 (3,000 cfs; Operational Scenario C)**

5 **Impact GEO-1: Loss of Property, Personal Injury, or Death from Structural Failure Resulting** 6 **from Strong Seismic Shaking of Water Conveyance Features during Construction**

7 *NEPA Effects:* Alternative 5 would include the same physical/structural components as Alternative
8 1A, except that it would entail four less intakes and four less pumping plants. These differences
9 would present a lower hazard of structural failure from seismic shaking but would not substantially
10 change the hazard of loss of property, personal injury, or death during construction compared to
11 Alternative 1A. The effects of Alternative 5 would, therefore, be the same as 1A. See the description
12 and findings under Alternative 1A. There would be no adverse effect.

13 *CEQA Conclusion:* Seismically induced ground shaking could cause collapse or other failure of
14 project facilities while under construction. However, DWR would conform to Cal-OSHA and other
15 state code requirements, such as shoring, bracing, lighting, excavation depth restrictions, required
16 slope angles, and other measures, to protect worker safety. Conformance with these standards and
17 codes is an environmental commitment of the project (see Appendix 3B, *Environmental*
18 *Commitments, AMMs, and CMs*). Conformance with these health and safety requirements and the
19 application of accepted, proven construction engineering practices would reduce this risk and there
20 would be no increased likelihood of loss of property, personal injury or death due to construction of
21 Alternative 5. This impact would be less than significant. No mitigation is required.

22 **Impact GEO-2: Loss of Property, Personal Injury, or Death from Settlement or Collapse** 23 **Caused by Dewatering during Construction of Water Conveyance Features**

24 *NEPA Effects:* Alternative 5 would include the same physical/structural components as Alternative
25 1A, except that it would entail four less intakes and four less pumping plants. These differences
26 would present a lower hazard of settlement or collapse caused by dewatering but would not
27 substantially change the hazard of loss of property, personal injury, or death during construction
28 compared to Alternative 1A. The effects of Alternative 5 would, therefore, be the same as 1A. See the
29 description and findings under Alternative 1A. There would be no adverse effect.

30 *CEQA Conclusion:* Settlement or failure of excavations during construction could result in loss of
31 property or personal injury. However, DWR would conform to Cal-OSHA and other state code
32 requirements, such as using seepage cutoff walls, shoring, and other measures, to protect worker
33 safety. DWR would also ensure that the design specifications are properly executed during
34 construction. DWR has made an environmental commitment to use the appropriate code and
35 standard requirements to minimize potential risks (Appendix 3B, *Environmental Commitments,*
36 *AMMs, and CMs*) and there would be no increased likelihood of loss of property, personal injury or
37 death due to construction of Alternative 5. The impact would be less than significant. No mitigation
38 is required.

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

3 **NEPA Effects:** Alternative 5 would include the same physical/structural components as Alternative
4 1A, except that it would entail four less intakes and four less pumping plants. These differences
5 would create a lower hazard of ground settlement over the tunnels 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 5 would, therefore, be the same as 1A. See the description
8 and findings under Alternative 1A. There would be no adverse effect.

9 **CEQA Conclusion:** Ground settlement above the tunneling operation could result in loss of property
10 or personal injury during construction. However, DWR would conform to Cal-OSHA, USACE, and
11 other design requirements to protect worker safety. DWR would also ensure that the design
12 specifications are properly executed during construction. DWR has made an environmental
13 commitment to use the appropriate code and standard requirements to minimize potential risks
14 (Appendix 3B, *Environmental Commitments, AMMs, and CMs*) and there would be no increased
15 likelihood of loss of property, personal injury or death due to construction of Alternative 5. Hazards
16 to workers and project structures would be controlled at safe levels and the impact would be less
17 than significant. No mitigation is required.

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

20 **NEPA Effects:** Alternative 5 would include the same physical/structural components as Alternative
21 1A, except that it would entail four less intakes and four less pumping plants. These differences
22 would present a lower hazard of slope failure at borrow and spoils storage sites but would not
23 substantially change the hazard of loss of property, personal injury, or death during construction
24 compared to Alternative 1A. The effects of Alternative 5 would, therefore, be the same as 1A. See the
25 description and findings under Alternative 1A. 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
28 would conform to Cal-OSHA and other state code requirements and conform to applicable
29 geotechnical design guidelines and standards, such as USACE design measures, the hazard would be
30 controlled to a safe level and there would be no increased likelihood of loss of property, personal
31 injury or death due to construction of Alternative 5. The impact would be less than significant. No
32 mitigation is required.

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

36 **NEPA Effects:** Alternative 5 would include the same physical/structural components as Alternative
37 1A, except that it would entail four less intakes and four less pumping plants. These differences
38 would present a lower hazard of structural failure from construction-related ground motions but
39 would not substantially change the hazard of loss of property, personal injury, or death during
40 construction compared to Alternative 1A. The effects of Alternative 5 would, therefore, be the same
41 as 1A. See the description and findings under Alternative 1A. There would be no adverse effect.

1 **CEQA Conclusion:** Construction-related ground motions and traffic effects could initiate
 2 liquefaction, which could cause failure of structures during construction, which could result in injury
 3 of workers at the construction sites. The impact could be significant. However, because DWR would
 4 conform to Cal-OSHA and other state code requirements and conform to applicable design
 5 guidelines and standards, such as USACE design measures, in addition to implementation of
 6 Mitigation Measures TRANS-2a and TRANS-2b, as well as the maintenance and reconstruction of
 7 levees through Mitigation Measure TRANS-2c, the hazard would be controlled to a level that would
 8 protect worker safety (see Appendix 3B, *Environmental Commitments, AMMs, and CMs*) and there
 9 would be no increased likelihood of loss of property, personal injury or death due to construction of
 10 Alternative 5. The impact would be less than significant.

11 **Mitigation Measure TRANS-2a: Prohibit Construction Activity on Physically Deficient**
 12 **Roadway Segments**

13 Please refer to Mitigation Measure TRANS-2a in Alternative 1A, Impact TRANS-2, in Chapter 19,
 14 *Transportation*.

15 **Mitigation Measure TRANS-2b: Limit Construction Activity on Physically Deficient**
 16 **Roadway Segments**

17 Please refer to Mitigation Measure TRANS-2b in Alternative 1A, Impact TRANS-2, in Chapter 19,
 18 *Transportation*.

19 **Mitigation Measure TRANS-2c: Improve Physical Condition of Affected Roadway Segments**
 20 **as Stipulated in Mitigation Agreements or Encroachment Permits**

21 Please refer to Mitigation Measure TRANS-2c in Alternative 1A, Impact TRANS-2, in Chapter 19,
 22 *Transportation*.

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

25 **NEPA Effects:** Alternative 5 would include the same physical/structural components as Alternative
 26 1A, except that it would entail four less intakes and four less pumping plants. These differences
 27 would present a lower hazard from an earthquake fault rupture but would not substantially change
 28 the hazard of loss of property, personal injury, or death during construction compared to Alternative
 29 1A. The effects of Alternative 5 would, therefore, be the same as 1A. See the description and findings
 30 under Alternative 1A. The impact would not be adverse.

31 **CEQA Conclusion:** There are no active faults capable of surface rupture that extend into the
 32 pipeline/tunnel alignment. Although the Thornton Arch and West Tracy blind thrusts occur beneath
 33 the pipeline/tunnel alignment, based on available information, they do not present a hazard of
 34 surface rupture and there would be no increased likelihood of loss of property, personal injury or
 35 death due to operation of Alternative 5. There would be no impact. Therefore, no mitigation is
 36 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 **NEPA Effects:** Alternative 5 would include the same physical/structural components as Alternative
 4 1A, except that it would entail four less intakes and four less pumping plants. These differences
 5 would present a lower hazard from seismic shaking but would not substantially change the hazard
 6 of loss of property, personal injury, or death during construction compared to Alternative 1A. The
 7 effects of Alternative 5 would, therefore, be the same as 1A. See the description and findings under
 8 Alternative 1A. The impact would not be adverse.

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

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

29 **NEPA Effects:** Alternative 5 would include the same physical/structural components as Alternative
 30 1A, except that it would entail four less intakes and four less pumping plants. These differences
 31 would present a lower hazard of structural failure from ground failure but would not substantially
 32 change the hazard of loss of property, personal injury, or death during construction compared to
 33 Alternative 1A. The effects of Alternative 5 would, therefore, be the same as 1A. See the description
 34 and findings under Alternative 1A. There would be no adverse effect.

35 **CEQA Conclusion:** Seismically induced ground shaking could cause liquefaction. Liquefaction could
 36 damage pipelines, tunnels, intake facilities, pumping plants, and other facilities, and thereby disrupt
 37 the water supply through the conveyance system. In an extreme event, an uncontrolled release of
 38 water from the damaged conveyance system could result in flooding and inundation of structures.
 39 (Please refer to Chapter 6, *Surface Water*, for a detailed discussion of potential flood impacts.)
 40 However, through the final design process, measures to address the liquefaction hazard would be
 41 required to conform to applicable design codes, guidelines, and standards. As described in Section
 42 9.3.1, *Methods for Analysis*, and in Appendix 3B, *Environmental Commitments, AMMs, and CMs*, such
 43 design codes, guidelines, and standards include USACE's *Engineering and Design—Stability Analysis*
 44 *of Concrete Structures and Soil Liquefaction during Earthquakes*, by the Earthquake Engineering

1 Research Institute. Conformance with these design standards is an environmental commitment by
 2 DWR to ensure that liquefaction risks are minimized as the water conveyance features are operated.
 3 The hazard would be controlled to a safe level and there would be no increased likelihood of loss of
 4 property, personal injury or death due to operation of Alternative 5. The impact would be less than
 5 significant. No mitigation is required.

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

8 **NEPA Effects:** Alternative 5 would include the same physical/structural components as Alternative
 9 1A, except that it would entail four less intakes and four less pumping plants. These differences
 10 would present a lower hazard from landslides and other slope instability but would not
 11 substantially change the hazard of loss of property, personal injury, or death during construction
 12 compared to Alternative 1A. The effects of Alternative 5 would, therefore, be the same as 1A. See the
 13 description and findings under Alternative 1A. There would be no adverse effect.

14 **CEQA Conclusion:** Unstable levee slopes and natural stream banks may fail, either from high pore-
 15 water pressure caused by high rainfall and weak soil, or from seismic shaking. Structures
 16 constructed on these slopes could be damaged or fail entirely as a result of slope instability.
 17 However, through the final design process, measures to address this hazard would be required to
 18 conform to applicable design codes, guidelines, and standards. As described in Section 9.3.1,
 19 *Methods for Analysis*, and in Appendix 3B, *Environmental Commitments, AMMs, and CMs*, such design
 20 codes, guidelines, and standards include the California Building Code and resource agency and
 21 professional engineering specifications, such as USACE's *Engineering and Design—Earthquake*
 22 *Design and Evaluation for Civil Works Projects*. Conformance with these codes and standards is an
 23 environmental commitment by DWR to ensure cut and fill slopes and embankments would be stable
 24 as the water conveyance features are operated and there would be no increased likelihood of loss of
 25 property, personal injury or death due to operation of Alternative 5. The impact would be less than
 26 significant. No mitigation is required.

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

29 **NEPA Effects:** Alternative 5 would include the same physical/structural components as Alternative
 30 1A, except that it would entail four less intakes and four less pumping plants. These differences
 31 would not present a lower hazard of a seiche or tsunami and would not substantially change the
 32 hazard of loss of property, personal injury, or death during construction compared to Alternative 1A.
 33 The effects of Alternative 5 would, therefore, be the same as 1A. See the description and findings
 34 under Alternative 1A. There would be no adverse effect.

35 **CEQA Conclusion:** Based on recorded tsunami wave heights at the Golden Gate (Contra Costa
 36 Transportation Agency 2009) and in the interior of the San Francisco Bay and on tsunami
 37 inundation maps prepared by the California Department of Conservation (2009), the height of a
 38 tsunami wave reaching the Suisun Marsh and the Delta would be small because of the distance from
 39 the ocean and attenuating effect of the San Francisco Bay. Similarly, the potential for a significant
 40 seiche to occur in most parts of the Plan Area is considered low because the seismic hazard and the
 41 geometry of the water bodies (i.e., wide and shallow) near conveyance facilities are not favorable for
 42 a seiche to occur. However, assuming the West Tracy fault is potentially active, a potential exists for
 43 a seiche to occur in the Clifton Court Forebay and the Byron Tract Forebay (Fugro Consultants

2011). The impact would not be significant because the Byron Tract Forebay embankment would be designed and constructed according to applicable design codes, guidelines, and standards to contain and withstand the anticipated maximum seiche wave height. There would be no increased likelihood of loss of property, personal injury or death due to operation of Alternative 5 from seiche or tsunami. The impact would be less than significant. No mitigation is required.

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

NEPA Effects: Alternative 5 would not involve construction of unlined canals; therefore, there would be no increase in groundwater surface elevations and consequently no effect caused by canal seepage. There would be no effect.

CEQA Conclusion: Alternative 5 would not involve construction of unlined canals; therefore, there would be no increase in groundwater surface elevations and consequently no impact caused by canal seepage. There would be no impact. No mitigation is required.

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

NEPA Effects: Conservation measures would be the same under Alternative 5 as under 1A, except that only up to 25,000 acres of tidal habitat would be restored. The effects of Alternative 5 relating to the hazard of loss of property, personal injury, or death from rupture of an earthquake fault would, therefore, be similar to that of Alternative 1A, but of a lower magnitude (fewer new levees and berms in restoration areas). See description and findings under Alternative 1A. There would be no adverse effect.

CEQA Conclusion: Rupture of the Cordelia and Green Valley faults could occur at the Suisun Marsh ROA and damage ROA facilities, such as levees and berms. Damage to these features could result in their failure, causing flooding of otherwise protected areas. However, through the final design process for conservation measures in the ROAs, measures to address the fault rupture 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, AMMs, and CMs*, 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 5 as under 1A, except that only up to 25,000 acres of tidal habitat would be restored. The effects of Alternative 5 relating to the hazard of loss of property, personal injury, or death from a structural failure from seismic shaking would, therefore, be similar to that of Alternative 1A, but of a lower magnitude (fewer new

1 levees and berms in restoration areas). See description and findings under Alternative 1A. There
2 would be no adverse effect.

3 **CEQA Conclusion:** Ground shaking could damage levees, berms, and other structures. Among all the
4 ROAs, the Suisun Marsh ROA would be the most subject to ground shaking because of its proximity
5 to active faults. The Suisun Marsh ROA is subject to a PGA of approximately 0.31 to 0.35 g for 200-
6 year return interval, while the PGA for the other ROAs ranges from approximately 0.11 to 0.26 g.
7 Damage to these features could result in their failure, causing flooding of otherwise protected areas.
8 However, as described in Section 9.3.1, *Methods for Analysis*, and in Appendix 3B, *Environmental*
9 *Commitments, AMMs, and CMs*, design codes, guidelines, and standards, including the California
10 Building Code and resource agency and professional engineering specifications, such as 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* would be used for final design of
13 conservation features. Conformance with these design standards is an environmental commitment
14 by the BDCP proponents to ensure that strong seismic shaking risks are minimized as the
15 conservation measures are operated and there would be no increased likelihood of loss of property,
16 personal injury or death in the ROAs. The impact would be less than significant. No mitigation is
17 required.

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

21 **NEPA Effects:** Conservation measures would be the same under Alternative 5 as under 1A, except
22 that only up to 25,000 acres of tidal habitat would be restored. The effects of Alternative 5 relating
23 to the hazard of loss of property, personal injury, or death from ground failure would, therefore, be
24 similar to that of Alternative 1A, but of a lower magnitude (because of fewer new levees and berms
25 in restoration areas). See description and findings under Alternative 1A. There would be no adverse
26 effect.

27 **CEQA Conclusion:** Earthquake-induced ground shaking could cause liquefaction, resulting in
28 damage to or failure of levees, berms, and other features constructed at the restoration areas.
29 Failure of levees and other structures could result in flooding of otherwise protected areas.

30 However, through the final design process, measures to address the liquefaction hazard would be
31 required to conform to applicable design codes, guidelines, and standards. As described in Section
32 9.3.1, *Methods for Analysis*, and in Appendix 3B, *Environmental Commitments, AMMs, and CMs*, such
33 design codes, guidelines, and standards include USACE's *Engineering and Design—Stability Analysis*
34 *of Concrete Structures and Soil Liquefaction during Earthquakes*, by the Earthquake Engineering
35 Research Institute. Conformance with these design standards is an environmental commitment by
36 the BDCP proponents to ensure that liquefaction risks are minimized as the water conservation
37 features are implemented and there would be no increased likelihood of loss of property, personal
38 injury or death in the ROAs. The impact would be less than significant. No mitigation is required.

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

41 **NEPA Effects:** Conservation measures would be the same under Alternative 5 as under 1A, except
42 that only up to 25,000 acres of tidal habitat would be restored. The effects of Alternative 5 relating
43 to the hazard of loss of property, personal injury, or death from a landslide or other slope failure

1 would, therefore, be similar to that of Alternative 1A, but of a lower magnitude. See description and
2 findings under Alternative 1A. There would be no adverse effect.

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

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

11 **NEPA Effects:** Conservation measures under Alternative 5 would be similar to that as under
12 Alternative 1A. See description and findings under Alternative 1A. There would be no adverse effect.

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

19 **9.3.3.11 Alternative 6A—Isolated Conveyance with Pipeline/Tunnel and**
20 **Intakes 1–5 (15,000 cfs; Operational Scenario D)**

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

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
25 severed. These differences would not have a bearing on the hazard of loss of property, personal
26 injury, or death from seismic shaking 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
28 Alternative 1A. There would be no adverse effect.

29 **CEQA Conclusion:** Seismically induced ground shaking could cause collapse or other failure of
30 project facilities while under construction. However, DWR would conform to Cal-OSHA and other
31 state code requirements, such as shoring, bracing, lighting, excavation depth restrictions, required
32 slope angles, and other measures, to protect worker safety. Conformance with these standards and
33 codes is an environmental commitment of the project (see Appendix 3B, *Environmental*
34 *Commitments, AMMs, and CMs*). Conformance with these health and safety requirements and the
35 application of accepted, proven construction engineering practices would reduce this risk and there
36 would be no increased likelihood of loss of property, personal injury or death due to construction of
37 Alternative 6A. This impact would be less than significant. No mitigation is required.

1 **Impact GEO-2: Loss of Property, Personal Injury, or Death from Settlement or Collapse**
2 **Caused by Dewatering during Construction 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
5 severed. These differences would not have a bearing on the hazard of loss of property, personal
6 injury, or death from settlement or collapse caused by dewatering during construction compared to
7 Alternative 1A. The effects of Alternative 6A would, therefore, be the same as 1A. See the description
8 and 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 to 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
14 standard requirements to minimize potential risks (Appendix 3B, *Environmental Commitments,*
15 *AMMs, and CMs*) and there would be no increased likelihood of loss of property, personal injury or
16 death due to construction of Alternative 6A. The impact would be less than significant. No mitigation
17 is required.

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

20 **NEPA Effects:** Alternative 6A would include the same physical/structural components as Alternative
21 1A, but existing connections between the SWP and CVP south Delta export facilities would be
22 severed. These differences would not have a bearing on the hazard of loss of property, personal
23 injury, or death from ground settlement of tunnels during construction compared to Alternative 1A.
24 The effects of Alternative 6A 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:** Ground settlement above the tunneling operation could result in loss of property
27 or personal injury during construction. However, DWR would conform to Cal-OSHA, USACE, and
28 other design requirements to protect worker safety. DWR would also ensure that the design
29 specifications are properly executed during construction. DWR has made an environmental
30 commitment to use the appropriate code and standard requirements to minimize potential risks
31 (Appendix 3B, *Environmental Commitments, AMMs, and CMs*) and there would be no increased
32 likelihood of loss of property, personal injury or death due to construction of Alternative 6A.
33 Hazards to workers and project structures would be controlled at safe levels and the impact would
34 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 6A would include the same physical/structural components as Alternative
38 1A, but existing connections between the SWP and CVP south Delta export facilities would be
39 severed. These differences would not have a bearing on the hazard of loss of property, personal
40 injury, or death from slope failure at borrow and spoils storage sites during construction compared
41 to Alternative 1A. The effects of Alternative 6A would, therefore, be the same as 1A. See the
42 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
 3 would conform to Cal-OSHA and other state code requirements and conform to applicable
 4 geotechnical design guidelines and standards, such as USACE design measures, the hazard would be
 5 controlled to a safe level and there would be no increased likelihood of loss of property, personal
 6 injury or death due to construction of Alternative 6A. The impact would be less than significant. No
 7 mitigation is required.

8 **Impact GEO-5: Loss of Property, Personal Injury, or Death from Structural Failure Resulting**
 9 **from Construction-Related Ground Motions during Construction of Water Conveyance**
 10 **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
 13 severed. These differences would not have a bearing on the hazard of loss of property, personal
 14 injury, or death from structural failure from construction-related motions compared to Alternative
 15 1A. The effects of Alternative 6A would, therefore, be the same as 1A. See the description and
 16 findings under Alternative 1A. There would be no adverse effect.

17 **CEQA Conclusion:** Construction-related ground motions and traffic effects could initiate
 18 liquefaction, which could cause failure of structures during construction, which could result in injury
 19 of workers at the construction sites. The impact could be significant. However, because DWR would
 20 conform to Cal-OSHA and other state code requirements and conform to applicable design
 21 guidelines and standards, such as USACE design measures, in addition to implementation of
 22 Mitigation Measures TRANS-2a and TRANS-2b, as well as the maintenance and reconstruction of
 23 levees through Mitigation Measure TRANS-2c, the hazard would be controlled to a level that would
 24 protect worker safety (see Appendix 3B, *Environmental Commitments, AMMs, and CMs*) and there
 25 would be no increased likelihood of loss of property, personal injury or death due to construction of
 26 Alternative 6A. The impact would be less than significant.

27 **Mitigation Measure TRANS-2a: Prohibit Construction Activity on Physically Deficient**
 28 **Roadway Segments**

29 Please refer to Mitigation Measure TRANS-2a in Alternative 1A, Impact TRANS-2, in Chapter 19,
 30 *Transportation*.

31 **Mitigation Measure TRANS-2b: Limit Construction Activity on Physically Deficient**
 32 **Roadway Segments**

33 Please refer to Mitigation Measure TRANS-2b in Alternative 1A, Impact TRANS-2, in Chapter 19,
 34 *Transportation*.

35 **Mitigation Measure TRANS-2c: Improve Physical Condition of Affected Roadway Segments**
 36 **as Stipulated in Mitigation Agreements or Encroachment Permits**

37 Please refer to Mitigation Measure TRANS-2c in Alternative 1A, Impact TRANS-2, in Chapter 19,
 38 *Transportation*.

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 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
 5 severed. These differences would not have a bearing on the hazard of loss of property, personal
 6 injury, or death from rupture of an earthquake fault compared to Alternative 1A. The effects of
 7 Alternative 6A would, therefore, be the same as 1A. See the description and findings under
 8 Alternative 1A. There would be no adverse effect.

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 Alternative pipeline/tunnel, based on available information, they do not present a hazard of
 12 surface rupture and there would be no increased likelihood of loss of property, personal injury or
 13 death due to operation of Alternative 6A. There would be no impact. Therefore, no mitigation is
 14 required.

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

17 **NEPA Effects:** Alternative 6A would include the same physical/structural components as Alternative
 18 1A, but existing connections between the SWP and CVP south Delta export facilities would be
 19 severed. These differences would not have a bearing on the hazard of loss of property, personal
 20 injury, or death from seismic shaking during operation compared to Alternative 1A. The effects of
 21 Alternative 6A would, therefore, be the same as 1A. See the description and findings under
 22 Alternative 1A. There would be no adverse effect.

23 **CEQA Conclusion:** Seismically induced strong ground shaking could damage pipelines, tunnels,
 24 intake facilities, pumping plants, and other facilities. The damage could disrupt the water supply
 25 through the conveyance system.

26 In an extreme event, an uncontrolled release of water from the damaged conveyance system could
 27 cause flooding and inundation of structures. (Please refer to Chapter 6, *Surface Water*, for a detailed
 28 discussion of potential flood impacts.) However, through the final design process, measures to
 29 address this hazard would be required to conform to applicable design codes, guidelines, and
 30 standards. As described in Section 9.3.1, *Methods for Analysis*, and in Appendix 3B, *Environmental*
 31 *Commitments, AMMs, and CMs*, such design codes, guidelines, and standards include the California
 32 Building Code and resource agency and professional engineering specifications, such as the Division
 33 of Safety of Dams *Guidelines for Use of the Consequence-Hazard Matrix and Selection of Ground Motion*
 34 *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
 37 that ground shaking risks are minimized as the water conveyance features are operated. The hazard
 38 would be controlled to a safe level and there would be no increased likelihood of loss of property,
 39 personal injury or death due to operation of Alternative 6A. The impact would be less than
 40 significant. No mitigation is 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 **NEPA Effects:** Alternative 6A would include the same physical/structural components as Alternative
 5 1A, but existing connections between the SWP and CVP south Delta export facilities would be
 6 severed. These differences would not have a bearing on the hazard of loss of property, personal
 7 injury, or death from ground failure compared to Alternative 1A. The effects of Alternative 6A
 8 would, therefore, be the same as 1A. See the description and findings under Alternative 1A. There
 9 would be no adverse effect.

10 **CEQA Conclusion:** Seismically induced ground shaking could cause liquefaction. Liquefaction could
 11 damage pipelines, tunnels, intake facilities, pumping plants, and other facilities, and thereby disrupt
 12 the water supply through the conveyance system. In an extreme event, flooding and inundation of
 13 structures could result from an uncontrolled release of water from the damaged conveyance system.
 14 (Please refer to Chapter 6, *Surface Water*, for a detailed discussion of potential flood impacts.)

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, AMMs, and CMs*, such
 18 design codes, guidelines, and standards include USACE's *Engineering and Design—Stability Analysis*
 19 *of Concrete Structures and Soil Liquefaction during Earthquakes*, by the Earthquake Engineering
 20 Research Institute. Conformance with these design standards is an environmental commitment by
 21 DWR to ensure that liquefaction risks are minimized as the water conveyance features are operated.
 22 The hazard would be controlled to a safe level and there would be no increased likelihood of loss of
 23 property, personal injury or death due to operation of Alternative 6A. The impact would be less than
 24 significant. No mitigation is required.

25 **Impact GEO-9: Loss of Property, Personal Injury, or Death from Landslides and Other Slope**
 26 **Instability 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
 29 severed. These differences would not have a bearing on the hazard of loss of property, personal
 30 injury, or death from landslides and other slope instability compared to Alternative 1A. The effects
 31 of Alternative 6A would, therefore, be the same as 1A. See the description and findings under
 32 Alternative 1A. There would be no adverse effect.

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
 35 constructed on these slopes could be damaged or fail entirely as a result of slope instability.
 36 However, through the final design process, measures to address this hazard would be required to
 37 conform to applicable design codes, guidelines, and standards. As described in Section 9.3.1,
 38 *Methods for Analysis*, and in Appendix 3B, *Environmental Commitments, AMMs, and CMs*, such design
 39 codes, guidelines, and standards include the California Building Code and resource agency and
 40 professional engineering specifications, such as USACE's *Engineering and Design—Earthquake*
 41 *Design and Evaluation for Civil Works Projects*. Conformance with these codes and standards is an
 42 environmental commitment by DWR to ensure cut and fill slopes and embankments would be stable
 43 as the water conveyance features are operated and there would be no increased likelihood of loss of

1 property, personal injury or death due to operation of Alternative 6A. The impact would be less than
2 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 6A would include the same physical/structural components as Alternative
6 1A, but existing connections between the SWP and CVP south Delta export facilities would be
7 severed. These differences would not have a bearing on the hazard of loss of property, personal
8 injury, or death from seiche or tsunami compared to Alternative 1A. The effects of Alternative 6A
9 would, therefore, be the same as 1A. See the description and findings under Alternative 1A. There
10 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
13 inundation maps prepared by the California Department of Conservation (2009), the height of a
14 tsunami wave reaching the Suisun Marsh and the Delta would be small because of the distance from
15 the ocean and attenuating effect of the San Francisco Bay. Similarly, the potential for a significant
16 seiche to occur in most parts of the Plan Area is considered low because the seismic hazard and the
17 geometry of the water bodies (i.e., wide and shallow) near conveyance facilities are not favorable for
18 a seiche to occur. However, assuming the West Tracy fault is potentially active, a potential exists for
19 a seiche to occur in the Clifton Court Forebay and the Byron Tract Forebay (Fugro Consultants
20 2011). The impact would not be significant because the Byron Tract Forebay embankment would be
21 designed and constructed according to applicable design codes, guidelines, and standards to contain
22 and withstand the anticipated maximum seiche wave height. There would be no increased likelihood
23 of loss of property, personal injury or death due to operation of Alternative 6A from seiche or
24 tsunami. The impact would be 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 6A would not involve construction of unlined canals; therefore, there
28 would be no increase in groundwater surface elevations and consequently no effect caused by canal
29 seepage. There would be no effect.

30 *CEQA Conclusion:* Alternative 6A would not involve construction of unlined canals; therefore, there
31 would be no increase in groundwater surface elevations and consequently no impact caused by
32 canal seepage. There would be no impact. 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 6A 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
38 ROA and damage ROA facilities, such as levees and berms. Damage to these features could result in
39 their failure, causing flooding of otherwise protected areas. However, through the final design
40 process for conservation measures in the ROAs, measures to address the fault rupture hazard would
41 be required to conform to applicable design codes, guidelines, and standards. As described in

1 Section 9.3.1, *Methods for Analysis*, and in Appendix 3B, *Environmental Commitments, AMMs, and*
 2 *CMs*, such design codes, guidelines, and standards include the Division of Safety of Dams' *Guidelines*
 3 *for Use of the Consequence-Hazard Matrix and Selection of Ground Motion Parameters*, DWR's
 4 Division of Flood Management *FloodSAFE Urban Levee Design Criteria*, and USACE's *Engineering and*
 5 *Design—Earthquake Design and Evaluation for Civil Works Projects*. Conformance with these design
 6 standards is an environmental commitment by the BDCP proponents to ensure that fault rupture
 7 risks are minimized as the conservation measures are implemented. The hazard would be controlled
 8 to a safe level and there would be no increased likelihood of loss of property, personal injury or
 9 death in the ROAs. The impact would be less than significant. No mitigation is required.

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

12 **NEPA Effects:** Conservation measures would be the same under Alternative 6A as under 1A. See
 13 description and findings under Alternative 1A. There would be no adverse effect.

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
 16 to active faults. The Suisun Marsh ROA is subject to a PGA of approximately 0.31 to 0.35 g for 200-
 17 year return interval, while the PGA for the other ROAs ranges from approximately 0.11 to 0.26 g.
 18 Damage to these features could result in their failure, causing flooding of otherwise protected areas.

19 However, as described in Section 9.3.1, *Methods for Analysis*, and in Appendix 3B, *Environmental*
 20 *Commitments, AMMs, and CMs*, design codes, guidelines, and standards, including the California
 21 Building Code and resource agency and professional engineering specifications, such as DWR's
 22 Division of Flood Management *FloodSAFE Urban Levee Design Criteria* and USACE's *Engineering and*
 23 *Design—Earthquake Design and Evaluation for Civil Works Projects* would be used for final design of
 24 conservation features. Conformance with these design standards is an environmental commitment
 25 by the BDCP proponents to ensure that strong seismic shaking risks are minimized as the
 26 conservation measures are operated and there would be no increased likelihood of loss of property,
 27 personal injury or death in the ROAs. The impact would be less than significant. No mitigation is
 28 required.

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

32 **NEPA Effects:** Conservation measures would be the same under Alternative 6A as under 1A. See
 33 description and findings under Alternative 1A. There would be no adverse effect.

34 **CEQA Conclusion:** Earthquake-induced ground shaking could cause liquefaction, resulting in
 35 damage to or failure of levees, berms, and other features constructed at the restoration areas.
 36 Failure of levees and 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, AMMs, and CMs*, such
 40 design codes, guidelines, and standards include USACE's *Engineering and Design—Stability Analysis*
 41 *of Concrete Structures and Soil Liquefaction during Earthquakes*, by the Earthquake Engineering
 42 Research Institute. Conformance with these design standards is an environmental commitment by

1 the BDCP proponents to ensure that liquefaction risks are minimized as the water conservation
 2 features are implemented and there would be no increased likelihood of loss of property, personal
 3 injury or death in the ROAs. The impact would be less than significant. No mitigation is required.

4 **Impact GEO-15: Loss of Property, Personal Injury, or Death from Landslides and Other Slope**
 5 **Instability at Restoration Opportunity 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:* Unstable new and existing levee and embankment slopes could fail as a result of
 9 seismic shaking and as a result of high soil-water content during heavy rainfall and cause flooding of
 10 otherwise protected areas. However, because the BDCP proponents would conform to applicable
 11 design guidelines and standards, such as USACE design measures, the hazard would be controlled to
 12 a safe level and there would be no increased likelihood of loss of property, personal injury or death
 13 in the ROAs. The impact would be less than 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 6A 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 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
 20 ocean 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 in the Plan Area is
 22 considered low because conditions for a seiche to occur near conveyance facilities are not favorable
 23 and there would be no increased likelihood of loss of property, personal injury or death in the ROAs.
 24 The impact would be less than significant. No mitigation is required.

25 **9.3.3.12 Alternative 6B—Isolated Conveyance with East Alignment and**
 26 **Intakes 1–5 (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 6B would include the same physical/structural components as Alternative
 30 1B, but existing connections between the SWP and CVP south Delta export facilities would be
 31 severed. These differences would not have a bearing on the hazard of loss of property, personal
 32 injury, or death from seismic shaking during construction compared to Alternative 1B. The effects of
 33 Alternative 6B would, therefore, be the same as 1B. See the description and findings under
 34 Alternative 1B. There would be no adverse effect.

35 *CEQA Conclusion:* Seismically induced ground shaking could cause collapse or other failure of
 36 project facilities while under construction. However, DWR would conform to Cal-OSHA and other
 37 state code requirements, such as shoring, bracing, lighting, excavation depth restrictions, required
 38 slope angles, and other measures, to protect worker safety. Conformance with these standards and
 39 codes is an environmental commitment of the project (see Appendix 3B, *Environmental*
 40 *Commitments, AMMs, and CMs*). Conformance with these health and safety requirements and the

1 application of accepted, proven construction engineering practices would reduce this risk and there
 2 would be no increased likelihood of loss of property, personal injury or death due to construction of
 3 Alternative 6B. 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**
 5 **Caused by Dewatering during Construction of Water Conveyance Features**

6 *NEPA Effects:* Alternative 6B would include the same physical/structural components as Alternative
 7 1B, but existing connections between the SWP and CVP south Delta export facilities would be
 8 severed. These differences would not have a bearing on the hazard of loss of property, personal
 9 injury, or death from settlement or collapse caused by dewatering during construction compared to
 10 Alternative 1B. The effects of Alternative 6B would, therefore, be the same as 1B. See the description
 11 and findings under Alternative 1B. 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 to 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
 17 standard requirements to minimize potential risks (Appendix 3B, *Environmental Commitments,*
 18 *AMMs, and CMs*) and there would be no increased likelihood of loss of property, personal injury or
 19 death due to construction of Alternative 6B. The impact would be less than significant. No mitigation
 20 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 6B would include the same physical/structural components as Alternative
 24 1B, but existing connections between the SWP and CVP south Delta export facilities would be
 25 severed. These differences would not have a bearing on the hazard of loss of property, personal
 26 injury, or death from ground settlement during construction of tunnel siphons, compared to
 27 Alternative 1B. The effects of Alternative 6B would, therefore, be the same as 1B. See the description
 28 and findings under Alternative 1B. There would be no adverse effect.

29 *CEQA Conclusion:* Ground settlement above the tunneling operation could result in loss of property
 30 or personal injury during construction. However, DWR would conform to Cal-OSHA, USACE and
 31 other design requirements to protect worker safety. DWR would also ensure that the design
 32 specifications are properly executed during construction. DWR has made an environmental
 33 commitment to use the appropriate code and standard requirements to minimize potential risks
 34 (Appendix 3B, *Environmental Commitments, AMMs, and CMs*). Hazards to workers and project
 35 structures would be controlled at safe levels and there would be no increased likelihood of loss of
 36 property, personal injury or death due to construction of Alternative 6B. The impact would be less
 37 than significant. No mitigation is required.

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

40 *NEPA Effects:* Alternative 6B would include the same physical/structural components as Alternative
 41 1B, but existing connections between the SWP and CVP south Delta export facilities would be
 42 severed. These differences would not have a bearing on the hazard of loss of property, personal

1 injury, or death from slope failure at borrow and spoils storage sites during construction compared
 2 to Alternative 1B. The effects of Alternative 6B would, therefore, be the same as 1B. See the
 3 description and findings under Alternative 1B. There would be no adverse effect.

4 **CEQA Conclusion:** Settlement/failure of cutslopes of borrow sites and failure of soil/RTM fill slopes
 5 could result in loss of property or personal injury during construction. However, because DWR
 6 would conform to Cal-OSHA and other state code requirements and conform to applicable
 7 geotechnical design guidelines and standards, such as USACE design measures, the hazard would be
 8 controlled to a safe level and there would be no increased likelihood of loss of property, personal
 9 injury or death due to construction of Alternative 6B. The impact would be less than significant. No
 10 mitigation is required.

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

14 **NEPA Effects:** Alternative 6B would include the same physical/structural components as Alternative
 15 1B, but existing connections between the SWP and CVP south Delta export facilities would be
 16 severed. These differences would not have a bearing on the hazard of loss of property, personal
 17 injury, or death from structural failure from construction-related motions compared to Alternative
 18 1B. The effects of Alternative 6B would, therefore, be the same as 1B. See the description and
 19 findings under Alternative 1B. There would be no adverse effect.

20 **CEQA Conclusion:** Construction-related ground motions and traffic effects could initiate
 21 liquefaction, which could cause failure of structures during construction, which could result in injury
 22 of workers at the construction sites. The impact could be significant. However, because DWR has
 23 committed to conform to Cal-OSHA and other state code requirements and conform to applicable
 24 design guidelines and standards, such as USACE design measures, in addition to implementation of
 25 Mitigation Measures TRANS-2a and TRANS-2b, as well as the maintenance and reconstruction of
 26 levees through Mitigation Measure TRANS-2c, the hazard would be controlled to a level that would
 27 protect worker safety (see Appendix 3B, *Environmental Commitments, AMMs, and CMs*) and there
 28 would be no increased likelihood of loss of property, personal injury or death due to construction of
 29 Alternative 6B. The impact would be less than significant.

30 **Mitigation Measure TRANS-2a: Prohibit Construction Activity on Physically Deficient**
 31 **Roadway Segments**

32 Please refer to Mitigation Measure TRANS-2a in Alternative 1A, Impact TRANS-2, in Chapter 19,
 33 *Transportation*.

34 **Mitigation Measure TRANS-2b: Limit Construction Activity on Physically Deficient**
 35 **Roadway Segments**

36 Please refer to Mitigation Measure TRANS-2b in Alternative 1A, Impact TRANS-2, in Chapter 19,
 37 *Transportation*.

1 **Mitigation Measure TRANS-2c: Improve Physical Condition of Affected Roadway Segments**
 2 **as Stipulated in Mitigation Agreements or Encroachment Permits**

3 Please refer to Mitigation Measure TRANS-2c in Alternative 1A, Impact TRANS-2, in Chapter 19,
 4 *Transportation*.

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

7 **NEPA Effects:** Alternative 6B would include the same physical/structural components as Alternative
 8 1B, but existing connections between the SWP and CVP south Delta export facilities would be
 9 severed. These differences would not have a bearing on the hazard of loss of property, personal
 10 injury, or death from rupture of an earthquake fault compared to Alternative 1B. The effects of
 11 Alternative 6B would, therefore, be the same as 1B. See the description and findings under
 12 Alternative 1B. There would be no adverse effect.

13 **CEQA Conclusion:** There are no active faults capable of surface rupture that extend into the East
 14 alignment. Although the Thornton Arch and West Tracy blind thrusts occur beneath the East
 15 alignment, based on available information, they do not present a hazard of surface rupture and there
 16 would be no increased likelihood of direct loss, injury or death due to operation of Alternative 6B.
 17 There would be no impact. Therefore, no mitigation is required.

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

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
 22 severed. These differences would not have a bearing on the hazard of loss of property, personal
 23 injury, or death from seismic shaking during operation compared to Alternative 1B. The effects of
 24 Alternative 6B would, therefore, be the same as 1B. See the description and findings under
 25 Alternative 1B. There would be no adverse effect.

26 **CEQA Conclusion:** Seismically induced strong ground shaking could damage the canals, pipelines,
 27 tunnel and culvert siphons, intake facilities, pumping plants, and other facilities. The damage could
 28 disrupt the water supply through the conveyance system. In an extreme event, an uncontrolled
 29 release of water from the damaged conveyance system could cause flooding and inundation of
 30 structures. (Please refer to Chapter 6, *Surface Water*, for a detailed discussion of potential flood
 31 impacts.) However, through the final design process, measures to address this hazard would be
 32 required to conform to applicable design codes, guidelines, and standards. As described in Section
 33 9.3.1, *Methods for Analysis*, and in Appendix 3B, *Environmental Commitments, AMMs, and CMs*, such
 34 design codes, guidelines, and standards include the California Building Code and resource agency
 35 and professional engineering specifications, such as the Division of Safety of Dams' *Guidelines for Use*
 36 *of the Consequence-Hazard Matrix and Selection of Ground Motion Parameters*, DWR's Division of
 37 Flood Management *FloodSAFE Urban Levee Design Criteria*, and USACE's *Engineering and Design—*
 38 *Earthquake Design and Evaluation for Civil Works Projects*. Conformance with these codes and
 39 standards is an environmental commitment by DWR to ensure that ground shaking risks are
 40 minimized as the water conveyance features are operated and there would be no increased
 41 likelihood of loss of property, personal injury or death due to operation of Alternative 6B. The
 42 hazard would be controlled to a safe level. The impact would be less than significant. No mitigation
 43 is 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 **NEPA Effects:** Alternative 6B would include the same physical/structural components as Alternative
 5 1B, but existing connections between the SWP and CVP south Delta export facilities would be
 6 severed. These differences would not have a bearing on the hazard of loss of property, personal
 7 injury, or death from ground failure compared to Alternative 1B. The effects of Alternative 6B would,
 8 therefore, be the same as 1B. See the description and findings under Alternative 1B. There would be
 9 no adverse effect.

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

25 **Impact GEO-9: Loss of Property, Personal Injury, or Death from Landslides and Other Slope**
 26 **Instability during Operation 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
 29 severed. These differences would not have a bearing on the hazard of loss of property, personal
 30 injury, or death from landslides and other slope instability compared to Alternative 1B. The effects
 31 of Alternative 6B would, therefore, be the same as 1B. See the description and findings under
 32 Alternative 1B. There would be no adverse effect.

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
 35 constructed on these slopes could be damaged or fail entirely as a result of slope instability.
 36 However, through the final design process, measures to address this hazard would be required to
 37 conform to applicable design codes, guidelines, and standards. As described in Section 9.3.1,
 38 *Methods for Analysis*, and in Appendix 3B, *Environmental Commitments, AMMs, and CMs*, such design
 39 codes, guidelines, and standards include the California Building Code and resource agency and
 40 professional engineering specifications, such as USACE's *Engineering and Design—Earthquake*
 41 *Design and Evaluation for Civil Works Projects*. Conformance with these codes and standards is an
 42 environmental commitment by DWR to ensure cut and fill slopes and embankments would be stable
 43 as the water conveyance features are operated and there would be no increased likelihood of loss of

1 property, personal injury or death due to operation of Alternative 6B. The impact would be less than
2 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 6B would include the same physical/structural components as Alternative
6 1B, but existing connections between the SWP and CVP south Delta export facilities would be
7 severed. These differences would not have a bearing on the hazard of loss of property, personal
8 injury, or death from seiche or tsunami compared to Alternative 1B. The effects of Alternative 6B
9 would, therefore, be the same as 1B. See the description and findings under Alternative 1B. There
10 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
13 inundation maps prepared by the California Department of Conservation (2009), the height of a
14 tsunami wave reaching the Suisun Marsh and the Delta would be small because of the distance from
15 the ocean and attenuating effect of the San Francisco Bay. Similarly, the potential for a significant
16 seiche to occur in most parts of the Plan Area is considered low because the seismic hazard and the
17 geometry of the water bodies (i.e., wide and shallow) near conveyance facilities are not favorable for
18 a seiche to occur. However, assuming that the West Tracy fault is potentially active, a potential exists
19 for a seiche to occur in the Clifton Court Forebay and the Byron Tract Forebay (Fugro Consultants
20 2011). The impact would not be significant because the Byron Tract Forebay embankment would be
21 designed and constructed according to applicable design codes, guidelines, and standards to contain
22 and withstand the anticipated maximum seiche wave height. There would be no increased likelihood
23 of loss of property, personal injury or death due to operation of Alternative 6B from seiche or
24 tsunami. The impact would be 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 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
29 severed. These differences would not have a bearing on the hazard of loss of property, personal
30 injury, or death from seismic shaking during operation compared to Alternative 1B. The effects of
31 Alternative 6B would, therefore, be the same as 1B. See the description and findings under
32 Alternative 1B. There would be no adverse effect.

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
35 surface. The increased hazard of liquefaction could threaten the integrity of the canal in the event
36 that liquefaction occurs. However, because DWR would conform to applicable design guidelines and
37 standards, such as USACE design measures, 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 6B. 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 would be the same under Alternative 6B as under 1A. See
 4 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
 6 ROA and damage ROA facilities, such as levees and berms. Damage to these features could result in
 7 their failure, causing flooding of otherwise protected areas. However, through the final design
 8 process for conservation measures in the ROAs, measures to address the fault rupture hazard would
 9 be required to conform to applicable design codes, guidelines, and standards. As described in
 10 Section 9.3.1, *Methods for Analysis*, and in Appendix 3B, *Environmental Commitments, AMMs, and*
 11 *CMs*, such design codes, guidelines, and standards include the Division of Safety of Dams *Guidelines*
 12 *for Use of the Consequence-Hazard Matrix and Selection of Ground Motion Parameters*, DWR's
 13 Division of Flood Management *FloodSAFE Urban Levee Design Criteria*, and USACE's *Engineering and*
 14 *Design—Earthquake Design and Evaluation for Civil Works Projects*. Conformance with these design
 15 standards is an environmental commitment by the BDCP proponents to ensure that fault rupture
 16 risks are minimized as the conservation measures are implemented. The hazard would be controlled
 17 to a safe level and there would be no increased likelihood of loss of property, personal injury or
 18 death in the ROAs. The impact would be less than 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 would be the same under Alternative 6B as under 1A. See
 22 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
 25 to active faults. The Suisun Marsh ROA is subject to a PGA of approximately 0.31 to 0.35 g for 200-
 26 year return interval, while the PGA for the other ROAs ranges from approximately 0.11 to 0.26 g.
 27 Damage to these features could result in their failure, causing flooding of otherwise protected areas.

28 However, as described in Section 9.3.1, *Methods for Analysis*, and in Appendix 3B, *Environmental*
 29 *Commitments, AMMs, and CMs*, design codes, guidelines, and standards, including the California
 30 Building Code and resource agency and professional engineering specifications, such as DWR's
 31 Division of Flood Management *FloodSAFE Urban Levee Design Criteria* and USACE's *Engineering and*
 32 *Design—Earthquake Design and Evaluation for Civil Works Projects* would be used for final design of
 33 conservation features. Conformance with these design standards is an environmental commitment
 34 by the BDCP proponents to ensure that strong seismic shaking risks are minimized as the
 35 conservation measures are operated and there would be no increased likelihood of loss of property,
 36 personal injury or death in the ROAs. The impact would be less than significant. No mitigation is
 37 required.

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

41 **NEPA Effects:** Conservation measures would be the same under Alternative 6B as under 1A. See
 42 description and findings under Alternative 1A. There would be no adverse effect.

1 **CEQA Conclusion:** Earthquake-induced ground shaking could cause liquefaction, resulting in
2 damage to or failure of levees, berms, and other features constructed at the restoration areas.
3 Failure of levees and other structures could result in flooding of otherwise protected areas.

4 However, through the final design process, measures to address the liquefaction hazard would be
5 required to conform to applicable design codes, guidelines, and standards. As described in Section
6 9.3.1, *Methods for Analysis*, and in Appendix 3B, *Environmental Commitments, AMMs, and CMs*, such
7 design codes, guidelines, and standards include USACE's *Engineering and Design—Stability Analysis*
8 *of Concrete Structures* and *Soil Liquefaction during Earthquakes*, by the Earthquake Engineering
9 Research Institute. Conformance with these design standards is an environmental commitment by
10 the BDCP proponents to ensure that liquefaction risks are minimized as the water conservation
11 features are implemented. The hazard would be controlled to a safe level and there would be no
12 increased likelihood of loss of property, personal injury or death in the ROAs. The impact would be
13 less than significant. No mitigation is required.

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

16 **NEPA Effects:** Conservation measures would be the same under Alternative 6B as under 1A. See
17 description and findings under Alternative 1A. There would be no adverse effect.

18 **CEQA Conclusion:** Unstable levee slopes and natural stream banks may fail, either from high pore-
19 water pressure caused by high rainfall and weak soil, or from seismic shaking. Structures
20 constructed on these slopes could be damaged or fail entirely as a result of slope instability.
21 However, because the BDCP proponents would conform to applicable 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 in the ROAs. The
24 impact would be less than significant. Therefore, no mitigation is required.

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

27 **NEPA Effects:** Conservation measures under Alternative 6B would be similar to that as under
28 Alternative 1A. See description and findings under Alternative 1A. There would be no adverse effect.

29 **CEQA Conclusion:** Based on recorded tsunami wave heights at the Golden Gate, the height of a
30 tsunami wave reaching the Suisun Marsh and the Delta would be small because of the distance from
31 the ocean and attenuating effect of the San Francisco Bay. The impact would be less than significant.
32 No mitigation is required. Similarly, the potential for a significant seiche to occur at the ROAs is
33 considered low because conditions for a seiche to occur near conveyance facilities are not favorable
34 and there would be no increased likelihood of loss of property, personal injury or death in the ROAs.
35 The impact would be less than significant. No mitigation is required.

9.3.3.13 Alternative 6C—Isolated Conveyance with West Alignment and Intakes W1–W5 (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 6C would include the same physical/structural components as Alternative 1C, 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 1C. The effects of Alternative 6C 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, resulting in loss of property or personal injury. However, DWR would conform to 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, AMMs, and CMs*). 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 6C. 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 6C would include the same physical/structural components as Alternative 1C, 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 1C. The effects of Alternative 6C 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 to 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, AMMs, and CMs*) and there would be no increased likelihood of loss of property, personal injury or death due to construction of Alternative 6C. 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 6C would include the same physical/structural components as Alternative 1C, 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

1 injury, or death from ground settlement of tunnels and culvert siphons during construction
 2 compared to Alternative 1C. The effects of Alternative 6C would, therefore, be the same as 1C. See
 3 the description and findings under Alternative 1C. There would be no adverse effect.

4 **CEQA Conclusion:** Ground settlement above the tunneling operation could result in loss of property
 5 or personal injury during construction. However, DWR would conform to Cal-OSHA, USACE and
 6 other design requirements to protect worker safety. DWR would also ensure that the design
 7 specifications are properly executed during construction. DWR has made an environmental
 8 commitment to use the appropriate code and standard requirements to minimize potential risks
 9 (Appendix 3B, *Environmental Commitments, AMMs, and CMs*). Hazards to workers and project
 10 structures would be controlled at safe levels and there would be no increased likelihood of loss of
 11 property, personal injury or death due to construction of Alternative 6C. The impact would be less
 12 than significant. No mitigation is required.

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

15 **NEPA Effects:** Alternative 6C would include the same physical/structural components as Alternative
 16 1C, but existing connections between the SWP and CVP south Delta export facilities would be
 17 severed. These differences would not have a bearing on the hazard of loss of property, personal
 18 injury, or death from slope failure at borrow and spoils storage sites during construction compared
 19 to Alternative 1C. The effects of Alternative 6A would, therefore, be the same as 1C. See the
 20 description and findings under Alternative 1C. There would be no adverse effect.

21 **CEQA Conclusion:** Settlement/failure of cutslopes of borrow sites and failure of soil/RTM fill slopes
 22 could result in loss of property or personal injury during construction. However, because DWR
 23 would conform to Cal-OSHA and other state code requirements and conform to applicable
 24 geotechnical design guidelines and standards, such as USACE design measures, the hazard would be
 25 controlled to a safe level and there would be no increased likelihood of loss of property, personal
 26 injury or death due to construction of Alternative 6C. The impact would be less than significant. No
 27 mitigation is required.

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

31 **NEPA Effects:** Alternative 6C would include the same physical/structural components as Alternative
 32 1C, but existing connections between the SWP and CVP south Delta export facilities would be
 33 severed. These differences would not have a bearing on the hazard of loss of property, personal
 34 injury, or death from structural failure from construction-related motions compared to Alternative
 35 1C. The effects of Alternative 6C would, therefore, be the same as 1C. See the description and
 36 findings under Alternative 1C. There would be no adverse effect.

37 **CEQA Conclusion:** Construction-related ground motions and traffic effects could initiate
 38 liquefaction, which could cause failure of structures during construction, which could result in injury
 39 of workers at the construction sites. The impact could be significant. However, because DWR has
 40 committed to conform to Cal-OSHA and other state code requirements and conform to applicable
 41 design guidelines and standards, such as USACE design measures, in addition to implementation of
 42 Mitigation Measures TRANS-2a and TRANS-2b, as well as the maintenance and reconstruction of
 43 levees through Mitigation Measure TRANS-2c, the hazard would be controlled to a level that would

1 protect worker safety (see Appendix 3B, *Environmental Commitments, AMMs, and CMs*) and there
 2 would be no increased likelihood of loss of property, personal injury or death due to construction of
 3 Alternative 6C. The impact would be less than significant.

4 **Mitigation Measure TRANS-2a: Prohibit Construction Activity on Physically Deficient**
 5 **Roadway Segments**

6 Please refer to Mitigation Measure TRANS-2a in Alternative 1A, Impact TRANS-2, in Chapter 19,
 7 *Transportation*.

8 **Mitigation Measure TRANS-2b: Limit Construction Activity on Physically Deficient**
 9 **Roadway Segments**

10 Please refer to Mitigation Measure TRANS-2b in Alternative 1A, Impact TRANS-2, in Chapter 19,
 11 *Transportation*.

12 **Mitigation Measure TRANS-2c: Improve Physical Condition of Affected Roadway Segments**
 13 **as Stipulated in Mitigation Agreements or Encroachment Permits**

14 Please refer to Mitigation Measure TRANS-2c in Alternative 1A, Impact TRANS-2, in Chapter 19,
 15 *Transportation*.

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 6C would include the same physical/structural components as Alternative
 19 1C, but existing connections between the SWP and CVP south Delta export facilities would be
 20 severed. These differences would not have a bearing on the hazard of loss of property, personal
 21 injury, or death from rupture of an earthquake fault compared to Alternative 1C. The effects of
 22 Alternative 6C would, therefore, be the same as 1C. See the description and findings under
 23 Alternative 1C. There would be no adverse effect.

24 **CEQA Conclusion:** There are no active faults capable of surface rupture that extend into the West
 25 alignment. Although the Thornton Arch and West Tracy blind thrusts occur beneath the West
 26 alignment, based on available information, they do not present a hazard of surface rupture and there
 27 would be no increased likelihood of loss of property, personal injury or death due to operation of
 28 Alternative 6C. 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 6C would include the same physical/structural components as Alternative
 32 1C, but existing connections between the SWP and CVP south Delta export facilities would be
 33 severed. These differences would not have a bearing on the hazard of loss of property, personal
 34 injury, or death from seismic shaking during operation compared to Alternative 1C. The effects of
 35 Alternative 6C would, therefore, be the same as 1C. See the description and findings under
 36 Alternative 1C. There would be no adverse effect.

37 **CEQA Conclusion:** Seismically induced strong ground shaking could damage the canals, pipelines,
 38 tunnel, culvert siphons, intake facilities, pumping plants, and other facilities. The damage could
 39 disrupt the water supply through the conveyance system. In an extreme event, an uncontrolled

1 release of water from the damaged conveyance system could cause flooding and inundation of
 2 structures. (Please refer to Chapter 6, *Surface Water*, for a detailed discussion of potential flood
 3 impacts.) However, through the final design process, measures to address this hazard would be
 4 required to conform to applicable design codes, guidelines, and standards. As described in Section
 5 9.3.1, *Methods for Analysis*, and in Appendix 3B, *Environmental Commitments, AMMs, and CMs*, such
 6 design codes, guidelines, and standards include the California Building Code and resource agency
 7 and professional engineering specifications, such as the Division of Safety of Dams' *Guidelines for Use*
 8 *of the Consequence-Hazard Matrix and Selection of Ground Motion Parameters*, DWR's Division of
 9 Flood Management *FloodSAFE Urban Levee Design Criteria*, and USACE's *Engineering and Design—*
 10 *Earthquake Design and Evaluation for Civil Works Projects*. Conformance with these codes and
 11 standards is an environmental commitment by DWR to ensure that ground shaking risks are
 12 minimized as the water conveyance features are operated. The hazard would be controlled to a safe
 13 level and there would be no increased likelihood of loss of property, personal injury or death due to
 14 operation of Alternative 6C. The impact would be less than significant. No mitigation is required.

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

18 **NEPA Effects:** Alternative 6C would include the same physical/structural components as Alternative
 19 1C, but existing connections between the SWP and CVP south Delta export facilities would be
 20 severed. These differences would not have a bearing on the hazard of loss of property, personal
 21 injury, or death from ground failure compared to Alternative 1C. The effects of Alternative 6C would,
 22 therefore, be the same as 1C. See the description and findings under Alternative 1C. There would be
 23 no adverse effect.

24 **CEQA Conclusion:** Seismically induced ground shaking could cause liquefaction. Liquefaction could
 25 damage pipelines, tunnels, culvert siphons, intake facilities, pumping plants, and other facilities, and
 26 thereby disrupt the water supply through the conveyance system. In an extreme event, flooding and
 27 inundation of structures could result from an uncontrolled release of water from the damaged
 28 conveyance system. (Please refer to Chapter 6, *Surface Water*, for a detailed discussion of potential
 29 flood impacts.) However, through the final design process, measures to address the liquefaction
 30 hazard would be required to conform to applicable design codes, guidelines, and standards. As
 31 described in Section 9.3.1, *Methods for Analysis*, and in Appendix 3B, *Environmental Commitments,*
 32 *AMMs, and CMs*, such design codes, guidelines, and standards include USACE's *Engineering and*
 33 *Design—Stability Analysis of Concrete Structures and Soil Liquefaction during Earthquakes*, by the
 34 Earthquake Engineering Research Institute. Conformance with these design standards is an
 35 environmental commitment by DWR to ensure that liquefaction risks are minimized as the water
 36 conveyance features are operated. The hazard would be controlled to a safe level and there would
 37 be no increased likelihood of loss of property, personal injury or death due to operation of
 38 Alternative 6C. The impact would be less than significant. No mitigation is required.

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

41 **NEPA Effects:** Alternative 6C would include the same physical/structural components as Alternative
 42 1C, but existing connections between the SWP and CVP south Delta export facilities would be
 43 severed. These differences would not have a bearing on the hazard of loss of property, personal
 44 injury, or death from landslides and other slope instability compared to Alternative 1C. The effects

1 of Alternative 6C would, therefore, be the same as 1C. See the description and findings under
2 Alternative 1C. There would be no adverse effect.

3 **CEQA Conclusion:** Unstable levee slopes and natural stream banks may fail, either from high pore-
4 water pressure caused by high rainfall and weak soil, or from seismic shaking. Structures
5 constructed on these slopes could be damaged or fail entirely as a result of slope instability.
6 However, through the final design process, measures to address this hazard would be required to
7 conform to applicable design codes, guidelines, and standards. As described in Section 9.3.1,
8 *Methods for Analysis*, and in Appendix 3B, *Environmental Commitments, AMMs, and CMs*, such design
9 codes, guidelines, and standards include the California Building Code and resource agency and
10 professional engineering specifications, such as USACE's *Engineering and Design—Earthquake*
11 *Design and Evaluation for Civil Works Projects*. Conformance with these codes and standards is an
12 environmental commitment by DWR to ensure cut and fill slopes and embankments would be stable
13 as the water conveyance features are operated and there would be no increased likelihood of loss of
14 property, personal injury or death due to operation of Alternative 6C. The impact would be less than
15 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 6C would include the same physical/structural components as Alternative
19 1C, but existing connections between the SWP and CVP south Delta export facilities would be
20 severed. These differences would not have a bearing on the hazard of loss of property, personal
21 injury, or death from seiche or tsunami compared to Alternative 1C. The effects of Alternative 6C
22 would, therefore, be the same as 1C. See the description and findings under Alternative 1C. There
23 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
26 inundation maps prepared by the California Department of Conservation (2009), the height of a
27 tsunami wave reaching the Suisun Marsh and the Delta would be small because of the distance from
28 the ocean and attenuating effect of the San Francisco Bay. Similarly, the potential for a significant
29 seiche to occur in most parts of the Plan Area is considered low because the seismic hazard and the
30 geometry of the water bodies (i.e., wide and shallow) near conveyance facilities are not favorable for
31 a seiche to occur. However, assuming that the West Tracy fault is potentially active, a potential exists
32 for a seiche to occur in the Clifton Court Forebay and the Byron Tract Forebay (Fugro Consultants
33 2011). The impact would not be significant because the Byron Tract Forebay embankment would be
34 designed and constructed according to applicable design codes, guidelines, and standards to contain
35 and withstand the anticipated maximum seiche wave height. There would be no increased likelihood
36 of loss of property, personal injury or death due to operation of Alternative 6C from seiche or
37 tsunami. The impact would 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 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
42 severed. These differences would not have a bearing on the hazard of loss of property, personal
43 injury, or death from seismic shaking during operation compared to Alternative 1C. The effects of

1 Alternative 6C would, therefore, be the same as 1C. See the description and findings under
2 Alternative 1C. There would be no adverse effect.

3 **CEQA Conclusion:** Seepage from an unlined canal could raise the water table level along the canal,
4 thereby increasing the hazard of liquefaction where the water table is not already close to the
5 surface. The increased hazard of liquefaction could threaten the integrity of the canal in the event
6 that liquefaction occurs. However, because DWR would conform to applicable design guidelines and
7 standards, such as USACE design measures, the hazard would be controlled to a safe level and there
8 would be no increased likelihood of loss of property, personal injury or death due to operation of
9 Alternative 6C. The impact would be less than significant. No mitigation is required.

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

12 **NEPA Effects:** Conservation measures would be the same under Alternative 6C as under 1A. See
13 description and findings under Alternative 1A. There would be no adverse effect.

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

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

30 **NEPA Effects:** Conservation measures would be the same under Alternative 6C as under 1A. See
31 description and findings under Alternative 1A. There would be no adverse effect.

32 **CEQA Conclusion:** Ground shaking could damage levees, berms, and other structures. Among all the
33 ROAs, the Suisun Marsh ROA would be the most subject to ground shaking because of its proximity
34 to active faults. The Suisun Marsh ROA is subject to a PGA of approximately 0.31 to 0.35 g for 200-
35 year return interval, while the PGA for the other ROAs ranges from approximately 0.11 to 0.26 g.
36 Damage to these features could result in their failure, causing flooding of otherwise protected areas.
37 However, as described in Section 9.3.1, *Methods for Analysis*, and in Appendix 3B, *Environmental*
38 *Commitments, AMMs, and CMs*, design codes, guidelines, and standards, including the California
39 Building Code and resource agency and professional engineering specifications, such as DWR's
40 *Division of Flood Management FloodSAFE Urban Levee Design Criteria* and USACE's *Engineering and*
41 *Design—Earthquake Design and Evaluation for Civil Works Projects* would be used for final design of
42 conservation features. Conformance with these design standards is an environmental commitment
43 by the BDCP proponents to ensure that strong seismic shaking risks are minimized as the

1 conservation measures are operated and there would be no increased likelihood of loss of property,
 2 personal injury or death in the ROAs. The impact would be less than significant. No mitigation is
 3 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**
 6 **Opportunity Areas**

7 *NEPA Effects:* Conservation measures would be the same under Alternative 6C as under 1A. See
 8 description and findings under Alternative 1A. There would be no adverse effect.

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

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

24 *NEPA Effects:* Conservation measures would be the same under Alternative 6C as under 1A. See
 25 description and findings under Alternative 1A. There would be no adverse effect.

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

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

34 *NEPA Effects:* Conservation measures under Alternative 6C would be similar to that as under
 35 Alternative 1A. See description and findings under Alternative 1A. There would be no adverse effect.

36 *CEQA Conclusion:* Based on recorded tsunami wave heights at the Golden Gate, the height of a
 37 tsunami wave reaching the ROAs would be small because of the distance from the ocean and
 38 attenuating effect of the San Francisco Bay. The impact would be less than significant. No mitigation
 39 is required. Similarly, the potential for a significant seiche to occur in the Plan Area that would cause
 40 loss of property, personal injury, or death at the ROAs is considered low because conditions for a

1 seiche to occur near conveyance facilities are not favorable. The impact would be less than
2 significant. No mitigation is required.

3 **9.3.3.14 Alternative 7—Dual Conveyance with Pipeline/Tunnel, Intakes 2,** 4 **3, and 5, and Enhanced Aquatic Conservation (9,000 cfs;** 5 **Operational Scenario E)**

6 **Impact GEO-1: Loss of Property, Personal Injury, or Death from Structural Failure Resulting** 7 **from Strong Seismic Shaking of Water Conveyance Features during Construction**

8 **NEPA Effects:** Alternative 7 would include the same physical/structural components as Alternative
9 1A, but would entail two less intakes and two less pumping plants. These differences would present
10 a slightly lower hazard of structural failure from seismic shaking but would not substantially change
11 the hazard of loss of property, personal injury, or death during construction compared to Alternative
12 1A. The effects of Alternative 7 would, therefore, be the same as 1A. See the description and findings
13 under Alternative 1A. There would be no adverse effect.

14 **CEQA Conclusion:** Seismically induced ground shaking could cause collapse or other failure of
15 project facilities while under construction. However, DWR would conform to Cal-OSHA and other
16 state code requirements, such as shoring, bracing, lighting, excavation depth restrictions, required
17 slope angles, and other measures, to protect worker safety. Conformance with these standards and
18 codes is an environmental commitment of the project (see Appendix 3B, *Environmental*
19 *Commitments, AMMs, and CMs*). Conformance with these health and safety requirements and the
20 application of accepted, proven construction engineering practices would reduce this risk and there
21 would be no increased likelihood of loss of property, personal injury or death due to construction of
22 Alternative 7. This impact would be less than significant. No mitigation is required.

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

25 **NEPA Effects:** Alternative 7 would include the same physical/structural components as Alternative
26 1A, but would entail two less intakes and two less pumping plants. These differences would present
27 a slightly lower hazard of settlement or collapse caused by dewatering but would not substantially
28 change the hazard of loss of property, personal injury, or death during construction compared to
29 Alternative 1A. The effects of Alternative 7 would, therefore, be the same as 1A. See the description
30 and findings under Alternative 1A. There would be no adverse effect.

31 **CEQA Conclusion:** Settlement or failure of excavations during construction could result in loss of
32 property or personal injury. However, DWR would conform to Cal-OSHA and other state code
33 requirements, such as using seepage cutoff walls, shoring, and other measures, to protect worker
34 safety. DWR would also ensure that the design specifications are properly executed during
35 construction. DWR has made an environmental commitment to use the appropriate code and
36 standard requirements to minimize potential risks (Appendix 3B, *Environmental Commitments,*
37 *AMMs, and CMs*) and there would be no increased likelihood of loss of property, personal injury or
38 death due to construction of Alternative 7. The impact would be less than significant. No mitigation
39 is required.

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

3 **NEPA Effects:** Alternative 7 would include the same physical/structural components as Alternative
4 1A, but would entail two less intakes and two less pumping plants. These differences would present
5 a slightly lower hazard of ground settlement hazard on the tunnel but 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 7 would, therefore, be the same as 1A. See the description
8 and findings under Alternative 1A. There would be no adverse effect.

9 **CEQA Conclusion:** Settlement/failure of cutslopes of borrow sites and failure of soil/RTM fill slopes
10 could result in loss of property or personal injury during construction. However, DWR would
11 conform to Cal-OSHA, USACE, and other design requirements to protect worker safety. DWR would
12 also ensure that the design specifications are properly executed during construction. DWR has made
13 an environmental commitment to use the appropriate code and standard requirements to minimize
14 potential risks (Appendix 3B, *Environmental Commitments, AMMs, and CMs*) and there would be no
15 increased likelihood of loss of property, personal injury or death due to construction of Alternative
16 7. Hazards to workers and project structures would be controlled at safe levels and the impact
17 would be less than significant. No mitigation is required.

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

20 **NEPA Effects:** Alternative 7 would include the same physical/structural components as Alternative
21 1A, but would entail two less intakes and two less pumping plants. These differences would present
22 a slightly lower hazard of slope failure at borrow and spoils storage sites but 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 7 would, therefore, be the same as 1A. See the description
25 and findings under Alternative 1A. 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
28 would conform to Cal-OSHA and other state code requirements and conform to applicable
29 geotechnical design guidelines and standards, such as USACE design measures, the hazard would be
30 controlled to a safe level and there would be no increased likelihood of loss of property, personal
31 injury or death due to construction of Alternative 7. The impact would be less than significant. No
32 mitigation is required.

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

36 **NEPA Effects:** Alternative 7 would include the same physical/structural components as Alternative
37 1A, but would entail two less intakes and two less pumping plants. These differences would present
38 a 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 and traffic effects could initiate
 2 liquefaction, which could cause failure of structures during construction, which could result in injury
 3 of workers at the construction sites. The impact could be significant. However, because DWR would
 4 conform to Cal-OSHA and other state code requirements and conform to applicable design
 5 guidelines and standards, such as USACE design measures, in addition to implementation of
 6 Mitigation Measures TRANS-2a and TRANS-2b, as well as the maintenance and reconstruction of
 7 levees through Mitigation Measure TRANS-2c, the hazard would be controlled to a level that would
 8 protect worker safety (see Appendix 3B, *Environmental Commitments, AMMs, and CMs*) and there
 9 would be no increased likelihood of loss of property, personal injury or death due to construction of
 10 Alternative 7. The impact would be less than significant.

11 **Mitigation Measure TRANS-2a: Prohibit Construction Activity on Physically Deficient**
 12 **Roadway Segments**

13 Please refer to Mitigation Measure TRANS-2a in Alternative 1A, Impact TRANS-2, in Chapter 19,
 14 *Transportation*.

15 **Mitigation Measure TRANS-2b: Limit Construction Activity on Physically Deficient**
 16 **Roadway Segments**

17 Please refer to Mitigation Measure TRANS-2b in Alternative 1A, Impact TRANS-2, in Chapter 19,
 18 *Transportation*.

19 **Mitigation Measure TRANS-2c: Improve Physical Condition of Affected Roadway Segments**
 20 **as Stipulated in Mitigation Agreements or Encroachment Permits**

21 Please refer to Mitigation Measure TRANS-2c in Alternative 1A, Impact TRANS-2, in Chapter 19,
 22 *Transportation*.

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

25 **NEPA Effects:** Alternative 7 would include the same physical/structural components as Alternative
 26 1A, but would entail two less intakes and two less pumping plants. These differences would not
 27 reduce the hazard structural damage from rupture of an earthquake fault and would not
 28 substantially change the hazard of loss of property, personal injury, or death during construction
 29 compared to Alternative 1A. The effects of Alternative 7 would, therefore, be the same as 1A. See the
 30 description and findings under Alternative 1A. There would be no adverse effect.

31 **CEQA Conclusion:** There are no active faults capable of surface rupture that extend into the
 32 pipeline/tunnel alignment. Although the Thornton Arch and West Tracy blind thrusts occur beneath
 33 the pipeline/tunnel alignment, based on available information, they do not present a hazard of
 34 surface rupture and there would be no increased likelihood of loss of property, personal injury or
 35 death due to operation of Alternative 7. There would be no impact. No mitigation is required.

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

38 **NEPA Effects:** Alternative 7 would include the same physical/structural components as Alternative
 39 1A, but would entail two less intakes and two less pumping plants. These differences would present

1 a slightly lower hazard of seismic shaking but would not substantially change the hazard of loss of
 2 property, personal injury, or death during construction compared to Alternative 1A. The effects of
 3 Alternative 7 would, therefore, be the same as 1A. See the description and findings under Alternative
 4 1A. There would be no adverse effect.

5 **CEQA Conclusion:** Seismically induced strong ground shaking could damage pipelines, tunnels,
 6 intake facilities, pumping plants, and other facilities. The damage could disrupt the water supply
 7 through the conveyance system. In an extreme event, an uncontrolled release of water from the
 8 damaged conveyance system could cause flooding and inundation of structures. (Please refer to
 9 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, AMMs, and CMs*, such design codes, guidelines, and
 13 standards include the California Building Code and resource agency and professional engineering
 14 specifications, such as the Division of Safety of Dams' *Guidelines for Use of the Consequence-Hazard*
 15 *Matrix and Selection of Ground Motion Parameters*, DWR's Division of Flood Management *FloodSAFE*
 16 *Urban Levee Design Criteria*, and USACE's *Engineering and Design—Earthquake Design and*
 17 *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
 19 water conveyance features are operated. The hazard would be controlled to a safe level and there
 20 would be no increased likelihood of loss of property, personal injury or death due to operation of
 21 Alternative 7. 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 7 would include the same physical/structural components as Alternative
 26 1A, but would entail two less intakes and two less pumping plants. These differences would present
 27 a slightly lower hazard of structural failure from ground failure but would not substantially change
 28 the hazard of loss of property, personal injury, or death during construction compared to Alternative
 29 1A. The effects of Alternative 7 would, therefore, be the same as 1A. See the description and findings
 30 under Alternative 1A. There would be no adverse effect.

31 **CEQA Conclusion:** Seismically induced ground shaking could cause liquefaction. Liquefaction could
 32 damage pipelines, tunnels, intake facilities, pumping plants, and other facilities, and thereby disrupt
 33 the water supply through the conveyance system. In an extreme event, flooding and inundation of
 34 structures could result from an uncontrolled release of water from the damaged conveyance system.
 35 (Please refer to Chapter 6, *Surface Water*, for a detailed discussion of potential flood impacts.)
 36 However, through the final design process, measures to address the liquefaction hazard would be
 37 required to conform to applicable design codes, guidelines, and standards. As described in Section
 38 9.3.1, *Methods for Analysis*, and in Appendix 3B, *Environmental Commitments, AMMs, and CMs*, such
 39 design codes, guidelines, and standards include USACE's *Engineering and Design—Stability Analysis*
 40 *of Concrete Structures and Soil Liquefaction during Earthquakes*, by the Earthquake Engineering
 41 Research Institute. Conformance with these design standards is an environmental commitment by
 42 DWR to ensure that liquefaction risks are minimized as the water conveyance features are operated.
 43 The hazard would be controlled to a safe level and there would be no increased likelihood of loss of
 44 property, personal injury or death due to operation of Alternative 7. The impact would be less than
 45 significant. No mitigation is 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 7 would include the same physical/structural components as Alternative
 4 1A, but would entail two less intakes and two less pumping plants. These differences would present
 5 a slightly lower hazard from landslides and other slope instability but 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 7 would, therefore, be the same as 1A. See the description
 8 and findings under Alternative 1A. There 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
 11 constructed on these slopes could be damaged or fail entirely as a result of slope instability.
 12 However, through the final design process, measures to address this hazard would be required to
 13 conform to applicable design codes, guidelines, and standards. As described in Section 9.3.1,
 14 *Methods for Analysis*, and in Appendix 3B, *Environmental Commitments, AMMs, and CMs*, such design
 15 codes, guidelines, and standards include the California Building Code and resource agency and
 16 professional engineering specifications, such as 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 cut and fill slopes and embankments would be stable
 19 as the water conveyance features are operated and there would be no increased likelihood of loss of
 20 property, personal injury or death due to operation of Alternative 7. The impact would be less than
 21 significant. No mitigation is required.

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

24 **NEPA Effects:** Alternative 7 would include the same physical/structural components as Alternative
 25 1A, but would entail two less intakes and two less pumping plants. These differences would present
 26 a slightly lower hazard from a seiche or tsunami but would not substantially change the hazard of
 27 loss of property, personal injury, or death during construction compared to Alternative 1A. The
 28 effects of Alternative 7 would, therefore, be the same as 1A. See the description and findings under
 29 Alternative 1A. There would be no adverse effect.

30 **CEQA Conclusion:** Based on recorded tsunami wave heights at the Golden Gate (Contra Costa
 31 Transportation Agency 2009) and in the interior of the San Francisco Bay and on tsunami
 32 inundation maps prepared by the California Department of Conservation (2009), the height of a
 33 tsunami wave reaching the Suisun Marsh and the Delta would be small because of the distance from
 34 the ocean and attenuating effect of the San Francisco Bay. Similarly, the potential for a significant
 35 seiche to occur in most parts of the Plan Area is considered low because the seismic hazard and the
 36 geometry of the water bodies (i.e., wide and shallow) near conveyance facilities are not favorable for
 37 a seiche to occur. However, assuming the West Tracy fault is potentially active, a potential exists for
 38 a seiche to occur in the Clifton Court Forebay and the Byron Tract Forebay (Fugro Consultants
 39 2011). The impact would not be significant because the Byron Tract Forebay embankment would be
 40 designed and constructed according to applicable design codes, guidelines, and standards to contain
 41 and withstand the anticipated maximum seiche wave height. There would be no increased likelihood
 42 of loss of property, personal injury or death due to operation of Alternative 7 from seiche or
 43 tsunami. The impact would 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 7 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
 5 seepage. There would be no effect.

6 **CEQA Conclusion:** Alternative 7 would not involve construction of unlined canals; therefore, there
 7 would be no increase in groundwater surface elevations and consequently no impact caused by
 8 canal seepage. There would be no impact. 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 under Alternative 7 would be the same that as under
 12 Alternative 1A, except up to an additional 20 linear miles of channel margin habitat would be
 13 created and up to an additional 10,000 acres of seasonally inundated floodplain habitat would be
 14 restored. The potential effects of a structural failure from rupture of an earthquake fault would
 15 pertain only to the Suisun Marsh ROA, which is the only ROA in which AP faults are found. However,
 16 the same engineering design and construction requirements that apply to all the ROAs would ensure
 17 that levees and other structures would withstand the effect of a fault rupture. The effect of
 18 Alternative 7 would, therefore, be the similar to that of Alternative 1A. See description and findings
 19 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
 21 ROA and damage ROA facilities, such as levees and berms. Damage to these features could result in
 22 their failure, causing flooding of otherwise protected areas.

23 However, through the final design process for conservation measures in the ROAs, measures to
 24 address the fault rupture hazard would be required to conform to applicable design codes,
 25 guidelines, and standards. As described in Section 9.3.1, *Methods for Analysis*, and in Appendix 3B,
 26 *Environmental Commitments, AMMs, and CMs*, such design codes, guidelines, and standards include
 27 the Division of Safety of Dams *Guidelines for Use of the Consequence-Hazard Matrix and Selection of*
 28 *Ground Motion Parameters*, DWR's Division of Flood Management *FloodSAFE Urban Levee Design*
 29 *Criteria*, and USACE's *Engineering and Design—Earthquake Design and Evaluation for Civil Works*
 30 *Projects*. Conformance with these design standards is an environmental commitment by the BDCP
 31 proponents to ensure that fault rupture risks are minimized as the conservation measures are
 32 implemented. The hazard would be controlled to a safe level and there would be no increased
 33 likelihood of loss of property, personal injury or death in the ROAs. The impact would be less than
 34 significant. No mitigation is required.

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

37 **NEPA Effects:** Conservation measures under Alternative 7 would be the same that as under
 38 Alternative 1A, except that up to an additional 20 linear miles of channel margin habitat would be
 39 created and up to an additional 10,000 acres of seasonally inundated floodplain habitat would be
 40 restored. The potential effects of a structural failure from seismic shaking would also be of a greater
 41 magnitude than that of Alternative 1A. However, the same engineering design and construction
 42 requirements that apply to all the ROAs would ensure that levees and other structures would

1 withstand the effects of seismic shaking. The effect of Alternative 7 would, therefore, be the similar
 2 to that of Alternative 1A but of a greater magnitude. See description and findings under Alternative
 3 1A. There would be no adverse effect.

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

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

22 **NEPA Effects:** Conservation measures under Alternative 7 would be the same that as under
 23 Alternative 1A, except that up to an additional 20 linear miles of channel margin habitat would be
 24 created and up to an additional 10,000 acres of seasonally inundated floodplain habitat would be
 25 restored. The potential effects of a structural failure from ground failure would also be of a greater
 26 magnitude than that of Alternative 1A. However, the same engineering design and construction
 27 requirements that apply to all the ROAs would ensure that levees and other structures would
 28 withstand the effects of liquefaction. The effect of Alternative 7 would, therefore, be the similar to
 29 that of Alternative 1A but of a greater magnitude. See description and findings under Alternative 1A.
 30 There would be no adverse effect.

31 **CEQA Conclusion:** Earthquake-induced ground shaking could cause liquefaction, resulting in
 32 damage to or failure of levees, berms, and other features constructed at the restoration areas.
 33 Failure of levees and 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, AMMs, and CMs*, such
 37 design codes, guidelines, and standards include USACE's *Engineering and Design—Stability Analysis*
 38 *of Concrete Structures and Soil Liquefaction during Earthquakes*, by the Earthquake Engineering
 39 Research Institute. Conformance with these design standards is an environmental commitment by
 40 the BDCP proponents to ensure that liquefaction risks are minimized as the water conservation
 41 features are implemented. The hazard would be controlled to a safe level and there would be no
 42 increased likelihood of loss of property, personal injury or death in the ROAs. The impact would be
 43 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 Conservation measures under Alternative 7 would be the same that as under Alternative 1A, except
4 that up to an additional 20 linear miles of channel margin habitat would be created and up to an
5 additional 10,000 acres of seasonally inundated floodplain habitat would be restored. The potential
6 effects of a landslide or other slope instability would also be of a greater magnitude than that of
7 Alternative 1A. However, the same engineering design and construction requirements that apply to
8 all the ROAs would ensure that levees and other structures would withstand the effects of landslides
9 and other slope instability. The effect of Alternative 7 would, therefore, be the similar to that of
10 Alternative 1A but of a greater magnitude. See description and findings under Alternative 1A.

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

14 As outlined in Chapter 3, *Description of Alternatives*, erosion protection measures and protection
15 against related failure of adjacent levees would be taken where levee breaches were developed.
16 Erosion protection could include geotextile fabrics, rock revetments, or other material selected
17 during future evaluations for each location. Aggregate rock could be placed on the remaining levees
18 to provide an access road to the breach location. Erosion protection measures would also be taken
19 where levee lowering is done for the purposes of allowing seasonal or periodic inundation of lands
20 during high flows or high tides to improve habitat or to reduce velocities and elevations of
21 floodwaters. To reduce erosion potential on the new levee crest, a paved or gravel access road could
22 be constructed with short (approximately 1 foot) retaining walls on each edge of the crest to reduce
23 undercutting of the roadway by high tides. Levee modifications could also include excavation of
24 watersides of the slopes to allow placement of slope protection, such as riprap or geotextile fabric,
25 and to modify slopes to provide levee stability. Erosion and scour protection could be placed on the
26 landside of the levee and continued for several feet onto the land area away from the levee toe.
27 Neighboring levees could require modification to accommodate increased flows or to reduce effects
28 of changes in water elevation or velocities along channels following inundation of tidal marshes.
29 Hydraulic modeling would be used during subsequent analyses to determine the need for such
30 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
33 described for the new levees at intake locations. Any new levees would be required to be designed
34 and implemented to conform to applicable flood management standards and permitting processes.
35 This would be coordinated with the appropriate flood management agencies, which may include
36 USACE, 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
39 the various anticipated loading conditions. As discussed in Chapter 3, foundation soil beneath
40 embankments and levees could be improved to increase its strength and to reduce settlement and
41 deformation. Foundation soil improvement could involve excavation and replacement with
42 engineered fill; preloading; ground modifications using jet-grouting, compaction grouting, chemical
43 grouting, shallow soil mixing, deep soil mixing, vibro-compaction, or vibro-replacement; or other
44 methods. Engineered fill could also be used to construct new embankments and levees.

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

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

8 Conformance to the above and other applicable design specifications and standards would ensure
 9 that the hazard of slope instability would not jeopardize the integrity of levee and other features
 10 thereby creating an increased likelihood of loss of property, personal injury or death of individuals
 11 in the ROAs. Therefore, there would be no adverse effect.

12 **CEQA Conclusion:** Unstable new and existing levee and embankment slopes could fail as a result of
 13 seismic shaking and as a result of high soil-water content during heavy rainfall and cause flooding of
 14 otherwise protected areas. However, because BDCP proponents would conform to applicable design
 15 guidelines and standards, such as USACE design measures, 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 in the
 17 ROAs. The impact would be less than significant. Therefore, no mitigation is required.

18 **Impact GEO-16: Loss of Property, Personal Injury, or Death from Seiche or Tsunami at** 19 **Restoration Opportunity Areas as a Result of Implementing the Conservation Actions**

20 **NEPA Effects:** Conservation measures under Alternative 7 would be similar to that as under
 21 Alternative 1A. See description and findings under Alternative 1A. There would be no adverse effect.

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

28 **9.3.3.15 Alternative 8—Dual Conveyance with Pipeline/Tunnel, Intakes 2,** 29 **3, and 5, and Increased Delta Outflow (9,000 cfs; Operational** 30 **Scenario F)**

31 **Impact GEO-1: Loss of Property, Personal Injury, or Death from Structural Failure Resulting** 32 **from Strong Seismic Shaking of Water Conveyance Features during Construction**

33 **NEPA Effects:** Alternative 8 would include the same physical/structural components as Alternative
 34 1A, but would entail two less intakes and two less pumping plants. These differences would present
 35 a slightly lower hazard of structural failure from seismic shaking but would not substantially change
 36 the hazard of loss of property, personal injury, or death during construction compared to Alternative
 37 1A. The effects of Alternative 8 would, therefore, be the same as 1A. See the description and findings
 38 under Alternative 1A. There would be no adverse effect.

39 **CEQA Conclusion:** Seismically induced ground shaking could cause collapse or other failure of
 40 project facilities while under construction. However, DWR would conform to Cal-OSHA and other

1 state code requirements, such as shoring, bracing, lighting, excavation depth restrictions, required
 2 slope angles, and other measures, to protect worker safety. Conformance with these standards and
 3 codes is an environmental commitment of the project (see Appendix 3B, *Environmental*
 4 *Commitments, AMMs, and CMs*). Conformance with these health and safety requirements and the
 5 application of accepted, proven construction engineering practices would reduce this risk and there
 6 would be no increased likelihood of loss of property, personal injury or death due to the
 7 construction of Alternative 8. This impact would be less than significant. No mitigation is required.

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

10 **NEPA Effects:** Alternative 8 would include the same physical/structural components as Alternative
 11 1A, but would entail two less intakes and two less pumping plants. These differences would present
 12 a slightly lower hazard of settlement or collapse caused by dewatering but would not substantially
 13 change the hazard of loss of property, personal injury, or death during construction compared to
 14 Alternative 1A. The effects of Alternative 8 would, therefore, be the same as 1A. See the description
 15 and findings under Alternative 1A. There would be no adverse effect.

16 **CEQA Conclusion:** Settlement or failure of excavations during construction could result in loss of
 17 property or personal injury. However, DWR would conform to Cal-OSHA and other state code
 18 requirements, such as using seepage cutoff walls, shoring, and other measures, to protect worker
 19 safety. DWR would also ensure that the design specifications are properly executed during
 20 construction. DWR has made an environmental commitment to use the appropriate code and
 21 standard requirements to minimize potential risks (Appendix 3B, *Environmental Commitments,*
 22 *AMMs, and CMs*) and there would be no increased likelihood of loss of property, personal injury or
 23 death due to the construction of Alternative 8. The impact would be less than significant. No
 24 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 **NEPA Effects:** Alternative 8 would include the same physical/structural components as Alternative
 28 1A, but would entail two less intakes and two less pumping plants. These differences would present
 29 a slightly lower hazard of ground settlement on the tunnel but would not substantially change the
 30 hazard of loss of property, personal injury, or death during construction compared to Alternative 1A.
 31 The effects of Alternative 8 would, therefore, be the same as 1A. See the description and findings
 32 under Alternative 1A. There would be no adverse effect.

33 **CEQA Conclusion:** Ground settlement above the tunneling operation could result in loss of property
 34 or personal injury during construction. However, DWR would conform to Cal-OSHA, USACE, and
 35 other design requirements to protect worker safety. DWR would also ensure that the design
 36 specifications are properly executed during construction. DWR has made an environmental
 37 commitment to use the appropriate code and standard requirements to minimize potential risks
 38 (Appendix 3B, *Environmental Commitments, AMMs, and CMs*) and there would be no increased
 39 likelihood of loss of property, personal injury or death due to the construction of Alternative 8.
 40 Hazards to workers and project structures would be controlled at safe levels and the impact would
 41 be less than significant. No mitigation is required.

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

3 **NEPA Effects:** Alternative 8 would include the same physical/structural components as Alternative
 4 1A, but would entail two less intakes and two less pumping plants. These differences would present
 5 a slightly lower hazard of slope failure at borrow and spoils storage sites but 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 8 would, therefore, be the same as 1A. See the description
 8 and findings under Alternative 1A. There would be no adverse effect.

9 **CEQA Conclusion:** Settlement/failure of cutslopes of borrow sites and failure of soil/RTM fill slopes
 10 could result in loss of property or personal injury during construction. However, because DWR
 11 would conform to Cal-OSHA and other state code requirements and conform to applicable
 12 geotechnical design guidelines and standards, such as USACE design measures, the hazard would be
 13 controlled to a safe level and there would be no increased likelihood of loss of property, personal
 14 injury or death due to the construction of Alternative 8. The impact would be less than significant.
 15 No mitigation is required.

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

19 **NEPA Effects:** Alternative 8 would include the same physical/structural components as Alternative
 20 1A, but would entail two less intakes and two less pumping plants. These differences would present
 21 a slightly lower hazard of structural failure from construction-related ground motions but would not
 22 substantially change the hazard of loss of property, personal injury, or death during construction
 23 compared to Alternative 1A. The effects of Alternative 8 would, therefore, be the same as 1A. See the
 24 description and findings under Alternative 1A. There would be no adverse effect.

25 **CEQA Conclusion:** Construction-related ground motions and traffic effects could initiate
 26 liquefaction, which could cause failure of structures during construction, which could result in injury
 27 of workers at the construction sites. The impact could be significant. However, because DWR would
 28 conform to Cal-OSHA and other state code requirements and conform to applicable design
 29 guidelines and standards, such as USACE design measures, in addition to implementation of
 30 Mitigation Measures TRANS-2a and TRANS-2b, as well as the maintenance and reconstruction of
 31 levees through Mitigation Measure TRANS-2c, the hazard would be controlled to a level that would
 32 protect worker safety (see Appendix 3B, *Environmental Commitments, AMMs, and CMs*) and there
 33 would be no increased likelihood of loss of property, personal injury or death due to the
 34 construction of Alternative 8. The impact would be less than significant.

35 **Mitigation Measure TRANS-2a: Prohibit Construction Activity on Physically Deficient**
 36 **Roadway Segments**

37 Please refer to Mitigation Measure TRANS-2a in Alternative 1A, Impact TRANS-2, in Chapter 19,
 38 *Transportation*.

1 **Mitigation Measure TRANS-2b: Limit Construction Activity on Physically Deficient**
 2 **Roadway Segments**

3 Please refer to Mitigation Measure TRANS-2b in Alternative 1A, Impact TRANS-2, in Chapter 19,
 4 *Transportation*.

5 **Mitigation Measure TRANS-2c: Improve Physical Condition of Affected Roadway Segments**
 6 **as Stipulated in Mitigation Agreements or Encroachment Permits**

7 Please refer to Mitigation Measure TRANS-2c in Alternative 1A, Impact TRANS-2, in Chapter 19,
 8 *Transportation*.

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 8 would include the same physical/structural components as Alternative
 12 1A, but would entail two less intakes and two less pumping plants. These differences would not
 13 create a change in the hazard of structural damage from rupture of an earthquake fault and would
 14 not substantially change the hazard of loss of property, personal injury, or death during construction
 15 compared to Alternative 1A. The effects of Alternative 8 would, therefore, be the same as 1A. See the
 16 description and findings under 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
 20 surface rupture and there would be no increased likelihood of loss of property, personal injury or
 21 death due to the operation of Alternative 8. There would be no impact. Therefore, no mitigation is
 22 required.

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

25 **NEPA Effects:** Alternative 8 would include the same physical/structural components as Alternative
 26 1A, but would entail two less intakes and two less pumping plants. These differences would present
 27 a slightly lower hazard of seismic shaking but would not substantially change the hazard of loss of
 28 property, personal injury, or death during construction compared to Alternative 1A. The effects of
 29 Alternative 8 would, therefore, be the same as 1A. See the description and findings under Alternative
 30 1A. There would be no adverse effect.

31 **CEQA Conclusion:** Seismically induced strong ground shaking could damage pipelines, tunnels,
 32 intake facilities, pumping plants, and other facilities. The damage could disrupt the water supply
 33 through the conveyance system. In an extreme event, an uncontrolled release of water from the
 34 damaged conveyance system could cause flooding and inundation of structures. (Please refer to
 35 Chapter 6, *Surface Water*, for a detailed discussion of potential flood impacts.) However, through the
 36 final design process, measures to address this hazard would be required to conform to applicable
 37 design codes, guidelines, and standards. As described in Section 9.3.1, *Methods for Analysis*, and in
 38 Appendix 3B, *Environmental Commitments, AMMs, and CMs*, such design codes, guidelines, and
 39 standards include the California Building Code and resource agency and professional engineering
 40 specifications, such as the Division of Safety of Dams' *Guidelines for Use of the Consequence-Hazard*
 41 *Matrix and Selection of Ground Motion Parameters*, DWR's Division of Flood Management *FloodSAFE*

1 *Urban Levee Design Criteria*, and USACE's *Engineering and Design—Earthquake Design and*
 2 *Evaluation for Civil Works Projects*. Conformance with these codes and standards is an
 3 environmental commitment by DWR to ensure that ground shaking risks are minimized as the
 4 water conveyance features are operated. 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 operation of
 6 Alternative 8. The impact would be less than significant. No mitigation is required.

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

10 **NEPA Effects:** Alternative 8 would include the same physical/structural components as Alternative
 11 1A, but would entail two less intakes and two less pumping plants. These differences would present
 12 a slightly lower hazard of structural failure from ground failure but would not substantially change
 13 the hazard of loss of property, personal injury, or death during construction compared to Alternative
 14 1A. The effects of Alternative 8 would, therefore, be the same as 1A. See the description and findings
 15 under Alternative 1A. There would be no adverse effect.

16 **CEQA Conclusion:** Seismically induced ground shaking could cause liquefaction. Liquefaction could
 17 damage pipelines, tunnels, intake facilities, pumping plants, and other facilities, and thereby disrupt
 18 the water supply through the conveyance system.

19 In an extreme event, an uncontrolled release of water from the damaged conveyance system could
 20 cause flooding and inundation of structures. (Please refer to Chapter 6, *Surface Water*, for a detailed
 21 discussion of potential flood impacts.) However, through the final design process, measures to
 22 address the liquefaction hazard would be required to conform to applicable design codes,
 23 guidelines, and standards. As described in Section 9.3.1, *Methods for Analysis*, and in Appendix 3B,
 24 *Environmental Commitments, AMMs, and CMs*, such design codes, guidelines, and standards include
 25 USACE's *Engineering and Design—Stability Analysis of Concrete Structures and Soil Liquefaction*
 26 *during Earthquakes*, by the Earthquake Engineering Research Institute. Conformance with these
 27 design standards is an environmental commitment by DWR to ensure that liquefaction risks are
 28 minimized as the water conveyance features are operated. The hazard would be controlled to a safe
 29 level and there would be no increased likelihood of loss of property, personal injury or death due to
 30 the operation of Alternative 8. The impact would be less than significant. No mitigation is required.

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

33 **NEPA Effects:** Alternative 8 would include the same physical/structural components as Alternative
 34 1A, but would entail two less intakes and two less pumping plants. These differences would present
 35 a slightly lower hazard from landslides and other slope instability 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
 38 and findings under Alternative 1A. There would be no adverse effect.

39 **CEQA Conclusion:** Unstable levee slopes and natural stream banks may fail, either from high pore-
 40 water pressure caused by high rainfall and weak soil, or from seismic shaking. Structures
 41 constructed on these slopes could be damaged or fail entirely as a result of slope instability.
 42 However, through the final design process, measures to address this hazard would be required to
 43 conform to applicable design codes, guidelines, and standards. As described in Section 9.3.1,

1 *Methods for Analysis*, and in Appendix 3B, *Environmental Commitments, AMMs, and CMs*, such design
 2 codes, guidelines, and standards include the California Building Code and resource agency and
 3 professional engineering specifications, such as USACE's *Engineering and Design—Earthquake*
 4 *Design and Evaluation for Civil Works Projects*. Conformance with these codes and standards is an
 5 environmental commitment by DWR to ensure cut and fill slopes and embankments would be stable
 6 as the water conveyance features are operated and there would be no increased likelihood of loss of
 7 property, personal injury or death due to the operation of Alternative 8. The impact would be less
 8 than significant. No mitigation is required.

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

11 **NEPA Effects:** Alternative 8 would include the same physical/structural components as Alternative
 12 1A, but would entail two less intakes and two less pumping plants. These differences would present
 13 a slightly lower hazard from a seiche or tsunami but would not substantially change the hazard of
 14 loss of property, personal injury, or death during construction compared to Alternative 1A. The
 15 effects of Alternative 8 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:** Based on recorded tsunami wave heights at the Golden Gate (Contra Costa
 18 Transportation Agency 2009) and in the interior of the San Francisco Bay and on tsunami
 19 inundation maps prepared by the California Department of Conservation (2009), the height of a
 20 tsunami wave reaching the Suisun Marsh and the Delta would be small because of the distance from
 21 the ocean and attenuating effect of the San Francisco Bay. Similarly, the potential for a significant
 22 seiche to occur in most parts of the Plan Area is considered low because the seismic hazard and the
 23 geometry of the water bodies (i.e., wide and shallow) near conveyance facilities are not favorable for
 24 a seiche to occur. However, assuming the West Tracy fault is potentially active, a potential exists for
 25 a seiche to occur in the Clifton Court Forebay and the Byron Tract Forebay (Fugro Consultants
 26 2011). The impact would not be significant because the Byron Tract Forebay embankment would be
 27 designed and constructed according to applicable design codes, guidelines, and standards to contain
 28 and withstand the anticipated maximum seiche wave height. There would be no increased likelihood
 29 of loss of property, personal injury or death due to the operation of Alternative 8 from seiche or
 30 tsunami. The impact would be less than significant. No mitigation is required.

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

33 **NEPA Effects:** Alternative 8 would not involve construction of unlined canals; therefore, there would
 34 be no increase in groundwater surface elevations and consequently no effect caused by canal
 35 seepage. There would be no effect.

36 **CEQA Conclusion:** Alternative 8 would not involve construction of unlined canals; therefore, there
 37 would be no increase in groundwater surface elevations and consequently no impact caused by
 38 canal seepage. There would be no impact. No mitigation is required.

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

41 **NEPA Effects:** Conservation measures under Alternative 8 would be the same as those under
 42 Alternative 1A. See description and findings under Alternative 1A. There would be no adverse effect.

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

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

17 **NEPA Effects:** Conservation measures under Alternative 8 would be the same as those under
 18 Alternative 1A. See description and findings under Alternative 1A. There would be no adverse effect.

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

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

37 **NEPA Effects:** Conservation measures under Alternative 8 would be the same as those under
 38 Alternative 1A. See description and findings under Alternative 1A. There would be no adverse effect.

39 **CEQA Conclusion:** Earthquake-induced ground shaking could cause liquefaction, resulting in
 40 damage to or failure of levees, berms, and other features constructed at the restoration areas.
 41 Failure of levees and other structures could result in flooding of otherwise protected areas.

42 However, through the final design process, measures to address the liquefaction hazard would be
 43 required to conform to applicable design codes, guidelines, and standards. As described in Section

1 9.3.1, *Methods for Analysis*, and in Appendix 3B, *Environmental Commitments, AMMs, and CMs*, such
 2 design codes, guidelines, and standards include USACE's *Engineering and Design—Stability Analysis*
 3 *of Concrete Structures and Soil Liquefaction during Earthquakes*, by the Earthquake Engineering
 4 Research Institute. Conformance with these design standards is an environmental commitment by
 5 the BDCP proponents to ensure that liquefaction risks are minimized as the water conservation
 6 features are implemented and there would be no increased likelihood of loss of property, personal
 7 injury or death in the ROAs. The impact would be less than significant. No mitigation is required.

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

10 **NEPA Effects:** Conservation measures under Alternative 8 would be the same as those under
 11 Alternative 1A. See description and findings under Alternative 1A. There would be no adverse effect.

12 **CEQA Conclusion:** Unstable new and existing levee and embankment slopes could fail as a result of
 13 seismic shaking and as a result of high soil-water content during heavy rainfall and cause flooding of
 14 otherwise protected areas. However, because the BDCP proponents would conform to applicable
 15 design guidelines and standards, such as USACE design measures, 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
 17 in the ROAs. The impact would be less than significant. No mitigation is required.

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

20 **NEPA Effects:** Conservation measures under Alternative 8 would be similar to that as under
 21 Alternative 1A. See description and findings under Alternative 1A. There would be no adverse effect.

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

28 **9.3.3.16 Alternative 9—Through Delta/Separate Corridors (15,000 cfs;**
 29 **Operational Scenario G)**

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

32 Construction of water conveyance facilities under Alternative 9 would involve two screened intakes
 33 the Delta Cross Channel and Georgiana Slough near Locke and Walnut Grove, culvert siphons, canals,
 34 pumping plants, borrow areas, enlargement of a channel, operable barriers, and other facilities. The
 35 locations of some of the Alternative 9 facilities would be different than those of any of the other
 36 alternatives. The operable barriers along Delta channels and the two pumping plants on Old River
 37 and Middle River would be in locations not discussed for other alternatives (see Figure 3-16 in
 38 Chapter 3, *Description of Alternatives*).

1 Table 9-28 lists the expected PGA and 1.0- S_a values in 2020 at selected facility locations. As with
 2 other alternatives, ground motions with a return period of 72 years and calculated for 2005 are used
 3 to represent the construction period (2020) motions.

4 **Table 9-28. Expected Earthquake Ground Motions at Locations of Selected Major Facilities during**
 5 **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.

6
 7 **NEPA Effects:** The seismic study employed time-dependent seismic source models for several major
 8 faults in the region. These models were characterized based on the elapsed times since the last
 9 major seismic events on the faults. Therefore, the exposure risks predicted by the seismic study
 10 would increase if no major events take place on these faults through 2020. The effect could be
 11 substantial because seismically induced ground shaking could cause loss of property or personal
 12 injury at the Alternative 9 construction sites (including intake locations, canals, and operable
 13 barriers) as a result of collapse of facilities. For example, facilities lying directly on or near active
 14 blind faults, such as the concrete batch plant and fuel station north of Locke, both intakes, the
 15 operable barriers on the Mokelumne River near Lost Slough and on Snodgrass Slough near the
 16 Mokelumne River, extension of Meadows Slough to the Sacramento River, and operable barrier on
 17 Meadows Slough, the boat lock and channel at the diversion structure at Georgiana Slough, the
 18 operable barrier at Threemile Slough, the operable barrier at Fisherman's Cut at False River for
 19 Alternative 9, which may result in an increased likelihood of loss of property or personal injury at
 20 these sites in the event of seismically induced ground shaking. Although these blind thrusts are not
 21 expected to rupture to the ground surface under the forebays during earthquake events, they may
 22 produce ground or near-ground shear zones, bulging, or both (California Department of Water
 23 Resources 2007a). For a map of all permanent facilities and temporary work areas associated with
 24 this conveyance alignment, see Mapbook Figure M3-5 in Chapter 3, *Description of Alternatives*.

25 The overall hazard of loss of property, personal injury, or death from structural failure caused by
 26 seismic shaking during construction would be less than that of Alternative 1A due to the fact that
 27 fewer facilities would be constructed. The same engineering design and construction requirements
 28 that apply to all the project facilities would reduce the risk of structural failure from seismic shaking.
 29 The effects of Alternative 9 would be of a similar nature but greatly reduced compared to those of
 30 Alternative 1A. See the description and findings under Alternative 1A. There would be no adverse
 31 effect.

1 **CEQA Conclusion:** Seismically induced ground shaking could cause collapse or other failure of
 2 project facilities while under construction. However, DWR would conform to Cal-OSHA and other
 3 state code requirements, such as shoring, bracing, lighting, excavation depth restrictions, required
 4 slope angles, and other measures, to protect worker safety. Conformance with these standards and
 5 codes is an environmental commitment of the project (see Appendix 3B, *Environmental*
 6 *Commitments, AMMs, and CMs*). Conformance with these health and safety requirements and the
 7 application of accepted, proven construction engineering practices would reduce this risk and there
 8 would be no increased likelihood of loss of property, personal injury or death due to the
 9 construction of Alternative 9. This impact would be less than significant. No mitigation is required.

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

12 **NEPA Effects:** Construction of water conveyance facilities under Alternative 9 would involve an
 13 array of intakes, pumping plants, pipelines, culvert siphons, canals, borrow areas, enlargement of a
 14 channel, and other facilities. The locations of some of the Alternative 9 facilities would be different
 15 than that of any of the other alternatives. The operable barriers along Delta channels and the two
 16 pumping plants on Old River and Middle River would be in locations not discussed for other
 17 alternatives (see Figure 3-16 in Chapter 3, *Description of Alternatives*). At the primary two such
 18 locations, operable barriers would be constructed. The same engineering design and construction
 19 requirements that apply to all the project facilities would prevent settlement or collapse during
 20 dewatering and would not substantially change the hazard of loss of property, personal injury, or
 21 death during construction compared to Alternative 1A. The effects of Alternative 9 would, therefore,
 22 be similar to that of Alternative 1A. See the description and findings under Alternative 1A. There
 23 would be no adverse effect.

24 **CEQA Conclusion:** Settlement or failure of excavations during construction could result in loss of
 25 property or personal injury. However, DWR would conform to Cal-OSHA and other state code
 26 requirements, such as using seepage cutoff walls, shoring, and other measures, to protect worker
 27 safety. DWR would also ensure that the design specifications are properly executed during
 28 construction. DWR has made an environmental commitment to use the appropriate code and
 29 standard requirements to minimize potential risks (Appendix 3B, *Environmental Commitments,*
 30 *AMMs, and CMs*) and there would be no increased likelihood of loss of property, personal injury or
 31 death due to the construction of Alternative 9. The impact would be less than significant. No
 32 mitigation is required.

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

35 Construction of water conveyance facilities under Alternative 9 would involve an array of intakes,
 36 pumping plants, pipelines, culvert siphons, canals, borrow areas, enlargement of a channel, fish
 37 screens, and other facilities. The locations of some of the Alternative 9 facilities would be different
 38 than that of any of the other alternatives. The operable barriers along Delta channels and the two
 39 pumping plants on Old River and Middle River would be in locations not discussed for other
 40 alternatives (Figure 3-16 in Chapter 3, *Description of Alternatives*). At the primary two such
 41 locations, operable barriers would be constructed.

42 Table 9-29 summarizes the geology of the Alternative 9 facilities as mapped by Atwater (1982)
 43 (Figure 9-3).

NEPA Effects: The overall hazard of loss of property or personal injury from ground settlement of culvert siphons during construction would be less than that of Alternative 1A. Additionally, the same engineering design and construction requirements that apply to all the project facilities would prevent ground settlement and would not substantially change the hazard of loss of property, personal injury, or death during construction compared to Alternative 1A. The effects of Alternative 9 would, therefore, be similar to those under Alternative 1A. See the discussion of Impact GEO-3. See the description and findings under Alternative 1A. There would be no adverse effect.

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

Sources: Hansen et al. 2001; Atwater 1982.

^a The reaches are defined in Chapter 3. *Description of Alternatives*, and shown on Figure 9-3.

CEQA Conclusion: Ground settlement above the tunneling operation for the culvert siphons could result in loss of property or personal injury during construction. However, DWR would conform to Cal-OSHA, USACE, and other design requirements 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, AMMs, and CMs*) and there would be no increased likelihood of loss of property, personal injury or death due to the construction of Alternative 9. Hazards to workers and project structures would be controlled at safe levels and the impact would be less than significant. No mitigation is required.

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

NEPA Effects: Construction of water conveyance facilities under Alternative 9 would involve an array of intakes, pumping plants, pipelines, culvert siphons, canals, borrow areas, enlargement of a channel, and other facilities. The locations of some of the Alternative 9 facilities would be different than that of any of the other alternatives. The operable barriers along Delta channels and the two

1 pumping plants on Old River and Middle River would be in locations not discussed for other
2 alternatives (see Figure 3-16 in Chapter 3, *Description of Alternatives*). At the primary two such
3 locations, operable barriers would be constructed. The overall hazard of loss of property or personal
4 injury from slope failure at borrow and spoils sites during construction would be less than that of
5 Alternative 1A. Additionally, the same engineering design and construction requirements that apply
6 to all the project facilities would prevent slope failure would not substantially change the hazard of
7 loss of property, personal injury, or death during construction compared to Alternative 1A. The
8 effects of Alternative 9 would, therefore, be similar to that of Alternative 1A. See the description and
9 findings under Alternative 1A. There would be no adverse effect.

10 **CEQA Conclusion:** Settlement/failure of cutslopes of borrow sites and failure of soil/RTM fill slopes
11 could result in loss of property or personal injury during construction. However, because DWR
12 would conform to Cal-OSHA requirements and conform to applicable geotechnical design guidelines
13 and standards, such as USACE design measures, the hazard would be controlled to a safe level and
14 there would be no increased likelihood of loss of property, personal injury or death due to the
15 construction of Alternative 9. The impact would be less than significant. No mitigation is required.

16 **Impact GEO-5: Loss of Property, Personal Injury, or Death from Structural Failure Resulting** 17 **from Construction-Related Ground Motions during Construction of Water Conveyance** 18 **Features**

19 **NEPA Effects:** Construction of water conveyance facilities under Alternative 9 would involve an
20 array of intakes, pumping plants, pipelines, culvert siphons, canals, borrow areas, enlargement of a
21 channel, and other facilities. The locations of some of the Alternative 9 facilities would be different
22 than that of any of the other alternatives. At the primary two such locations, operable barriers would
23 be constructed. Construction traffic may need to access levee roads at various points along SR 160
24 and other state routes as shown in Figure 9-7, as well as at locations shown along the Through
25 Delta/Separate Corridors Alignment in Figure 9-8b. The overall hazard of loss of property or
26 personal injury from structural failure from ground motions during construction would be overall
27 slightly greater than that of Alternative 1A because of the greater amount pile driving that would be
28 required. Additionally, the same engineering design and construction requirements that apply to all
29 the project facilities would prevent structural failure from construction-related ground motions and
30 would not substantially change the hazard of loss of property, personal injury, or death during
31 construction. The effects of Alternative 9 would, therefore, be similar to that of Alternative 1A. See
32 the description and findings under Alternative 1A. There would be no adverse effect.

33 **CEQA Conclusion:** Construction-related ground motions and traffic effects could initiate
34 liquefaction, which could cause failure of structures during construction, which could result in injury
35 of workers at the construction sites. The impact would be significant. However, because DWR would
36 conform to Cal-OSHA and other state code requirements and conform to applicable design
37 guidelines and standards, such as USACE design measures, in addition to implementation of
38 Mitigation Measures TRANS-2a and TRANS-2b, as well as the maintenance and reconstruction of
39 levees through Mitigation Measure TRANS-2c, the hazard would be controlled to a level that would
40 protect worker safety (see Appendix 3B, *Environmental Commitments, AMMs, and CMs*) and there
41 would be no increased likelihood of loss of property, personal injury or death due to the
42 construction of Alternative 9. The impact would be less than significant.

1 **Mitigation Measure TRANS-2a: Prohibit Construction Activity on Physically Deficient**
 2 **Roadway Segments**

3 Please refer to Mitigation Measure TRANS-2a in Alternative 1A, Impact TRANS-2, in Chapter 19,
 4 *Transportation*.

5 **Mitigation Measure TRANS-2b: Limit Construction Activity on Physically Deficient**
 6 **Roadway Segments**

7 Please refer to Mitigation Measure TRANS-2b in Alternative 1A, Impact TRANS-2, in Chapter 19,
 8 *Transportation*.

9 **Mitigation Measure TRANS-2c: Improve Physical Condition of Affected Roadway Segments**
 10 **as Stipulated in Mitigation Agreements or Encroachment Permits**

11 Please refer to Mitigation Measure TRANS-2c in Alternative 1A, Impact TRANS-2, in Chapter 19,
 12 *Transportation*.

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

15 Construction of water conveyance facilities under Alternative 9 would involve an array of intakes,
 16 pumping plants, pipelines, culvert siphons, canals, borrow areas, enlargement of a channel, and
 17 other facilities. The locations of some of the Alternative 9 facilities would be different than that of
 18 any of the other alternatives.

19 According to the available AP Earthquake Fault Zone Maps, none of the Alternative 9 constructed
 20 conveyance facilities would cross or be on any known active fault zones. Numerous AP fault zones
 21 have been mapped west of the conveyance alignment. The closest AP fault zone would be the
 22 Greenville fault, approximately 10.0 miles southwest of the constructed conveyance facilities.
 23 Because of their distances from the AP fault zones, the potential that the facilities would be directly
 24 subject to fault offsets is negligible.

25 In the Delta, active or potentially active blind thrust faults were identified in the seismic study. The
 26 operable barrier on Threemile Slough would be in the Montezuma Hills fault zone, and the extreme
 27 southwestern corner of the Byron Tract Forebay (to the northwest of the Clifton Court Forebay)
 28 may be underlain by the West Tracy fault (Figure 9-5). Although these blind thrusts are not expected
 29 to rupture to the ground surface under the forebay during earthquake events, they may produce
 30 ground or near-ground shear zones, bulging, or both (California Department of Water Resources
 31 2007a). Assuming that the West Tracy fault is potentially active, it could cause surface deformation
 32 in the western part of the Clifton Court Forebay (Fugro Consultants 2011) and the Byron Tract
 33 Forebay. In the seismic study (California Department of Water Resources 2007a), the Montezuma
 34 Hills and West Tracy blind thrusts have been assigned 50% and 90% probabilities of being active,
 35 respectively. The depth to the Montezuma Hills faults is unknown. The seismic study indicates that
 36 the West Tracy fault dies out as a discernible feature within approximately 3,000 to 6,000 feet bgs
 37 (in the upper 1 to 2 second depth two-way time, estimated to be approximately 3,000 to 6,000 feet
 38 using the general velocity function as published in the Association of Petroleum Geologists Pacific
 39 Section newsletter [Tolmachoff 1993]).

1 It appears that the potential of having any shear zones, bulging, or both at the depths of the facilities
2 is low because the depth to the blind thrust faults is generally deep. However, because of there is
3 limited information regarding depth for these faults, a geotechnical evaluation and seismic surveys
4 would be performed at these two blind thrust locations during the design phase to determine the
5 depths to the top of faults. The geotechnical work would provide the basis for design
6 recommendations as would be done at the other project facilities. As with the other facilities, the
7 facility design would conform to USACE design standards.

8 **NEPA Effects:** The effects of Alternative 9 would, therefore, be similar to that of Alternative 1A. See
9 the description and findings under Alternative 1A. There would be no adverse effect.

10 **CEQA Conclusion:** There are no active faults capable of surface rupture that extend into the
11 pipeline/tunnel alignment. Although the Thornton Arch and West Tracy blind thrusts occur beneath
12 the pipeline/tunnel alignment, based on available information, they do not present a hazard of
13 surface rupture and there would be no increased likelihood of loss of property, personal injury or
14 death due to the operation of Alternative 9. There would be no impact. No mitigation is required.

15 **Impact GEO-7: Loss of Property, Personal Injury, or Death from Structural Failure Resulting** 16 **from Strong Seismic Shaking during Operation of Water Conveyance Features**

17 Construction of water conveyance facilities under Alternative 9 would involve an array of intakes,
18 pumping plants, pipelines, culvert siphons, canals, borrow areas, enlargement of a channel, and
19 other facilities. The locations of some of the Alternative 9 facilities would be different than that of
20 any of the other alternatives. At the primary two such locations, operable barriers would be
21 constructed.

22 Similar to the earthquake ground shaking hazard during construction, earthquake occurrences on
23 the local and regional seismic sources for 2025 would subject the Alternative 9 facilities to ground
24 shaking.

25 Table 9-30 lists the expected PGA and 1.0- S_a values for 2025 at selected facility locations.
26 Earthquake ground shakings for the OBE (144-year return period) and MDE (975-year return
27 period) were estimated for the stiff soil site, as predicted in the seismic study (California
28 Department of Water Resources 2007a), and for the anticipated soil conditions at the facility
29 locations. No seismic study results exist for 2025, so the ground shakings estimated for 2050 were
30 used for 2025. The table shows that the proposed facilities would be subject to moderate-to-high
31 earthquake ground shakings for 2025.

1 **Table 9-30. Expected Earthquake Ground Motions at Locations of Selected Major Facilities in the Early**
 2 **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.

3
 4 **NEPA Effects:** The Alternative 9 facilities would be subject to the same engineering design and
 5 construction requirements that apply to all the project facilities, which would prevent structural
 6 failure from seismic shaking and not substantially change the hazard of loss of property, personal
 7 injury, or death compared to Alternative 1A. The effects of Alternative 9 would, therefore, be similar
 8 to that of Alternative 1A. See the description and findings under Alternative 1A. There would be no
 9 adverse effect.

10 **CEQA Conclusion:** Seismically induced strong ground shaking could damage culvert siphons, intake
 11 facilities, pumping plants, and other facilities. The damage could disrupt the water supply through
 12 the conveyance system. In an extreme event, flooding and inundation of structures could result from
 13 an uncontrolled release of water from the damaged conveyance system. (Please refer to Chapter 6,
 14 *Surface Water*, for a detailed discussion of potential flood impacts.) However, through the final
 15 design process, measures to address this hazard would be required to conform to applicable design
 16 codes, guidelines, and standards. As described in Section 9.3.1, *Methods for Analysis*, and in Appendix
 17 3B, *Environmental Commitments, AMMs, and CMs*, such design codes, guidelines, and standards
 18 include the California Building Code and resource agency and professional engineering
 19 specifications, such as the Division of Safety of Dams' *Guidelines for Use of the Consequence-Hazard*
 20 *Matrix and Selection of Ground Motion Parameters*, DWR's Division of Flood Management *FloodSAFE*
 21 *Urban Levee Design Criteria*, and USACE's *Engineering and Design—Earthquake Design and*
 22 *Evaluation for Civil Works Projects*. Conformance with these codes and standards is an
 23 environmental commitment by DWR to ensure that ground shaking risks are minimized as the

1 water conveyance features are operated. The hazard would be controlled to a safe level and there
 2 would be no increased likelihood of loss of property, personal injury or death due to the operation of
 3 Alternative 9. The impact would be less than significant. No mitigation is 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 **NEPA Effects:** Construction of water conveyance facilities under Alternative 9 would involve an
 8 array of intakes, pumping plants, pipelines, culvert siphons, canals, borrow areas, enlargement of a
 9 channel, and other facilities. (Some of the facilities would primarily involve in-water work and
 10 would have no bearing on geology and seismicity.) The locations of some of the Alternative 9
 11 facilities would be different than that of any of the other alternatives. At the primary two such
 12 locations, operable barriers would be constructed. The Alternative 9 facilities would be subject to
 13 the same engineering design and construction requirements that apply to all the project facilities,
 14 which would prevent structural failure from liquefaction and not substantially change the hazard of
 15 loss of property, personal injury, or death compared to Alternative 1A. The effects of Alternative 9
 16 would, therefore, be similar to that of Alternative 1A. See the description and findings under
 17 Alternative 1A. There would be no adverse effect.

18 **CEQA Conclusion:** Seismically induced ground shaking could cause liquefaction. Liquefaction could
 19 damage culvert siphons, intake facilities, pumping plants, and other facilities, and thereby disrupt
 20 the water supply through the conveyance system. In an extreme event, an uncontrolled release of
 21 water from the damaged conveyance system could cause flooding and inundation of structures.
 22 (Please refer to Chapter 6, *Surface Water*, for a detailed discussion of potential flood impacts.)
 23 However, through the final design process, measures to address the liquefaction hazard would be
 24 required to conform to applicable design codes, guidelines, and standards. As described in Section
 25 9.3.1, *Methods for Analysis*, and in Appendix 3B, *Environmental Commitments, AMMs, and CMs*, such
 26 design codes, guidelines, and standards include USACE's *Engineering and Design—Stability Analysis*
 27 *of Concrete Structures and Soil Liquefaction during Earthquakes*, by the Earthquake Engineering
 28 Research Institute. Conformance with these design standards is an environmental commitment by
 29 DWR to ensure that liquefaction risks are minimized as the water conveyance features are operated.
 30 The hazard would be controlled to a safe level and there would be no increased likelihood of loss of
 31 property, personal injury or death due to the operation of Alternative 9. The impact would be less
 32 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
 36 array of intakes, pumping plants, pipelines, culvert siphons, canals, borrow areas, enlargement of a
 37 channel, and other facilities. (Some of the facilities would primarily involve in-water work and
 38 would have no bearing on geology and seismicity.) The locations of some of the Alternative 9
 39 facilities would be different than that of any of the other alternatives. At the primary two such
 40 locations, operable barriers would be constructed. The Alternative 9 facilities are subject to a similar
 41 hazard of slope instability as Alternative 1A and would not substantially change the hazard of loss of
 42 property, personal injury, or death compared to Alternative 1A. The effects of Alternative 9 would,
 43 therefore, be similar to that of Alternative 1A. See the description and findings under Alternative 1A.
 44 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
 3 constructed on these slopes could be damaged or fail entirely as a result of slope instability.
 4 However, through the final design process, measures to address this hazard would be required to
 5 conform to applicable design codes, guidelines, and standards. As described in Section 9.3.1,
 6 *Methods for Analysis*, and in Appendix 3B, *Environmental Commitments, AMMs, and CMs*, such design
 7 codes, guidelines, and standards include the California Building Code and resource agency and
 8 professional engineering specifications, such as USACE's *Engineering and Design—Earthquake*
 9 *Design and Evaluation for Civil Works Projects*. Conformance with these codes and standards is an
 10 environmental commitment by DWR to ensure cut and fill slopes and embankments would be stable
 11 as the water conveyance features are operated and there would be no increased likelihood of loss of
 12 property, personal injury or death due to the operation of Alternative 9. The hazard would be
 13 controlled to a safe level. The impact would be less 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
 17 array of intakes, pumping plants, pipelines, culvert siphons, canals, borrow areas, enlargement of a
 18 channel, and other facilities. (Some of the facilities would primarily involve in-water work and
 19 would have no bearing on geology and seismicity.) The locations of some of the Alternative 9
 20 facilities would be different than that of any of the other alternatives. At the primary two such
 21 locations, operable barriers would be constructed. The Alternative 9 facilities are subject to a similar
 22 hazard of a seiche or tsunami as Alternative 1A and would not substantially change the hazard of
 23 loss of property, personal injury, or death from a seiche or tsunami compared to Alternative 1A, with
 24 the exception of the Byron Tract Forebay, which would not be a component of this alternative. The
 25 effects of Alternative 9 would, therefore, be similar to or less than that of Alternative 1A. See the
 26 description and findings under 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
 29 inundation maps prepared by the California Department of Conservation (2009), the height of a
 30 tsunami wave reaching the Suisun Marsh and the Delta would be small because of the distance from
 31 the ocean and attenuating effect of the San Francisco Bay. Similarly, the potential for a significant
 32 seiche to occur in the Plan Area is considered low because the seismic hazard and the geometry of
 33 the water bodies (i.e., wide and shallow) near conveyance facilities are not favorable for a seiche to
 34 occur. There would be no increased likelihood of loss of property, personal injury or death due to
 35 the operation of Alternative 9 from seiche or tsunami. The impact would be less than significant. No
 36 mitigation is required.

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

39 **NEPA Effects:** Alternative 9 would not involve construction of unlined canals; therefore, there would
 40 be no increase in groundwater surface elevations and consequently no effect caused by canal
 41 seepage. There would be no effect.

1 **CEQA Conclusion:** Alternative 9 would not involve construction of unlined canals; therefore, there
 2 would be no increase in groundwater surface elevations and consequently no impact caused by
 3 canal seepage. There would be no impact. 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 under Alternative 9 would be similar to that as under
 7 Alternative 1A. See 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
 9 ROA and damage ROA facilities, such as levees and berms. Damage to these features could result in
 10 their failure, causing flooding of otherwise protected areas. However, through the final design
 11 process for conservation measures in the ROAs, measures to address the fault rupture hazard would
 12 be required to conform to applicable design codes, guidelines, and standards. As described in
 13 Section 9.3.1, *Methods for Analysis*, and in Appendix 3B, *Environmental Commitments, AMMs, and*
 14 *CMs*, such design codes, guidelines, and standards include the Division of Safety of Dams' *Guidelines*
 15 *for Use of the Consequence-Hazard Matrix and Selection of Ground Motion Parameters*, DWR's
 16 Division of Flood Management *FloodSAFE Urban Levee Design Criteria*, and USACE's *Engineering and*
 17 *Design—Earthquake Design and Evaluation for Civil Works Projects*. Conformance with these design
 18 standards is an environmental commitment by the BDCP proponents to ensure that fault rupture
 19 risks are minimized as the conservation measures are implemented. The hazard would be controlled
 20 to a safe level and there would be no increased likelihood of loss of property, personal injury or
 21 death in the ROAs. The impact would be less than 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 under Alternative 9 would be similar to that as under
 25 Alternative 1A. See 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
 28 to active faults. The Suisun Marsh ROA is subject to a PGA of approximately 0.31 to 0.35 g for 200-
 29 year return interval, while the PGA for the other ROAs ranges from approximately 0.11 to 0.26 g.
 30 Damage to these features could result in their failure, causing flooding of otherwise protected areas.
 31 However, as described in Section 9.3.1, *Methods for Analysis*, and in Appendix 3B, *Environmental*
 32 *Commitments, AMMs, and CMs*, design codes, guidelines, and standards, including the California
 33 Building Code and resource agency and professional engineering specifications, such as DWR's
 34 Division of Flood Management *FloodSAFE Urban Levee Design Criteria* and USACE's *Engineering and*
 35 *Design—Earthquake Design and Evaluation for Civil Works Projects* would be used for final design of
 36 conservation features. Conformance with these design standards is an environmental commitment
 37 by the BDCP proponents to ensure that strong seismic shaking risks are minimized as the
 38 conservation measures are operated and there would be no increased likelihood of loss of property,
 39 personal injury or death in the ROAs. The impact would be less than significant. No mitigation is
 40 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**
 3 **Opportunity Areas**

4 **NEPA Effects:** Conservation measures under Alternative 9 would be similar to that as under
 5 Alternative 1A. See description and findings under Alternative 1A. There would be no adverse effect.

6 **CEQA Conclusion:** Earthquake-induced ground shaking could cause liquefaction, resulting in
 7 damage to or failure of levees, berms, and other features constructed at the restoration areas.
 8 Failure of levees and 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, AMMs, and CMs*, such
 12 design codes, guidelines, and standards include USACE's *Engineering and Design—Stability Analysis*
 13 *of Concrete Structures* and *Soil Liquefaction during Earthquakes*, by the Earthquake Engineering
 14 Research Institute. Conformance with these design standards is an environmental commitment by
 15 the BDCP proponents to ensure that liquefaction risks are minimized as the water conservation
 16 features are implemented and there would be no increased likelihood of loss of property, personal
 17 injury or death 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 Conservation measures under Alternative 9 would be similar to that as under Alternative 1A. See
 21 description and findings under Alternative 1A.

22 **NEPA Effects:** The effect would be adverse because levee slopes and embankments may fail, either
 23 from high pore-water pressure caused by high rainfall and weak soil, or from seismic shaking.
 24 Failure of these features could result in flooding of otherwise protected areas. During project design,
 25 a geotechnical engineer would develop slope stability design criteria (such as minimum slope safety
 26 factors and allowable slope deformation and settlement) for the various anticipated loading
 27 conditions. As discussed in Chapter 3, *Description of Alternatives*, foundation soil beneath
 28 embankments and levees could be improved to increase its strength and to reduce settlement and
 29 deformation. Foundation soil improvement could involve excavation and replacement with
 30 engineered fill; preloading; ground modifications using jet-grouting, compaction grouting, chemical
 31 grouting, shallow soil mixing, deep soil mixing, vibro-compaction, or vibro-replacement; or other
 32 methods. Engineered fill could also be used to construct new embankments and levees.

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

36 The BDCP proponents would ensure that the geotechnical design recommendations are included in
 37 the design of embankments and levees to minimize the potential effects from slope failure. The
 38 BDCP proponents would also ensure that the design specifications are properly executed during
 39 implementation.

40 Conformance to the above and other applicable design specifications and standards would ensure
 41 that the hazard of slope instability would not jeopardize the integrity of levee and other features at
 42 the ROAs. There would be no adverse effect.

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

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

9 **NEPA Effects:** Conservation measures under Alternative 9 would be similar to that as under
 10 Alternative 1A. See description and findings under Alternative 1A. There would be no adverse effect.

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

17 **9.3.4 Effects and Mitigation Approaches—Alternatives 4A,**
 18 **2D, and 5A**

19 **9.3.4.1 No Action Alternative Early Long-Term**

20 The effects of the No Action Alternative (ELT) as considered for the purposes of Alternative 4A, 2D,
 21 and 5A would be expected to be similar to those effects described for the No Action Alternative Late
 22 Long-Term (LLT) in Section 9.3.3.1. The No Action Alternative (ELT) considers changes in risk from
 23 geology and seismicity that would take place as a result of the continuation of existing plans,
 24 policies, and operations, as described in Chapter 3, *Description of Alternatives*. Due to the shorter
 25 time frame, the magnitude of total geologic and seismic impacts on construction associated with
 26 development and habitat restoration activities within the Plan Area would be less under the ELT
 27 timeframe than that considered in 2060 due to less development in the region.

28 **Earthquake Induced Ground Shaking, Liquefaction, and Slope Instability**

29 Under the No Action Alternative (ELT) it is anticipated that the current hazard resulting from
 30 earthquake-induced ground shaking from regional and local faults would be similar to that under
 31 the No Action Alternative (LLT). This would continue to present a risk of levee failure and
 32 subsequent flooding of Delta islands, with a concomitant influx of seawater into the Delta, thereby
 33 adversely affecting water quality and water supply. It is also anticipated that the current hazard of
 34 earthquake-induced liquefaction triggered by regional and local faults would persist. Liquefaction
 35 would continue to present a risk of levee failure and subsequent flooding of Delta islands, with
 36 concomitant water quality and water supply effects from seawater intrusion as described in
 37 Appendix 3E, *Potential Seismicity and Climate Change Risks to SWP/CVP Water Supplies*.

38 Ongoing and reasonably foreseeable future projects in parts of the Delta are expected to upgrade the
 39 levees to a “flood-safe” condition under the 100-year return flood elevation. Given the shorter
 40 timeframe, fewer projects would be implemented in the No Action Alternative (ELT). Regardless,

1 these projects would provide very little levee foundation strengthening and improvements directed
2 at improving the stability of the levees to better withstand ground shaking, liquefaction, and slope
3 instability.

4 **Tsunami and Seiche**

5 Under the No Action Alternative (ELT) it is anticipated that the current hazard resulting from
6 tsunami and seismically induced seiche on Delta and Suisun Marsh levees would be similar to that
7 under the No Action Alternative (LLT). The geometry of existing water bodies in the Delta and
8 Suisun Marsh and distance to seismic sources generally are not conducive to the occurrence of a
9 substantial seismically induced seiche, as described in Section 9.1.1.3, *Regional and Local Seismicity*.
10 However, because of its proximity to the potentially active West Tracy fault, there is a potential
11 hazard for a seiche to occur in the Clifton Court Forebay (Fugro Consultants 2011).

12 **Ongoing Plans, Policies, and Programs**

13 The programs, plans, and projects included in Table 9-13 would apply to the No Action Alternative
14 (ELT). Although not specifically directed at mitigating potential damage to levees caused by a
15 tsunami and seiche, the ongoing and reasonably foreseeable future projects directed to upgrade
16 levees to a “flood-safe” condition under the 100-year return flood elevation or projects involving
17 other similar levee improvements may provide some benefit to withstanding the potential effect of a
18 tsunami and seiche.

19 Given the shorter timeframe, fewer projects would be implemented in the No Action Alternative
20 (ELT), but there would be an indirect and beneficial effect upon the potential hazard of tsunami and
21 seiche in the Delta due to improvements in levee infrastructure as a part of implementation of these
22 projects or programs.

23 **Climate Change and Catastrophic Seismic Risks**

24 The Delta and vicinity is within a highly active seismic area, with a generally high potential for major
25 future earthquake events along nearby and/or regional faults, and with the probability for such
26 events increasing over time. Under the No Action Alternative (ELT), it is anticipated that the
27 potential for significant damage to, or failure of, these structures during a major local seismic event
28 would be similar to that under the No Action Alternative (LLT). In the instance of a large seismic
29 event, levees constructed on liquefiable foundations are expected to experience large deformations
30 (in excess of 10 feet) under a moderate to large earthquake in the region. There would potentially be
31 loss, injury or death resulting from ground rupture, ground shaking and liquefaction.

32 **CEQA Conclusion:** In total, the plans and programs under the No Action Alternative ELT would
33 result in a beneficial effect on an undetermined extent of levees in the Delta. Under the No Action
34 Alternative ELT, these plans, policies, and programs would have an indirect and beneficial effect
35 upon the potential hazard of tsunami and seiche in the Delta. These plans and programs, however,
36 would not decrease the risks associated with climate change or a catastrophic seismic event, as
37 discussed above and more thoroughly in Appendix 3E, *Seismic and Climate Change Risks to SWP/CVP*
38 *Water Supplies*. Given that construction and operation of any new water facilities and habitat
39 restoration would be undertaken following appropriate state codes and standards, there would be
40 no impact of the No Action Alternative (ELT) related to geology and seismicity (i.e., Impacts GEO-1
41 to GEO-15).

9.3.4.2 Alternative 4A—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 4A water conveyance facilities. Seismically induced ground shaking could cause injury of workers at the construction sites as a result of collapse of facilities.

As stated under Alternative 4, the results of the seismic study (California Department of Water Resources 2007a) 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).

The hazard of structural failure from seismic shaking under Alternative 4A resulting in loss of property, personal injury, or death during construction would be identical to Alternative 4.

NEPA Effects: Seismically induced ground shaking could cause loss of property or personal injury at the Alternative 4A construction sites (including intake locations, pipelines from intakes to the intermediate forebay, the tunnels, the pumping plant, and the expanded Clifton Court Forebay) as a result of collapse of facilities. Facilities lying directly on or near active blind faults may have an increased likelihood of loss of property or personal injury in the event of seismically induced ground shaking.

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 under the Alternative 4 analysis, and discussed in Appendix 3B, *Environmental Commitments, AMMs, and CMs*, for the anticipated seismic loads. 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, practicing crane and scaffold safety measures).

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

CEQA Conclusion: Seismically induced ground shaking that is estimated to occur and the resultant ground motion anticipated at Alternative 4A construction sites, including the intake locations, the tunnels, the pipelines and the forebays, could cause collapse or other failure of project facilities while under construction. As described under Alternative 4, DWR would conform to 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, AMMs, and CMs*). 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 4A. 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

As with Alternative 4, settlement of excavations could occur as a result of dewatering at Alternative 4A construction sites with shallow groundwater. Dewatering can stimulate settlement in excavation and tunneling sites. The settlement could cause the slopes of excavations to fail. Locations where dewatering would occur during construction of Alternative 4A water conveyance features would be identical to that under Alternative 4 and the potential impacts are identical under both alternatives.

NEPA Effects: This potential effect could be substantial because settlement or collapse during dewatering could cause injury of workers at the construction sites as a result of collapse of excavations.

The hazard of settlement and subsequent collapse of excavations would be evaluated by assessing site-specific geotechnical and hydrological conditions at intake locations, as well as where intake and forebay pipelines cross waterways and major irrigation canals. A California-registered civil engineer or California-certified engineering geologist would recommend measures in a geotechnical report to address these hazards, such as seepage cutoff walls and barriers, shoring, grouting of the bottom of the excavation, and strengthening of nearby structures, existing utilities, or buried structures. As described in Section 9.3.1, *Methods for Analysis*, the measures would conform to applicable design and building codes, guidelines, and standards, as described under Alternative 4.

DWR has made an environmental commitment to also conform to appropriate code and standard requirements to minimize potential risks (see Appendix 3B, *Environmental Commitments, AMMs, and CMs*). Generally, the applicable codes require that facilities be built in such a way that settlement is minimized. Mandatory 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).

Conformance to these and other applicable design specifications and standards would ensure that construction of Alternative 4A would not create an increased likelihood of loss of property, personal injury or death of individuals from settlement or collapse caused by dewatering. Therefore, 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 to Cal-OSHA and other state code requirements to protect worker safety as described under Alternative 4. DWR has also made an environmental commitment to conform to appropriate codes and standards to minimize potential risks (see Appendix 3B, *Environmental Commitments, AMMs, and CMs*). Additionally, DWR has made an environmental commitment that a geotechnical report be completed by a California-certified engineering geologist, that the report's geotechnical design recommendations be included in the design of project facilities, and that the report's design specifications are properly executed during construction to minimize the potential effects from settlement and failure of excavations. Proper

1 execution of these environmental commitments to minimize potential risks would result in no
 2 increased likelihood of loss of property, personal injury or death due to construction of Alternative
 3 4A. The impact would be less than significant. No mitigation is required.

4 **Impact GEO-3: Loss of Property, Personal Injury, or Death from Ground Settlement during** 5 **Construction of Water Conveyance Features**

6 The potential for ground settlement under Alternative 4A would be identical to that under
 7 Alternative 4. The geologic units in the area of the Alternative 4A modified pipeline/tunnel
 8 alignment are the same as those shown for Alternative 4 in Figure 9-3 and summarized in Table 9-
 9 26. The characteristics of each unit would affect the potential for settlement during geotechnical
 10 investigation and tunneling operations. Segments 1 and 3, located in the Clarksburg area and the
 11 area west of Locke, respectively, contain higher amounts of sand than the other segments, so they
 12 pose a greater risk of settlement.

13 Operator errors or highly unfavorable/unexpected ground conditions could result in larger
 14 settlement. Large ground settlements caused by tunnel construction are almost always the result of
 15 using inappropriate tunneling equipment (incompatible with the ground conditions), improperly
 16 operating the machine, or encountering sudden or unexpected changes in ground conditions.

17 Given the likely design depth of the tunnel, the amount of settlement beneath developed areas and
 18 critical infrastructure (i.e., the village of Hood, SR 4 and SR 12, the EBMUD aqueduct, and a
 19 potentially sensitive satellite dish facility) would be minor. At the evaluated infrastructure, the
 20 predicted maximum ground surface settlement would range from 0.0 to 2.9 inches, with a change in
 21 ground slope ratio ranging from 0 to 1:714 (the higher value corresponding to a 0.14% slope). The
 22 width of the settlement “trough,” as a cross-section oriented perpendicular to the tunnel alignment,
 23 would be 328 to 525 feet among the evaluated facilities. Other facilities that may be determined to
 24 be critical infrastructure include natural gas pipelines, the proposed EBMUD tunnel, levees, and local
 25 electrical distribution and communication lines.

26 **NEPA Effects:** Although the potential effect is expected to be minor, during detailed project design, a
 27 site-specific subsurface geotechnical evaluation would be conducted along the modified
 28 pipeline/tunnel alignment to verify or refine the findings of the preliminary geotechnical
 29 investigations. These effects would be reduced with implementation of DWR’s environmental
 30 commitments and avoidance and minimization measures (see Appendix 3B, *Environmental*
 31 *Commitments, AMMs, and CMs*). The results of the site-specific evaluation and the engineer’s
 32 recommendations would be documented in a detailed geotechnical report, which will contain site-
 33 specific evaluations of the settlement hazard associated with the site-specific soil conditions
 34 overlying the tunnel throughout the alignment. The report will also contain recommendations for
 35 the type of tunnel boring machine to be used and the tunneling techniques to be applied to avoid
 36 excessive settlement for specific critical assets, such as buildings, major roads, natural gas pipelines,
 37 electrical and communication lines, aqueducts, bridges, levees, and sensitive satellite dish facilities.
 38 Also included in the report will be recommendations for geotechnical and structural
 39 instrumentation for monitoring of settlement.

40 As described in Section 9.3.1, *Methods for Analysis*, the measures would conform to applicable design
 41 guidelines and standards, such as USACE design measures. See Appendix 3B, *Environmental*
 42 *Commitments, AMMs, and CMs*. In particular, conformance with the following federal design manuals
 43 and professional society and geotechnical literature would be used to predict the maximum amount
 44 of settlement that could occur for site-specific conditions, to identify the maximum allowable

1 settlement for individual critical assests, and to develop recommendations for tunneling to avoid
 2 excessive settlement, all to minimizethe likelihood of loss of property or personal injury from
 3 ground settlement above the tunneling operation during construction.

- 4 • *Technical Design Manual for Design and Construction of Road Tunnels* (U.S. Department of
 5 Transportation, Federal Highway Administration 2009).
- 6 • *A Method of Estimating Surface Settlement above Tunnels Constructed in Soft Ground* (National
 7 Research Council of Canada 1983).
- 8 • *Predicting the Dynamics of Ground Settlement and its Derivatives Caused by Tunnelling in Soil*
 9 (Attewell and Woodman 1982).
- 10 • *Predicting the Settlements above Twin Tunnels Constructed in Soft Ground* (Chapman et al. 2004).
- 11 • *Report on Settlements Induced by Tunneling in Soft Ground* (International Tunneling Association
 12 2007).
- 13 • *Closed-Face Tunnelling Machines and Ground Stability: A Guideline for Best Practice* (British
 14 Tunnelling Society 2005).

15 Generally, the applicable codes require that facilities be built so that they are designed for slope
 16 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
 18 standards specify protective measures that must be taken at construction sites to minimize the risk
 19 of injury or death from structural or earth failure Conformance to these and other applicable design
 20 specifications and standards would ensure that construction of Alternative 4A would not create an
 21 increased likelihood of loss of property, personal injury or death of individuals from ground
 22 settlement. Therefore, there would be no adverse effect.

23 **CEQA Conclusion:** Ground settlement above the tunneling operation could result in loss of property
 24 or personal injury during construction. However, DWR would conform to Cal-OSHA, USACE and
 25 other design requirements to protect worker safety as described under Alternative 4. DWR has
 26 made conformance to geotechnical design recommendations and monitoring an environmental
 27 commitment (see Appendix 3B, *Environmental Commitments, AMMs, and CMs*). Hazards to workers
 28 and project structures would be controlled at safe levels and there would be no increased likelihood
 29 of loss of property, personal injury or death due to construction of Alternative 4A. The impact would
 30 be less than significant. No mitigation is required.

31 **Impact GEO-4: Loss of Property, Personal Injury, or Death from Slope Failure during** 32 **Construction of Water Conveyance Features**

33 Excavation of borrow material could result in failure of cut slopes and application of temporary
 34 spoils and RTM at storage sites could cause excessive settlement in the spoils, potentially causing
 35 injury of workers at the construction sites. The potential for slope failure under Alternative 4A
 36 would be identical to that under Alternative 4.

37 **NEPA Effects:** The potential effect could be substantial because excavation of borrow material and
 38 the resultant cutslopes and potential failure of spoils/RTM fill slopes could cause injury of workers
 39 at the construction sites. The potential for slope failure under Alternative 4A would be identical to
 40 that under Alternative 4.

1 During design, the potential for native ground settlement below the spoils would be evaluated by a
2 geotechnical engineer using site-specific geotechnical and hydrological information. The use of
3 shoring, seepage cutoff walls, and ground modifications to prevent slope instability, soil boiling, or
4 excessive settlement would be considered in the design. As described in Section 9.3.1, *Methods for*
5 *Analysis*, the measures would conform to applicable design and building codes, guidelines, and
6 standards.

7 In addition to the risk of slope failure at borrow sites and spoils and RTM sites, there are also
8 potential impacts on levee stability resulting from construction of Alternative 4A water conveyance
9 facilities. All levee reconstruction/building pad construction would conform to applicable state and
10 federal flood management engineering and permitting requirements.

11 DWR would ensure that the geotechnical design recommendations are included in the design of
12 project facilities and construction specifications and are properly executed during construction to
13 minimize the potential effects from failure of excavations. Conformance with relevant codes and
14 standards would reduce the potential risk for increased likelihood of loss of property or personal
15 injury from settlement/failure of cutslopes of borrow sites and failure of soil or RTM fill slopes
16 during construction. The worker safety codes and standards specify protective measures that must
17 be taken at construction sites to minimize the risk of injury or death from structural or earth failure
18 (e.g., utilizing personal protective equipment, practicing crane and scaffold safety measures). The
19 relevant codes and standards represent performance standards that must be met by contractors and
20 these measures are subject to monitoring by state and local agencies. DWR has made this
21 conformance and monitoring process an environmental commitment (see Appendix 3B,
22 *Environmental Commitments, AMMs, and CMs*).

23 Conformance to these and other applicable design specifications and standards would ensure that
24 construction of Alternative 4A would not create an increased likelihood of loss of property, personal
25 injury or death of individuals from slope failure at borrow sites and spoils and RTM storage sites.
26 The maintenance and reconstruction of levees would improve levee stability over existing
27 conditions due to improved side slopes, erosion control measures (geotextile fabrics, rock
28 revetments, or other material), seepage reduction measures, and overall mass. Therefore, there
29 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
32 would conform to Cal-OSHA and other state code requirements and conform to applicable
33 geotechnical design guidelines and standards, such as USACE design measures, the hazard would be
34 controlled to a safe level and there would be no increased likelihood of loss of property, personal
35 injury or death due to construction of Alternative 4A at borrow sites and spoils and RTM storage
36 sites. The maintenance and reconstruction of levees would improve levee stability over existing
37 conditions due to improved side slopes, erosion control measures, seepage reduction measures, and
38 overall mass. The impact would be less than significant. No mitigation is required.

39 **Impact GEO-5: Loss of Property, Personal Injury, or Death from Structural Failure Resulting** 40 **from Construction-Related Ground Motions during Construction of Water Conveyance** 41 **Features**

42 Pile driving and other heavy equipment operations would cause vibrations that could initiate
43 liquefaction and associated ground movements in places where soil and groundwater conditions are
44 present to allow liquefaction to occur. The consequences of liquefaction could result in damage

1 nearby structures and levees. The potential for liquefaction under Alternative 4A would be identical
2 to that under Alternative 4.

3 **NEPA Effects:** The potential effect could be substantial because construction-related ground motions
4 could initiate liquefaction, which could cause failure of structures during construction, which could
5 result in injury of workers at the construction sites. Some of the potential levee effects that could
6 occur during the construction in the absence of corrective measures may include rutting, settlement,
7 and slope movement. The potential for liquefaction under Alternative 4A would be identical to that
8 under Alternative 4.

9 During design, the facility-specific potential for liquefaction would be investigated by a geotechnical
10 engineer. The investigations are an environmental commitment (see Appendix 3B, *Environmental*
11 *Commitments, AMMs, and CMs*). In areas determined to have a potential for liquefaction, the
12 California-registered civil engineer or California-certified engineering geologist would develop
13 design strategies and construction methods to ensure that pile driving and heavy equipment
14 operations do not cause liquefaction which otherwise could damage facilities under construction
15 and surrounding structures, and could threaten the safety of workers at the site.

16 Design measures to avoid pile-driving induced levee failure may include predrilling or jetting, using
17 open-ended pipe piles to reduce the energy needed for pile penetration, using CIDH piles/piers that
18 do not require driving, using pile jacking to press piles into the ground by means of a hydraulic
19 system, or driving piles during the drier summer months. Field data collected during design also
20 would be evaluated to determine the need for and extent of strengthening levees, embankments,
21 and structures to reduce the effect of vibrations. These construction methods would conform to
22 current seismic design codes and requirements, as described in Appendix 3B, *Environmental*
23 *Commitments, AMMs, and CMs*. Such design standards include USACE's *Engineering and Design—*
24 *Stability Analysis of Concrete Structures and Soil Liquefaction during Earthquakes*, by the Earthquake
25 Engineering Research Institute.

26 As with the effects related to design of conveyance facilities, potential construction traffic effects on
27 levees would be assessed prior to project construction to determine specific geotechnical issues
28 related to construction traffic loading. Based on the initial assessment from field reconnaissance,
29 geotechnical exploration and analyses would be performed for levee sections that need further
30 evaluations. Should the geotechnical evaluations indicate that certain segments of existing levee
31 roads need improvements to carry the expected construction truck traffic loads, DWR is committed
32 to carry out the necessary improvements to the affected levee sections or to find an alternative route
33 that would avoid the potential deficient levee sections (Mitigation Measures TRANS-2a through 2c).
34 As discussed in Chapter 19, *Transportation*, Mitigation Measure TRANS-2c, all affected roadways
35 would be returned to preconstruction condition or better following construction. Implementation of
36 this measure would ensure that construction activities would not worsen pavement and levee
37 conditions, relative to existing conditions. Prior to construction, DWR would make a good faith effort
38 to enter into mitigation agreements with or to obtain encroachment permits from affected agencies
39 to verify what the location, extent, timing, and fair share cost to be paid by the DWR for any
40 necessary pre- and post-construction physical improvements. Levee roads that are identified as
41 potential haul routes and expected to carry significant construction truck traffic would be monitored
42 to ensure that truck traffic is not adversely affecting the levee and to identify the need for corrective
43 action.

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

6 Generally, the applicable codes require that facilities be built so that if soil in the foundation or
 7 surrounding area are subject to liquefaction, the removal or densification of the liquefiable material
 8 should be considered, along with alternative foundation designs. Additionally, any modification to a
 9 federal levee system would require USACE approval under 33 USC 408 (a 408 Permit).

10 The worker safety codes and standards specify protective measures that must be taken at
 11 construction sites to minimize the risk of injury or death from structural or earth failure (e.g.,
 12 utilizing personal protective equipment, practicing crane and scaffold safety measures).

13 Conformance to construction method recommendations and other applicable specifications, as well
 14 as implementation of Mitigation Measures TRANS-2a through 2c, would ensure that construction of
 15 Alternative 4A would not create an increased likelihood of loss of property, personal injury or death
 16 of individuals due to construction- and traffic-related ground motions and resulting potential
 17 liquefaction in the work area. Therefore, there would be no adverse effect.

18 **CEQA Conclusion:** Construction-related ground motions and traffic effects could initiate
 19 liquefaction, which could cause failure of structures during construction. The impact could be
 20 significant. However, because DWR would conform to Cal-OSHA and other state code requirements
 21 and conform to applicable design guidelines and standards, such as USACE design measures, in
 22 addition to implementation of Mitigation Measures TRANS-2a and TRANS-2b, as well as the
 23 maintenance and reconstruction of levees through Mitigation Measure TRANS-2c, the hazard would
 24 be controlled to a level that would protect worker safety (see Appendix 3B, *Environmental*
 25 *Commitments, AMMs, and CMs*). Further, DWR has made an environmental commitment (see
 26 Appendix 3B) that the construction methods recommended by the geotechnical engineer are
 27 included in the design of project facilities and construction specifications to minimize the potential
 28 for construction-induced liquefaction. DWR also has committed to ensure that these methods are
 29 followed during construction. Proper execution of these environmental commitments would result
 30 in no increased likelihood of loss of property, personal injury or death due to construction of
 31 Alternative 4A. The impact would be less than significant.

32 **Mitigation Measure TRANS-2a: Prohibit Construction Activity on Physically Deficient**
 33 **Roadway Segments**

34 Please refer to Mitigation Measure TRANS-2a in Alternative 1A, Impact TRANS-2, in Chapter 19,
 35 *Transportation*.

36 **Mitigation Measure TRANS-2b: Limit Construction Activity on Physically Deficient**
 37 **Roadway Segments**

38 Please refer to Mitigation Measure TRANS-2b in Alternative 1A, Impact TRANS-2, in Chapter 19,
 39 *Transportation*.

1 **Mitigation Measure TRANS-2c: Improve Physical Condition of Affected Roadway Segments**
 2 **as Stipulated in Mitigation Agreements or Encroachment Permits**

3 Please refer to Mitigation Measure TRANS-2c in Alternative 1A, Impact TRANS-2, in Chapter 19,
 4 *Transportation*.

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

7 **NEPA Effects:** Alternative 4A would include the same physical/structural components as Alternative
 8 4, and therefore, the effects of Alternative 4A would be the same as Alternative 4. The effect would
 9 not be adverse because like Alternative 4, no active faults extend into the Alternative 4A alignment.
 10 Additionally, although the Thornton Arch and West Tracy blind thrusts occur beneath the
 11 Alternative 4A alignment, they do not present a hazard of surface rupture based on available
 12 information, including the AP Earthquake Fault Zone Map showing faults capable of surface rupture
 13 (see Figure 9-5).

14 However, because there is limited information regarding the depths of the Thornton Arch and West
 15 Tracy blind thrusts, seismic surveys would be performed on the blind thrust during the design phase
 16 to determine the depths to the top of the faults. More broadly, design-level geotechnical studies
 17 would be prepared by a geotechnical engineer licensed in the state of California during project
 18 design. Consistent with the environmental commitments (see Appendix 3B, *Environmental*
 19 *Commitments, AMMs, and CMs*), DWR would ensure that the geotechnical engineer's recommended
 20 measures to address adverse conditions would conform to applicable design codes, guidelines, and
 21 standards, would be included in the project design and construction specifications, and would be
 22 properly executed during construction. Generally, the applicable codes require that facilities be built
 23 so that they incur minimal damage in the event of a foreseeable seismic event and that they remain
 24 functional following such an event and that the facility is able to perform without catastrophic
 25 failure in the event of a maximum design earthquake (the greatest earthquake reasonably expected
 26 to be generated by a specific source on the basis of seismological and geological evidence). As
 27 described in Section 9.3.1, *Methods for Analysis*, such conformance with design codes, guidelines, and
 28 standards are considered environmental commitments by DWR (see Appendix 3B, *Environmental*
 29 *Commitments, AMMs, and CMs*).

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

34 The worker safety codes and standards specify protective measures that must be taken at
 35 construction sites to minimize the risk of injury or death from structural or earth failure (e.g.,
 36 utilizing personal protective equipment).

37 Conformance to these and other applicable design specifications and standards would ensure that
 38 operation of Alternative 4 would not create an increased likelihood of loss of property, personal
 39 injury or death of individuals in the event of ground movement in the vicinity of the project. There
 40 would be no adverse effect.

41 **CEQA Conclusion:** There are no active faults capable of surface rupture that extend into the
 42 Alternative 4A modified pipeline/tunnel alignment. Design-level geotechnical studies would be

1 prepared by a geotechnical engineer licensed in the state of California during project design. The
 2 studies would further assess site-specific conditions at and near all the project facility locations,
 3 including seismic activity, soil liquefaction, and other potential geologic and soil-related hazards.
 4 This information would be used to verify assumptions and conclusions included in the EIR/EIS.
 5 Consistent with the project's environmental commitments (see Appendix 3B, *Environmental*
 6 *Commitments, AMMs, and CMs*), DWR would ensure that the geotechnical engineer's recommended
 7 measures to address adverse conditions would conform to applicable design codes, guidelines, and
 8 standards, would be included in the project design and construction specifications, and would be
 9 properly executed during construction. Conformance to these and other applicable design
 10 specifications and standards would ensure that operation of Alternative 4 would not create an
 11 increased likelihood of loss of property, personal injury or death of individuals in the event of
 12 ground movement in the vicinity of the project. Therefore, such ground movements would not
 13 jeopardize the integrity of the surface and subsurface facilities along the Alternative 4A conveyance
 14 alignment or the proposed expanded Clifton Court Forebay and associated facilities adjacent to the
 15 existing Clifton Court Forebay. There would be no impact. No mitigation is required.

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

18 Earthquake events may occur on the local and regional seismic sources during operation of the
 19 Alternative 4A water conveyance facilities. The ground shaking could damage pipelines, tunnels,
 20 intake facilities, pumping plants, and other facilities, disrupting the water supply through the
 21 conveyance system. In an extreme event of strong seismic shaking, uncontrolled release of water
 22 from damaged pipelines, tunnels, intake facilities, pumping plant, and other facilities could cause
 23 flooding, disruption of water supplies to the south, and inundation of structures. These effects are
 24 discussed more fully in Appendix 3E, *Potential Seismicity and Climate Change Risks to SWP/CVP*
 25 *Water Supplies*.

26 **NEPA Effects:** This potential effect could be substantial because strong ground shaking could
 27 damage pipelines, tunnels, intake facilities, pumping plant, and other facilities and result in loss of
 28 property or personal injury. The effects of Alternative 4A would be identical to Alternative 4. The
 29 damage could disrupt the water supply through the conveyance system. In an extreme event, an
 30 uncontrolled release of water from the conveyance system could cause flooding and inundation of
 31 structures. Please refer to Chapter 6, *Surface Water*, and Appendix 3E, *Potential Seismicity and*
 32 *Climate Change Risks to SWP/CVP Water Supplies*, for a detailed discussion of potential flood effects.

33 The structure of the underground conveyance facility would decrease the likelihood of loss of
 34 property or personal injury of individuals from structural shaking of surface and subsurface
 35 facilities along the Alternative 4A conveyance alignment in the event of strong seismic shaking.

36 In accordance with the DWR's environmental commitments (see Appendix 3B, *Environmental*
 37 *Commitments, AMMs, and CMs*), design-level geotechnical studies would be conducted by a licensed
 38 civil engineer who practices in geotechnical engineering. 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.

41 DWR would ensure that the geotechnical design recommendations are included in the design of
 42 project facilities and construction specifications to minimize the potential effects from seismic
 43 events and the presence of adverse soil conditions. Generally, the applicable codes require that
 44 facilities be built so that they incur minimal damage in the event of a foreseeable seismic event and

1 that they remain functional following such an event and that the facility is able to perform without
 2 catastrophic failure in the event of a maximum design earthquake (the greatest earthquake
 3 reasonably expected to be generated by a specific source on the basis of seismological and geological
 4 evidence). DWR would also ensure that the design specifications are properly executed during
 5 construction. See Appendix 3B, *Environmental Commitments, AMMs, and CMs*.

6 The worker safety codes and standards specify protective measures that must be taken at
 7 construction sites to minimize the risk of injury or death from structural or earth failure (e.g.,
 8 utilizing personal protective equipment).

9 Conformance to these and other applicable design specifications and standards would ensure that
 10 operation of Alternative 4A would not create an increased likelihood of loss of property, personal
 11 injury or death of individuals from structural shaking of surface and subsurface facilities along the
 12 Alternative 4A conveyance alignment in the event of strong seismic shaking. Therefore, there would
 13 be no adverse effect.

14 **CEQA Conclusion:** The impacts of Alternative 4A would be identical to Alternative 4. Seismically
 15 induced strong ground shaking could damage pipelines, tunnels, intake facilities, pumping plant, and
 16 other facilities. The damage could disrupt the water supply through the conveyance system. In an
 17 extreme event, an uncontrolled release of water from the damaged conveyance system could cause
 18 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, which would be
 20 supported by geotechnical investigations required by DWR's environmental commitments (see
 21 Appendix 3B, *Environmental Commitments, AMMs, and CMs*), measures to address this hazard would
 22 be required to conform to applicable design codes, guidelines, and standards. Conformance with
 23 these codes and standards is an environmental commitment by DWR to ensure that ground shaking
 24 risks are minimized as the water conveyance features are operated. The hazard would be controlled
 25 to a safe level and there would be no increased likelihood of loss of property, personal injury or
 26 death due to operation of Alternative 4A. The impact would be less than significant. No mitigation is
 27 required.

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

31 **NEPA Effects:** The potential effect could be substantial because seismically induced ground shaking
 32 could cause liquefaction, and damage pipelines, tunnels, intake facilities, pumping plant, and other
 33 facilities. The damage could disrupt the water supply through the conveyance system. In an extreme
 34 event, an uncontrolled release of water from the damaged conveyance system could cause flooding
 35 and inundation of structures. The effects of Alternative 4A would be identical to Alternative 4. Please
 36 refer to Appendix 3E, *Potential Seismicity and Climate Change Risks to SWP/CVP Water Supplies*, for a
 37 detailed discussion of potential flooding effects.

38 In the process of preparing final facility designs, site-specific geotechnical and groundwater
 39 investigations would be conducted to identify and characterize the vertical (depth) and horizontal
 40 (spatial) extents of liquefiable soil. During final design, site-specific potential for liquefaction would
 41 be investigated by a geotechnical engineer. In areas determined to have a potential for liquefaction,
 42 a California-registered civil engineer or California-certified engineering geologist would develop
 43 design measures and construction methods to meet design criteria established by building codes
 44 and construction standards to ensure that the design earthquake does not cause damage to or

1 failure of the facility. Such measures and methods include removing and replacing potentially
 2 liquefiable soil, strengthening foundations (for example, using post-tensioned slab, reinforced mats,
 3 and piles) to resist excessive total and differential settlements, and using *in situ* ground
 4 improvement techniques (such as deep dynamic compaction, vibro-compaction, vibro-replacement,
 5 compaction grouting, and other similar methods). The results of the site-specific evaluation and
 6 California-registered civil engineer or California-certified engineering geologist's recommendations
 7 would be documented in a detailed geotechnical report prepared in accordance with state
 8 guidelines, in particular *Guidelines for Evaluating and Mitigating Seismic Hazards in California*
 9 (California Geological Survey 2008). Conformance with these design requirements is an
 10 environmental commitment by DWR to ensure that liquefaction risks are minimized as the water
 11 conveyance features are operated (see Appendix 3B, *Environmental Commitments, AMMs, and CMs*).

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

16 Additionally, any modification to a federal levee system would require USACE approval under 33
 17 USC 408 (a 408 Permit).

18 The worker safety codes and standards specify protective measures that must be taken at
 19 construction sites to minimize the risk of injury or death from structural or earth failure (e.g.,
 20 utilizing personal protective equipment). Conformance to these and other applicable design
 21 specifications and standards would ensure that the hazard of liquefaction and associated ground
 22 movements would not create an increased likelihood of loss of property, personal injury or death of
 23 individuals from structural failure resulting from seismic-related ground failure along the
 24 Alternative 4A conveyance alignment during operation of the water conveyance features. Therefore,
 25 the effect would not be adverse.

26 **CEQA Conclusion:** The impacts of Alternative 4A would be identical to Alternative 4. Seismically
 27 induced ground shaking could cause liquefaction. Liquefaction could damage pipelines, tunnels,
 28 intake facilities, pumping plant, and other facilities, and thereby disrupt the water supply through
 29 the conveyance system. In an extreme event, flooding and inundation of structures could result from
 30 an uncontrolled release of water from the damaged conveyance system. (Please refer to Chapter 6,
 31 *Surface Water*, for a detailed discussion of potential flood impacts.) However, through the final
 32 design process, measures to address the liquefaction hazard would be required to conform to
 33 applicable design codes, guidelines, and standards. Conformance with these design standards is an
 34 environmental commitment by DWR to ensure that liquefaction risks are minimized as the water
 35 conveyance features are operated. See Appendix 3B, *Environmental Commitments, AMMs, and CMs*.
 36 The hazard would be controlled to a safe level and there would be no increased likelihood of loss of
 37 property, personal injury or death due to operation of Alternative 4A. The impact would be less than
 38 significant. No mitigation is required.

39 **Impact GEO-9: Loss of Property, Personal Injury, or Death from Landslides and Other Slope** 40 **Instability during Operation of Water Conveyance Features**

41 Alternative 4A would involve excavation that creates new cut-and-fill slopes and construction of
 42 new embankments and levees. As a result of ground shaking and high soil-water content during
 43 heavy rainfall, existing and new slopes that are not properly engineered and natural stream banks

1 could fail and cause damage to facilities. The effects of Alternative 4A would be identical to
2 Alternative 4.

3 **NEPA Effects:** The potential effect could be substantial because levee slopes and stream banks may
4 fail, either from high pore-water pressure caused by high rainfall and weak soil, or from seismic
5 shaking. Structures built on these slopes could be damaged or fail entirely as a result of slope
6 instability. As discussed in Impact SW-2 in Chapter 6, *Surface Water*, operation of the water
7 conveyance features under Alternative 4A would not result in an increase in potential risk for flood
8 management compared to existing conditions. Peak monthly flows under Alternative 4A in the
9 locations considered were similar to or less than those that would occur under existing conditions.
10 Since flows would not be substantially greater, the potential for increased rates of erosion or
11 seepage are low. For additional discussion on the possible exposure of people or structures to
12 impacts from flooding due to levee failure, please refer to Impact SW-6 in Chapter 6, *Surface Water*.

13 During project design, a geotechnical engineer would develop slope stability design criteria (such as
14 minimum slope safety factors and allowable slope deformation and settlement) for the various
15 anticipated loading conditions. The design criteria would be documented in a detailed geotechnical
16 report prepared in accordance with state guidelines, in particular *Guidelines for Evaluating and
17 Mitigating Seismic Hazards in California* (California Geological Survey 2008).

18 Site-specific geotechnical and hydrological information would be used, and the design would
19 conform to the current standards and construction practices. The design requirements would be
20 presented in a detailed geotechnical report. Conformance with these design requirements is an
21 environmental commitment by DWR to ensure that slope stability hazards would be avoided as the
22 water conveyance features are operated. See Appendix 3B, *Environmental Commitments, AMMs, and
23 CMs*. DWR would ensure that the geotechnical design recommendations are included in the design of
24 cut and fill slopes, embankments, and levees to minimize the potential effects from slope failure.
25 DWR would also ensure that the design specifications are properly executed during construction.

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

29 The worker safety codes and standards specify protective measures that must be taken at
30 construction sites to minimize the risk of injury or death from structural or earth failure (e.g.,
31 utilizing personal protective equipment). Conformance to the above and other applicable design
32 specifications and standards would ensure that the hazard of slope instability would not create an
33 increased likelihood of loss of property, personal injury of individuals along the Alternative 4A
34 conveyance alignment during operation of the water conveyance features. Therefore, the effect
35 would not be adverse.

36 **CEQA Conclusion:** Unstable levee slopes and natural stream banks may fail, either from high pore-
37 water pressure caused by high rainfall and weak soil, or from seismic shaking. Structures
38 constructed on these slopes could be damaged or fail entirely as a result of slope instability.

39 However, during the final project design process, as required by DWR's environmental
40 commitments (see Appendix 3B, *Environmental Commitments, AMMs, and CMs*), a geotechnical
41 engineer would develop slope stability design criteria (such as minimum slope safety factors and
42 allowable slope deformation and settlement) for the various anticipated loading conditions during
43 facility operations.

1 DWR would also ensure that measures to address this hazard would be required to conform to
2 applicable design codes, guidelines, and standards. Conformance with these codes and standards is
3 an environmental commitment by DWR to ensure cut and fill slopes and embankments would be
4 stable as the water conveyance features are operated and there would be no increased likelihood of
5 loss of property, personal injury or death due to operation of Alternative 4A. The impact would be
6 less than significant. No mitigation is required.

7 **Impact GEO-10: Loss of Property, Personal Injury, or Death from Seiche or Tsunami during** 8 **Operation of Water Conveyance Features**

9 The effects of Alternative 4A would be identical to Alternative 4.

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

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

20 However, design-level geotechnical studies would be conducted by a licensed civil engineer who
21 practices in geotechnical engineering. The studies would determine the peak ground acceleration
22 caused by movement of the West Tracy fault and the maximum probable seiche wave that could be
23 generated by the ground shaking. The California-registered civil engineer or California-certified
24 engineering geologist's recommended measures to address this hazard, as well as the hazard of a
25 seiche overtopping the expanded Clifton Court Forebay embankment, would conform to applicable
26 design codes, guidelines, and standards. Conformance with these codes and standards is an
27 environmental commitment by DWR to ensure that the adverse effects of a seiche are controlled to
28 an acceptable level while the forebay facility is operated. See Appendix 3B, *Environmental*
29 *Commitments, AMMs, and CMs*.

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

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

37 The worker safety codes and standards specify protective measures that must be taken at
38 construction sites to minimize the risk of injury or death from structural or earth failure (e.g.,
39 utilizing personal protective equipment). Conformance to these and other applicable design
40 specifications and standards would ensure that the embankment for the expanded portion of the
41 Clifton Court Forebay would be designed and constructed to contain and withstand the anticipated
42 maximum seiche wave height and would not create an increased likelihood of loss of property,

1 personal injury or death of individuals along the Alternative 4A conveyance alignment during
2 operation of the water conveyance features. Therefore, the effect would not be adverse.

3 **CEQA Conclusion:** The height of a tsunami wave reaching the Suisun Marsh and the Delta would be
4 small because of the distance from the ocean and attenuating effect of the San Francisco Bay.
5 Similarly, the potential for a significant seiche to occur in most parts of the Plan Area is considered
6 low because the seismic hazard and the geometry of the water bodies (i.e., wide and shallow) near
7 conveyance facilities are not favorable for a seiche to occur. However, assuming the West Tracy fault
8 is potentially active, a potential exists for a seiche to occur in the expanded Clifton Court Forebay
9 (Fugro Consultants 2011).

10 However, design-level geotechnical studies would be conducted by a licensed civil engineer who
11 practices in geotechnical engineering. The studies would determine the peak ground acceleration
12 caused by movement of the West Tracy fault and the maximum probable seiche wave that could be
13 generated by the ground shaking. The California-registered civil engineer or California-certified
14 engineering geologist's recommended measures to address this hazard, as well as the hazard of a
15 seiche overtopping the expanded Clifton Court Forebay embankment, would conform to applicable
16 design codes, guidelines, and standards. Conformance with these codes and standards is an
17 environmental commitment by DWR to ensure that the adverse effects of a seiche are controlled to
18 an acceptable level while the forebay facility is operated. DWR would ensure that the geotechnical
19 design recommendations are included in the design of project facilities and construction
20 specifications to minimize the potential effects from seismic events and consequent seiche waves.
21 DWR would also ensure that the design specifications are properly executed during construction.

22 The effect would not be adverse because the expanded Clifton Court Forebay embankment would be
23 designed and constructed according to applicable design codes, guidelines, and standards to contain
24 and withstand the anticipated maximum seiche wave height, as required by DWR's environmental
25 commitments (see Appendix 3B, *Environmental Commitments, AMMs, and CMs*). There would be no
26 increased likelihood of loss of property, personal injury or death due to operation of Alternative 4A
27 from seiche or tsunami. The impact would be less than significant. No additional mitigation is
28 required.

29 **Impact GEO-11: Ground Failure Caused by Increased Groundwater Surface Elevations from** 30 **Unlined Canal Seepage as a Result of Operating the Water Conveyance Facilities**

31 **NEPA Effects:** Alternative 4A would not involve construction of unlined canals; therefore, there
32 would be no increase in groundwater surface elevations and consequently no effect caused by canal
33 seepage. There would be no effect.

34 **CEQA Conclusion:** Alternative 4A would not involve construction of unlined canals; therefore, there
35 would be no increase in groundwater surface elevations and consequently no impact caused by
36 canal seepage. There would be no impact. No mitigation is required.

37 **Impact GEO-12: Loss of Property, Personal Injury, or Death Resulting from Structural Failure** 38 **Caused by Rupture of a Known Earthquake Fault at Restoration Opportunity Areas**

39 According to the available AP Earthquake Fault Zone Maps, only the Suisun Marsh ROA could be
40 affected by rupture of an earthquake fault. The active Green Valley fault crosses the southwestern
41 corner of the ROA. The active Cordelia fault extends approximately 1 mile into the northwestern
42 corner of the ROA. Rupture of these faults could damage levees and berms constructed as part of the

1 restoration, which could result in failure of the levees and flooding of otherwise protected areas.
2 Under Alternative 4A, no Environmental Commitments would be implemented in the Suisun Marsh
3 ROA.

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

16 **NEPA Effects:** Effects related to rupture of a known earthquake fault within an ROA under
17 Alternative 4A would be similar in mechanism to those described for Alternative 4, but to a
18 substantially smaller magnitude based on the conservation activities proposed under Alternative 4A
19 (and as described in Chapter 3, *Description of Alternatives*).

20 Because there is limited information regarding the depths of the blind faults mentioned above,
21 seismic surveys would be performed in the vicinity of the faults as part of final design. These surveys
22 would be used to verify fault depths where levees and other features would be constructed.
23 Collection of this depth information would be part of broader, design-level geotechnical studies
24 conducted by a geotechnical engineer licensed in the state of California to support all aspects of site-
25 specific project design. The studies would assess site-specific conditions at and near all the project
26 facility locations, including the nature and engineering properties of all soils and underlying geologic
27 strata, and groundwater conditions. The geotechnical engineers' information would be used to
28 develop final engineering solutions to any hazardous condition, consistent with the code and
29 standards requirements of federal, state and local oversight agencies. Conformance with these
30 design standards is an environmental commitment by the project proponents to ensure that risks
31 from a fault rupture are minimized as levees for habitat restoration areas are constructed and
32 maintained (see Appendix 3B, *Environmental Commitments, AMMs, and CMs*). The hazard would be
33 controlled to a safe level by following the proper design standards.

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

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

43 The worker safety codes and standards specify protective measures that must be taken at
44 construction sites to minimize the risk of injury or death from structural or earth failure (e.g.,

1 utilizing personal protective equipment, practicing crane and scaffold safety measures).
 2 Conformance to these and other applicable design specifications and standards would ensure that
 3 the hazard of ground movement in the vicinity of the blind thrusts underlying the ROAs would not
 4 jeopardize the integrity of the levees and other features constructed in the ROAs and would not
 5 create an increased likelihood of loss of property, personal injury or death of individuals in the
 6 ROAs. This effect would not be adverse.

7 **CEQA Conclusion:** As noted above, effects related to rupture of a known earthquake fault within an
 8 ROA under Alternative 4A would be similar in mechanism to those described for Alternative 4, but
 9 to a substantially smaller magnitude based on the restoration activities proposed under Alternative
 10 4A. Rupture of the Cordelia and Green Valley faults could occur at the Suisun Marsh ROA and
 11 damage ROA facilities, such as levees and berms. Damage to these features could result in their
 12 failure, causing flooding of otherwise protected areas. Environmental Commitments under
 13 Alternative 4A would not be implemented in the Suisun Marsh area.

14 However, through the final design process for conservation activities in the ROAs and because there
 15 is limited information regarding the depths of the blind faults mentioned above, seismic surveys
 16 would be performed in the vicinity of the faults as part of final designs. These surveys would be used
 17 to verify fault depths where levees and other features would be constructed. Collection of this depth
 18 information would be part of broader, design-level geotechnical studies conducted by a geotechnical
 19 engineer licensed in the state of California to support all aspects of site-specific project design. The
 20 studies would assess site-specific conditions at and near all the project facility locations, including
 21 the nature and engineering properties of all soils and underlying geologic strata, and groundwater
 22 conditions. The geotechnical engineer's information would be used to develop final engineering
 23 solutions and project designs to any hazardous condition, consistent with DWR's environmental
 24 commitments (see Appendix 3B, *Environmental Commitments, AMMs, and CMs*).

25 Additionally, measures to address the fault rupture hazard would be required to conform to
 26 applicable design codes, guidelines, and standards. Conformance with these design codes,
 27 guidelines, and standards is an environmental commitment by the project proponents to ensure that
 28 fault rupture risks are minimized as the conservation activities are implemented. The hazard would
 29 be controlled to a safe level and there would be no increased likelihood of loss of property, personal
 30 injury or death in the ROAs. The impact would be less than significant. No mitigation is required.

31 **Impact GEO-13: Loss of Property, Personal Injury, or Death from Structural Failure Resulting** 32 **from Strong Seismic Shaking at Restoration Opportunity Areas**

33 Effects related to strong seismic shaking within an ROA under Alternative 4A would be similar in
 34 mechanism to those described for Alternative 4, but to a substantially smaller magnitude based on
 35 the conservation activities proposed under Alternative 4A (and as described in Chapter 3,
 36 *Description of Alternatives*).

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

1 Among all the ROAs, the Suisun Marsh ROA would be most subject to ground shaking because of its
2 proximity to active faults. The Suisun Marsh ROA is subject to a PGA of approximately 0.31–0.35 g
3 for 200-year return interval, while the PGA for the other ROAs ranges from approximately 0.11–0.26
4 g. The ground shaking could damage levees and other structures, and in an extreme event cause
5 levees to fail such that protected areas flood. However, Environmental Commitments under
6 Alternative 4A would not be implemented in the Suisun Marsh area.

7 **NEPA Effects:** All temporary facilities would be designed and built to meet the safety and
8 collapse-prevention requirements for the above-anticipated seismic loads. Therefore, this effect is
9 considered not adverse. No additional mitigation measures are required.

10 Site-specific geotechnical information would be used to further assess the effects of local soil on the
11 OBE and MDE ground shaking and to develop design criteria that minimize the potential of damage.
12 Design-level geotechnical studies would be prepared by a geotechnical engineer licensed in the state
13 of California during project design. The studies would assess site-specific conditions at and near all
14 the project facility locations and provide the basis for designing the levees and other features to
15 withstand the peak ground acceleration caused by fault movement in the region. The geotechnical
16 engineer's recommended measures to address this hazard would conform to applicable design
17 codes, guidelines, and standards. Conformance with these design standards is an environmental
18 commitment by the project proponents to ensure that strong seismic shaking risks are minimized as
19 the conservation activities are implemented (see Appendix 3B, *Environmental Commitments, AMMs,*
20 *and CMs*).

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

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

30 The worker safety codes and standards specify protective measures that must be taken at
31 construction sites to minimize the risk of injury or death from structural or earth failure (e.g.,
32 utilizing personal protective equipment, practicing crane and scaffold safety measures).
33 Conformance to these and other applicable design specifications and standards would ensure that
34 the hazard of seismic shaking would not jeopardize the integrity of levees and other features at the
35 ROAs and would not create an increased likelihood of loss of property, personal injury or death of
36 individuals in the ROAs. This effect would not be adverse.

37 **CEQA Conclusion:** Ground shaking could damage levees, berms, and other structures. Among all the
38 ROAs, the Suisun Marsh ROA would be the most subject to ground shaking because of its proximity
39 to active faults. However, Environmental Commitments under Alternative 4A would not be
40 implemented in the Suisun Marsh area. Damage to these features could result in their failure,
41 causing flooding of otherwise protected areas. Conformance with these design standards is an
42 environmental commitment by the project proponents to ensure that strong seismic shaking risks
43 are minimized as the conservation activities are operated and there would be no increased

1 likelihood of loss of property, personal injury or death in the ROAs (see Appendix 3B, *Environmental*
2 *Commitments, AMMs, and CMs*). The 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**
5 **Opportunity Areas**

6 Effects related to seismic-related ground failure beneath an ROA under Alternative 4A would be
7 similar in mechanism to those described for Alternative 4, but to a substantially smaller magnitude
8 based on the conservation activities proposed under Alternative 4A (and as described in Chapter 3,
9 *Description of Alternatives*).

10 New structural features are proposed at the ROAs, such as levees as part of Environmental
11 Commitment 4, setback levees as part of Environmental Commitment 6. However, the amount of
12 restoration being proposed under Alternative 4A is much smaller in breadth than under Alternative
13 4. Earthquake induced ground shaking could cause liquefaction, resulting in damage to or failure of
14 these levees and other features constructed at the restoration areas. The consequences of
15 liquefaction are manifested in terms of compaction or settlement, loss of bearing capacity, lateral
16 spreading (horizontal soil movement), and increased lateral soil pressure. Failure of levees and
17 other structures could result in flooding of otherwise protected areas in Suisun Marsh and behind
18 new setback levees along the Sacramento and San Joaquin Rivers and in the South Delta ROA

19 The ROAs vary with respect to their liquefaction hazard (see Figure 9-6). All of the levees in the
20 Suisun Marsh ROA have a medium vulnerability to failure from seismic shaking and resultant
21 liquefaction. The liquefaction vulnerability among the other ROAs in which seismically induced
22 levee failure vulnerability has been assessed (see Figure 9-6) (i.e., in parts or all the Cache Slough
23 Complex and South Delta ROAs) is medium or high.

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

27 During final design of conservation facilities, site-specific geotechnical and groundwater
28 investigations would be conducted by a geotechnical engineer to identify and characterize the
29 vertical (depth) and horizontal (spatial) extent of liquefiable soil.

30 In areas determined to have a potential for liquefaction, the engineer would develop design
31 parameters and construction methods to meet the design criteria established to ensure that design
32 earthquake does not cause damage to or failure of the facility. Conformance with these design
33 standards is an environmental commitment by the project proponents to ensure that liquefaction
34 risks are minimized as the conservation activities are implemented.

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. The hazard would be controlled to
38 a safe level.

39 The worker safety codes and standards specify protective measures that must be taken at
40 construction sites to minimize the risk of injury or death from structural or earth failure (e.g.,
41 utilizing personal protective equipment, practicing crane and scaffold safety measures). As required
42 by the environmental commitments (see Appendix 3B, *Environmental Commitments, AMMs, and*

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

7 **CEQA Conclusion:** Earthquake induced ground shaking could cause liquefaction, resulting in damage
 8 to or failure of levees, berms, and other features constructed at the restoration areas. Failure of
 9 levees and other structures could result in flooding of otherwise protected areas. As required by the
 10 environmental commitments (see Appendix 3B, *Environmental Commitments, AMMs, and CMs*), site-
 11 specific geotechnical and groundwater investigations would be conducted to identify and
 12 characterize the vertical (depth) and horizontal (spatial) extent of liquefiable soil. The project
 13 proponents would ensure that the geotechnical design recommendations are included in the design
 14 of levees and construction specifications to minimize the potential effects from liquefaction and
 15 associated hazard. The project proponents would also ensure that the design specifications are
 16 properly executed during implementation and would not create an increased likelihood of loss of
 17 property, personal injury or death of individuals in the ROAs. Further, through the final design
 18 process, measures to address the liquefaction hazard would be required to conform to applicable
 19 design codes, guidelines, and standards. Conformance with these design standards is an
 20 environmental commitment by the project proponents to ensure that liquefaction risks are
 21 minimized as the water conservation features are implemented and there would be no increased
 22 likelihood of loss of property, personal injury or death in the ROAs. The impact would be less than
 23 significant. No mitigation is required.

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

26 Effects related to landslides and slope instability at an ROA under Alternative 4A would be similar in
 27 mechanism to those described for Alternative 4, but to a substantially smaller magnitude based on
 28 the conservation activities proposed under Alternative 4A (and as described in Chapter 3,
 29 *Description of Alternatives*).

30 Implementation of Environmental Commitments 3, 4, 6, and 7 could involve breaching, modification
 31 or removal of existing levees and construction of new levees and embankments. Levee
 32 modifications, including levee breaching or lowering, may be performed to reintroduce tidal
 33 exchange, reconnect remnant sloughs, restore natural remnant meandering tidal channels,
 34 encourage development of dendritic channel networks, and improve floodwater conveyance.

35 Levee modifications could involve the removal of vegetation and excavation of levee materials.
 36 Excess earthen materials could be temporarily stockpiled, then re-spread on the surface of the new
 37 levee slopes where applicable or disposed of offsite. Any breaching or other modifications would be
 38 required to be designed and implemented to maintain the integrity of the levee system and to
 39 conform to flood management standards and permitting processes. This would be coordinated with
 40 the appropriate flood management agencies. Those agencies may include USACE, DWR, CVFPB, and
 41 other flood management agencies. For more detail on potential modifications to levees as a part of
 42 conservation activities, please refer to Chapter 3, *Conservation Strategy*, of the Draft BDCP, and
 43 Appendix 11F, *Substantive BDCP Revisions*.

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

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

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

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

14 As outlined in Appendix 3B, *Environmental Commitments, AMMs, and CMs*, erosion protection
15 measures and protection against related failure of adjacent levees would be taken where levee
16 breaches were developed. Erosion protection measures would also be taken where levee lowering is
17 done for the purposes of allowing seasonal or periodic inundation of lands during high flows or high
18 tides to improve habitat or to reduce velocities and elevations of floodwaters. Neighboring levees
19 could require modification to accommodate increased flows or to reduce effects of changes in water
20 elevation or velocities along channels following inundation of tidal marshes. Hydraulic modeling
21 would be used 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
24 described for the new levees at intake locations. Any new levees would be required to be designed
25 and implemented to conform to applicable flood management standards and permitting processes.

26 Additionally, during project design, a geotechnical engineer would develop slope stability design
27 criteria (such as minimum slope safety factors and allowable slope deformation and settlement) for
28 the various anticipated loading conditions.

29 Site-specific geotechnical and hydrological information would be used, and the design would
30 conform to the current standards and construction practices, as described in Appendix 3B,
31 *Environmental Commitments, AMMs, and CMs*.

32 The project proponents would ensure that the geotechnical design recommendations are included in
33 the design of embankments and levees to minimize the potential effects from slope failure. The
34 project proponents would also ensure that the design specifications are properly executed during
35 implementation.

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

39 The worker safety codes and standards specify protective measures that must be taken at
40 construction sites to minimize the risk of injury or death from structural or earth failure (e.g.,
41 utilizing personal protective equipment). Conformance to the above and other applicable design
42 specifications and standards would ensure that the hazard of slope instability would not jeopardize

1 the integrity of levees and other features at the ROAs and would not create an increased likelihood
 2 of loss of property, personal injury or death of individuals in the ROAs. This effect would not be
 3 adverse.

4 **CEQA Conclusion:** Unstable new and existing levee and embankment slopes could fail as a result of
 5 seismic shaking and as a result of high soil-water content during heavy rainfall and cause flooding of
 6 otherwise protected areas. However, during project design and as required by the project
 7 proponents' environmental commitments (see Appendix 3B, *Environmental Commitments, AMMs,*
 8 *and CMs*), a geotechnical engineer would develop slope stability design criteria (such as minimum
 9 slope safety factors and allowable slope deformation and settlement) for the various anticipated
 10 loading conditions. The project proponents would ensure that the geotechnical design
 11 recommendations are included in the design of embankments and levees to minimize the potential
 12 effects from slope failure. The project proponents would also ensure that the design specifications
 13 are properly executed during implementation.

14 Additionally, as required by the project proponents' environmental commitments (see Appendix 3B,
 15 *Environmental Commitments, AMMs, and CMs*), site-specific geotechnical and hydrological
 16 information would be used to ensure conformance with applicable design guidelines and standards,
 17 such as USACE design measures. Through implementation of these environmental commitments, the
 18 hazard would be controlled to a safe level and there would be no increased likelihood of loss of
 19 property, personal injury or death in the ROAs. The impact would be less than significant. Therefore,
 20 no mitigation is required.

21 **Impact GEO-16: Loss of Property, Personal Injury, or Death from Seiche or Tsunami at** 22 **Restoration Opportunity Areas as a Result of Implementing the Conservation Actions**

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

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

32 **9.3.4.3 Alternative 2D—Dual Conveyance with Modified** 33 **Pipeline/Tunnel and Intakes 1, 2, 3, 4, and 5 (15,000 cfs;** 34 **Operational Scenario B)**

35 **Impact GEO-1: Loss of Property, Personal Injury, or Death from Structural Failure Resulting** 36 **from Strong Seismic Shaking of Water Conveyance Features during Construction**

37 **NEPA Effects:** Alternative 2D would include the same physical/structural components as Alternative
 38 4, but would entail two additional intakes. These intakes would be located where the intakes are
 39 sited for Alternative 1A. These differences would present a slightly higher hazard of seismic shaking
 40 but would not substantially change the hazard of loss of property, personal injury, or death during

1 construction. The effects of Alternative 2D would, therefore, be similar to those of Alternative 4. See
2 the discussion of Impact GEO-1 under Alternative 4. There would be no adverse effect.

3 **CEQA Conclusion:** Seismically induced ground shaking that is estimated to occur and the resultant
4 ground motion anticipated at Alternative 2D construction sites, including the intake locations, the
5 tunnels, the pipelines and the forebays, could cause collapse or other failure of project facilities
6 while under construction. DWR would conform to Cal-OSHA and other state code requirements,
7 such as shoring, bracing, lighting, excavation depth restrictions, required slope angles, and other
8 measures, to protect worker safety. Conformance with these standards and codes is an
9 environmental commitment of the project (see Appendix 3B, *Environmental Commitments, AMMs,*
10 *and CMs*). Conformance with these health and safety requirements and the application of accepted,
11 proven construction engineering practices would reduce this risk and there would be no increased
12 likelihood of loss of property, personal injury or death due to construction of Alternative 2D. This
13 impact would be less than significant. No mitigation is required.

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

16 Alternative 2D would include the same physical/structural components as Alternative 4, but would
17 entail two additional intakes. Soil excavation in areas with shallow or perched groundwater levels
18 would require the pumping of groundwater from the excavations to allow for construction of
19 facilities. This can be anticipated at all intake locations (Sites 1–5) and the pumping plant site, where
20 70% of the dewatering for Alternative 2D would take place. All of the intake locations for Alternative
21 2D are located on alluvial floodbasin deposits, alluvial floodplain deposits and natural levee
22 deposits. Similar dewatering may be necessary where intake and forebay pipelines cross waterways
23 and major irrigation canals east of the Sacramento River and north of the proposed intermediate
24 forebay. The conveyance pipeline built between Intake 1 and the first (northernmost) tunnel shaft
25 would cross three canals or ditches prior to joining with the conveyance pipeline from Intake 2. The
26 conveyance pipeline built between Intake 3 and the intermediate forebay would cross five canals or
27 ditches prior to joining the conveyance pipeline for Intake 4.

28 **NEPA Effects:** This potential effect could be substantial because settlement or collapse during
29 dewatering could cause injury of workers at the construction sites as a result of collapse of
30 excavations. The hazard of settlement and subsequent collapse of excavations would be evaluated
31 by assessing site-specific geotechnical and hydrological conditions at intake locations, as well as
32 where intake and forebay pipelines cross waterways and major irrigation canals. The additional
33 intakes would present a slightly higher hazard of settlement or collapse but would not substantially
34 change the hazard of loss of property, personal injury, or death during construction. The effects of
35 Alternative 2D would, therefore, be similar to those of Alternative 4. See the description and findings
36 under Impact GEO-2, Alternative 4. There would be no adverse effect.

37 **CEQA Conclusion:** Settlement or failure of excavations during construction could result in loss of
38 property or personal injury. However, DWR would conform to Cal-OSHA and other state code
39 requirements, such as using seepage cutoff walls, shoring, and other measures, to protect worker
40 safety. DWR has made an environmental commitment to use the appropriate code and standard
41 requirements to minimize potential risks (Appendix 3B, *Environmental Commitments, AMMs, and*
42 *CMs*) and there would be no increased likelihood of loss of property, personal injury or death due to
43 construction of Alternative 2D. The impact would be less than significant. No mitigation is required.

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

3 **NEPA Effects:** Alternative 2D would include the same physical/structural components as Alternative
4 4, but would entail two additional intakes. These differences would present a slightly higher hazard
5 of ground settlement of tunnels but would not change the hazard of loss of property, personal injury,
6 or death during construction. The effects of Alternative 2D would, therefore, be similar to those of
7 Alternative 4, but somewhat greater due to the two additional structures. See the description and
8 findings under Alternative 4. There would be no adverse effect.

9 **CEQA Conclusion:** Ground settlement as a result of geotechnical investigation and the tunneling
10 operation could result in loss of property or personal injury during construction. However, DWR
11 would conform to Cal-OSHA, USACE and other design requirements to protect worker safety. DWR
12 has made conformance to geotechnical design recommendations and monitoring an environmental
13 commitment and an AMM (see Appendix 3B, *Environmental Commitments, AMMs, and CMs*). Hazards
14 to workers and project structures would be controlled at safe levels and there would be no
15 increased likelihood of loss of property, personal injury or death due to construction of Alternative
16 2D. The impact would be less than significant. No mitigation is required.

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

19 **NEPA Effects:** Alternative 2D would include the same physical/structural components as Alternative
20 4, but would entail two additional intakes. These additional intakes would have a slightly higher
21 hazard of slope failure at borrow and storage sites and would not change the hazard of loss of
22 property, personal injury, or death during construction. The effects of Alternative 2D would,
23 therefore, be similar to those of Alternative 4. See the description and findings under Alternative 4.
24 There would be no adverse effect.

25 **CEQA Conclusion:** Settlement/failure of cutslopes of borrow sites and failure of soil/RTM fill slopes
26 could result in loss of property or personal injury during construction. However, because DWR
27 would conform to Cal-OSHA and other state code requirements and conform to applicable
28 geotechnical design guidelines and standards, such as USACE design measures, the hazard would be
29 controlled to a safe level and there would be no increased likelihood of loss of property, personal
30 injury or death due to construction of Alternative 2D. The impact would be less than significant. No
31 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**
34 **Features**

35 **NEPA Effects:** Alternative 2D would include the same physical/structural components as Alternative
36 4, but would entail two additional intakes. These additional structures would have a slightly higher
37 hazard of structural failure from construction-related ground motions and would create only a
38 slightly greater hazard of loss of property, personal injury, or death during operation of the water
39 conveyance features due to a greater number of structures. The effects of Alternative 2D would,
40 therefore, be similar to 4. See the description and findings under Alternative 4. There would be no
41 adverse effect.

1 **CEQA Conclusion:** Construction-related ground motions and traffic effects could initiate
 2 liquefaction, which could cause failure of structures during construction. The impact could be
 3 significant. However, because DWR would conform to Cal-OSHA and other state code requirements
 4 and conform to applicable design guidelines and standards, such as USACE design measures, in
 5 addition to implementation of Mitigation Measures TRANS-2a and TRANS-2b, as well as the
 6 maintenance and reconstruction of levees through Mitigation Measure TRANS-2c, the hazard would
 7 be controlled to a level that would protect worker safety (see Appendix 3B, *Environmental*
 8 *Commitments, AMMs, and CMs*) and there would be no increased likelihood of loss of property,
 9 personal injury or death due to construction of Alternative 2D. The impact would be less than
 10 significant.

11 **Mitigation Measure TRANS-2a: Prohibit Construction Activity on Physically Deficient**
 12 **Roadway Segments**

13 Please refer to Mitigation Measure TRANS-2a in Alternative 1A, Impact TRANS-2, in Chapter 19,
 14 *Transportation*.

15 **Mitigation Measure TRANS-2b: Limit Construction Activity on Physically Deficient**
 16 **Roadway Segments**

17 Please refer to Mitigation Measure TRANS-2b in Alternative 1A, Impact TRANS-2, in Chapter 19,
 18 *Transportation*.

19 **Mitigation Measure TRANS-2c: Improve Physical Condition of Affected Roadway Segments**
 20 **as Stipulated in Mitigation Agreements or Encroachment Permits**

21 Please refer to Mitigation Measure TRANS-2c in Alternative 1A, Impact TRANS-2, in Chapter 19,
 22 *Transportation*.

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

25 **NEPA Effects:** Alternative 2D would include the same physical/structural components as Alternative
 26 4, but would entail two additional intakes. These additional intakes would have a slightly higher
 27 hazard of fault rupture and would cause a slight increase in the hazard of loss of property, personal
 28 injury, or death during operation of the water conveyance features due to the additional structures.
 29 The effects of Alternative 2D would, therefore, be similar to those of Alternative 4. See the
 30 description and findings under Alternative 4. There would be no adverse effect.

31 **CEQA Conclusion:** There are no active faults capable of surface rupture that extend into the
 32 Alternative 2D alignment. Facilities lying directly on or near active blind faults, such as the concrete
 33 batch plants and fuel stations near Twin Cities Road and Interstate 5 and at the expanded Clifton
 34 Court Forebay, as well as the expanded Forebay itself for Alternative 2D, may have an increased
 35 likelihood of loss of property or personal injury at these sites in the event of seismically induced
 36 ground movement. However, DWR would conform to Cal-OSHA and other state code requirements,
 37 such as shoring, bracing, lighting, excavation depth restrictions, required slope angles, and other
 38 measures, to protect worker safety. Conformance with these standards and codes is an
 39 environmental commitment of the project (see Appendix 3B, *Environmental Commitments, AMMs,*
 40 *and CMs*). Conformance with these health and safety requirements and the application of accepted,
 41 proven construction engineering practices would reduce this risk and there would be no increased

1 likelihood of loss of property, personal injury or death due to construction of Alternative 2D. This
2 impact would be less than significant. No mitigation is required.

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

5 **NEPA Effects:** Alternative 2D would include the same physical/structural components as Alternative
6 4, but would entail two additional intakes. These additional intakes would have a slightly higher
7 hazard of structural failure from seismic shaking and would marginally increase the hazard of loss of
8 property, personal injury, or death during operation of the water conveyance features due to the
9 greater number of structures. The effects of Alternative 2D would, therefore, be similar to those of
10 Alternative 4. See the description and findings under Alternative 4. There would be no adverse
11 effect.

12 **CEQA Conclusion:** Seismically induced strong ground shaking could damage pipelines, tunnels,
13 intake facilities, pumping plant, and other facilities. The damage could disrupt the water supply
14 through the conveyance system. In an extreme event, an uncontrolled release of water from the
15 damaged conveyance system could cause flooding and inundation of structures. (Please refer to
16 Chapter 6, *Surface Water*, for a detailed discussion of potential flood impacts.) However, through the
17 final design process, which would be supported by geotechnical investigations required by DWR's
18 environmental commitments (see Appendix 3B, *Environmental Commitments, AMMs, and CMs*),
19 measures to address this hazard would be required to conform to applicable design codes,
20 guidelines, and standards. Conformance with these codes and standards is an environmental
21 commitment by DWR to ensure that ground shaking risks are minimized as the water conveyance
22 features are operated (see Appendix 3B). 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 operation of
24 Alternative 2D. The impact would be less than significant. No mitigation is required.

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

28 **NEPA Effects:** Alternative 2D would include the same physical/structural components as Alternative
29 4, but would entail two additional intakes. These additional intakes would have a slightly higher
30 hazard of structural failure from ground failure and would result in a marginal increase in the
31 hazard of loss of property, personal injury, or death during operation of the water conveyance
32 features due to the greater number of structures. The effects of Alternative 2D would, therefore, be
33 similar to those of Alternative 4. See the description and findings under Alternative 4. There would
34 be no adverse effect.

35 **CEQA Conclusion:** Seismically induced ground shaking could cause liquefaction. Liquefaction could
36 damage pipelines, tunnels, intake facilities, pumping plant, and other facilities, and thereby disrupt
37 the water supply through the conveyance system. In an extreme event, flooding and inundation of
38 structures could result from an uncontrolled release of water from the damaged conveyance system.
39 (Please refer to Chapter 6, *Surface Water* for a detailed discussion of potential flood impacts.)
40 However, through the final design process, measures to address the liquefaction hazard would be
41 required to conform to applicable design codes, guidelines, and standards. Conformance with these
42 design standards is an environmental commitment by DWR to ensure that liquefaction risks are
43 minimized as the water conveyance features are operated (see Appendix 3B, *Environmental*

1 *Commitments, AMMs, and CMs*). The hazard would be controlled to a safe level and there would be no
 2 increased likelihood of loss of property, personal injury or death due to operation of Alternative 2D.
 3 The impact would be less than significant. No mitigation is required.

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

6 **NEPA Effects:** Alternative 2D would include the same physical/structural components as Alternative
 7 4, but would entail two additional intakes. These additional structures create a slightly higher
 8 hazard of landslides and other slope instability and would only marginally increase the hazard of
 9 loss of property, personal injury, or death during operation of the water conveyance features. The
 10 effects of Alternative 2D would, therefore, be similar to those of Alternative 4. See the description
 11 and findings under Alternative 4. There would be no adverse effect.

12 **CEQA Conclusion:** Unstable levee slopes and natural stream banks may fail, either from high pore-
 13 water pressure caused by high rainfall and weak soil, or from seismic shaking. Structures
 14 constructed on these slopes could be damaged or fail entirely as a result of slope instability.
 15 However, through the final design process, measures to address this hazard would be required to
 16 conform to applicable design codes, guidelines, and standards. As described in Appendix 3B,
 17 *Environmental Commitments, AMMs, and CMs*, a geotechnical engineer would develop slope stability
 18 design criteria (such as minimum slope safety factors and allowable slope deformation and
 19 settlement) for the various anticipated loading conditions during facility operations. DWR would
 20 also ensure that measures to address this hazard would be required to conform to applicable design
 21 codes, guidelines, and standards. Conformance with these codes and standards is an environmental
 22 commitment by DWR to ensure cut and fill slopes and embankments would be stable as the water
 23 conveyance features are operated and there would be no increased likelihood of loss of property,
 24 personal injury or death due to operation of Alternative 2D (see Appendix 3B). The impact would be
 25 less than significant. No mitigation is required.

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

28 **NEPA Effects:** Alternative 2D would include the same physical/structural components as Alternative
 29 4, but would entail two additional intakes. These additional intakes would create a slightly higher
 30 hazard of seiche or tsunami and would only marginally change the hazard of loss of property,
 31 personal injury, or death during operation of the water conveyance features due to the additional
 32 structures. The effects of Alternative 2D would, therefore, be similar to those of Alternative 4. See
 33 the description and findings under Alternative 4. There would be no adverse effect.

34 **CEQA Conclusion:** Based on recorded tsunami wave heights at the Golden Gate (Contra Costa
 35 Transportation Agency 2009) and in the interior of the San Francisco Bay and on tsunami
 36 inundation maps prepared by the California Department of Conservation (2009), the height of a
 37 tsunami wave reaching the Suisun Marsh and the Delta would be small because of the distance from
 38 the ocean and attenuating effect of the San Francisco Bay. Similarly, the potential for a significant
 39 seiche to occur in most parts of the project area is considered low because the seismic hazard and
 40 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 the West Tracy fault is potentially active, a
 42 potential exists for a seiche to occur in the expanded Clifton Court Forebay. The impact would not be
 43 significant because the expanded Clifton Court Forebay embankment would be designed and

1 constructed according to applicable design codes, guidelines, and standards to contain and
 2 withstand the anticipated maximum seiche wave height, as required by DWR's environmental
 3 commitments (see Appendix 3B, *Environmental Commitments, AMMs, and CMs*). There would be no
 4 increased likelihood of loss of property, personal injury or death due to operation of Alternative 2D
 5 from seiche or tsunami. The impact would be less than significant. No additional mitigation is
 6 required.

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

9 **NEPA Effects:** Alternative 2D would not involve construction of unlined canals; therefore, there
 10 would be no increase in groundwater surface elevations and consequently no effect caused by canal
 11 seepage. There would be no effect.

12 **CEQA Conclusion:** Alternative 2D would not involve construction of unlined canals; therefore, there
 13 would be no increase in groundwater surface elevations and consequently no impact caused by
 14 canal seepage. There would be no impact. No mitigation is required.

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

17 **NEPA Effects:** Implementation of Environmental Commitments 3, 4, 6–12, 15, and 16 would be
 18 similar under Alternative 2D to that under Alternative 4A, but would involve up to approximately
 19 14,958 acres of restoration. The effect would be similar to that of Alternative 4A. See Impact GEO-12
 20 under Alternative 4A. There would be no adverse effect.

21 **CEQA Conclusion:** According to the available AP Earthquake Fault Zone Maps, only the Suisun Marsh
 22 ROA could be affected by rupture of an earthquake fault. The active Green Valley fault crosses the
 23 southwestern corner of the ROA. The active Cordelia fault extends approximately 1 mile into the
 24 northwestern corner of the ROA. Rupture of the Cordelia and Green Valley faults could occur at the
 25 Suisun Marsh ROA and damage ROA facilities, such as levees and berms. Damage to these features
 26 could result in their failure, causing flooding of otherwise protected areas. However, Alternative 2D
 27 would not include implementation of Environmental Commitments in the Suisun Marsh area.

28 Additionally, the final design process for habitat restoration and enhancement activities in the ROAs
 29 would include measures to address the fault rupture hazard, as required to conform to applicable
 30 design codes, guidelines, and standards. As described in Appendix 3B, *Environmental Commitments,*
 31 *AMMs, and CMs*, such design codes, guidelines, and standards include the Division of Safety of Dams
 32 *Guidelines for Use of the Consequence-Hazard Matrix and Selection of Ground Motion Parameters,*
 33 *DWR's Division of Flood Management FloodSAFE Urban Levee Design Criteria,* and USACE's
 34 *Engineering and Design—Earthquake Design and Evaluation for Civil Works Projects.* Conformance
 35 with these design standards is an environmental commitment by the project proponents to ensure
 36 that fault rupture risks are minimized as the Environmental Commitments are implemented (see
 37 Appendix 3B). Therefore, any hazard would be controlled to a safe level and would not create an
 38 increased likelihood of loss of property, personal injury or death of individuals in the ROAs. The
 39 impact would be less than significant. No mitigation is required.

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

3 **NEPA Effects:** Implementation of Environmental Commitments 3, 4, 6–12, 15, and 16 would be
 4 similar under Alternative 2D as under Alternative 4A but would involve up to approximately 14,958
 5 acres of restoration. See Impact GEO-13 under Alternative 4A. There would be no adverse effect.

6 **CEQA Conclusion:** Ground shaking could damage levees, berms, and other structures. Among all the
 7 ROAs, the Suisun Marsh ROA would be the most subject to ground shaking because of its proximity
 8 to active faults. However, Alternative 2D would not include implementation of Environmental
 9 Commitments in the Suisun Marsh area. Additionally, conformance with design standards is an
 10 environmental commitment by the project proponents to ensure that any remaining strong seismic
 11 shaking risks are minimized as the conservation activities are operated and there would be no
 12 increased likelihood of loss of property, personal injury or death in the ROAs (see Appendix 3B,
 13 *Environmental Commitments, AMMs, and CMs*). The impact would be less than significant. No
 14 mitigation is required.

15 **Impact GEO-14: Loss of Property, Personal Injury, or Death from Structural Failure Resulting**
 16 **from Seismic-Related Ground Failure (Including Liquefaction beneath Restoration**
 17 **Opportunity Areas)**

18 **NEPA Effects:** Implementation of Environmental Commitments 3, 4, 6–12, 15, and 16 would be
 19 similar under Alternative 2D as under Alternative 4A but would involve up to approximately 14,958
 20 acres of restoration, as described in Section 9.3.4.2. See Impact GEO-14 under Alternative 4A. There
 21 would be no adverse effect.

22 **CEQA Conclusion:** Earthquake-induced ground shaking could cause liquefaction, resulting in
 23 damage to or failure of levees, berms, and other features constructed at the restoration areas.
 24 Failure of levees and other structures could result in flooding of otherwise protected areas.
 25 However, through the final design process, measures to address the liquefaction hazard would be
 26 required to conform to applicable design codes, guidelines, and standards. As described in Appendix
 27 3B, *Environmental Commitments, AMMs, and CMs*, such design codes, guidelines, and standards
 28 include USACE's *Engineering and Design—Stability Analysis of Concrete Structures and Soil*
 29 *Liquefaction during Earthquakes*, by the Earthquake Engineering Research Institute. Conformance
 30 with these design standards is an environmental commitment by the project proponents to ensure
 31 that liquefaction risks are minimized as the water conservation features are implemented (see
 32 Appendix 3B). The hazard would be controlled to a safe level and would not create an increased
 33 likelihood of loss of property, personal injury or death of individuals in the ROAs. The impact would
 34 be less than significant. No mitigation is required.

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

37 **NEPA Effects:** Implementation of Environmental Commitments 3, 4, 6–12, 15, and 16 would be
 38 similar under Alternative 2D as under 4A but would involve up to approximately 14,958 acres of
 39 restoration, as described in Section 9.3.4.2. See Impact GEO-15 under Alternative 4A. There would
 40 be no adverse effect.

1 **CEQA Conclusion:** Unstable new and existing levee and embankment slopes could fail as a result of
 2 seismic shaking and as a result of high soil-water content during heavy rainfall and cause flooding of
 3 otherwise protected areas. However, because project proponents would conform to applicable
 4 design guidelines and standards, such as USACE design measures, the hazard would be controlled to
 5 a safe level and would not create an increased likelihood of loss of property, personal injury or death
 6 of individuals in the ROAs. The impact would be less than significant. No mitigation is required.

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

9 **NEPA Effects:** Implementation of Environmental Commitments 3, 4, 6–12, 15, and 16 would be
 10 similar under Alternative 2D as under Alternative 4A but would involve up to approximately 14,958
 11 acres of restoration, as described in Section 9.3.4.2. The distance from the ocean and attenuating
 12 effect of the San Francisco Bay would likely allow only a low tsunami wave height to reach the
 13 Suisun Marsh and the Delta. Conditions for a seiche to occur at the ROAs are not favorable.
 14 Therefore, the effect would not be adverse.

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

21 **9.3.4.4 Alternative 5A—Dual Conveyance with Modified**
 22 **Pipeline/Tunnel and Intake 2 (3,000 cfs; Operational Scenario C)**

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 5A would include the same physical/structural components as Alternative
 26 4, but would entail two fewer intakes. These differences would not substantially change the hazard
 27 of loss of property, personal injury, or death during construction. The effects of Alternative 5A
 28 would, therefore, be similar to Alternative 4 but lesser in magnitude due to fewer structures. See the
 29 discussion of Impact GEO-1 under Alternative 4. There would be no adverse effect.

30 **CEQA Conclusion:** Seismically induced ground shaking that is estimated to occur and the resultant
 31 ground motion anticipated at Alternative 5A construction sites, including the intake locations, the
 32 tunnels, the pipelines and the forebays, could cause collapse or other failure of project facilities
 33 while under construction. DWR would conform to Cal-OSHA and other state code requirements,
 34 such as shoring, bracing, lighting, excavation depth restrictions, required slope angles, and other
 35 measures, to protect worker safety. Conformance with these standards and codes is an
 36 environmental commitment of the project (see Appendix 3B, *Environmental Commitments, AMMs,*
 37 *and CMs*). Conformance with these health and safety requirements and the application of accepted,
 38 proven construction engineering practices would reduce this risk and there would be no increased
 39 likelihood of loss of property, personal injury or death due to construction of Alternative 5A. This
 40 impact would be less than significant. No mitigation is required.

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

3 **NEPA Effects:** Alternative 5A would include the same physical/structural components as Alternative
4 4, except that it would entail two fewer intakes. Because the tunnels would connect directly to the
5 Intake 2 work area, Alternative 5 would not involve excavations for pipelines between intakes and
6 tunnels; therefore, these differences would present a lower hazard of settlement or collapse of
7 excavations caused by dewatering but would not substantially change the hazard of loss of property,
8 personal injury, or death during construction compared to Alternative 4. The effects of Alternative
9 5A would, therefore, be similar to Alternative 4. See the description and findings under Alternative
10 4. There would be no adverse effect.

11 **CEQA Conclusion:** Settlement or failure of excavations during construction could result in loss of
12 property or personal injury. However, DWR would conform to Cal-OSHA and other state code
13 requirements, such as using seepage cutoff walls, shoring, and other measures, to protect worker
14 safety. DWR has made an environmental commitment to use the appropriate code and standard
15 requirements to minimize potential risks (Appendix 3B, *Environmental Commitments, AMMs, and*
16 *CMs*) and there would be no increased likelihood of loss of property, personal injury or death due to
17 construction of Alternative 5A. The impact would be less than significant. No mitigation is required.

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

20 **NEPA Effects:** Alternative 5A would include the same physical/structural components as Alternative
21 4, except that it would entail two fewer intakes. These differences would create a lower hazard of
22 ground settlement over the tunnels and but would not substantially change the hazard of loss of
23 property, personal injury, or death during construction compared to Alternative 4. The effects of
24 Alternative 5A would, therefore, be similar to Alternative 4. See the description and findings under
25 Alternative 4. There would be no adverse effect.

26 **CEQA Conclusion:** Ground settlement as a result of geotechnical investigation and the tunneling
27 operation could result in loss of property or personal injury during construction. However, DWR
28 would conform to Cal-OSHA, USACE and other design requirements to protect worker safety. DWR
29 has made conformance to geotechnical design recommendations and monitoring an environmental
30 commitment and an AMM (Appendix 3B, *Environmental Commitments, AMMs, and CMs*). Hazards to
31 workers and project structures would be controlled at safe levels and there would be no increased
32 likelihood of loss of property, personal injury or death due to construction of Alternative 5A. The
33 impact would be less than significant. No mitigation is required.

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

36 **NEPA Effects:** Alternative 5A would include the same physical/structural components as Alternative
37 4, but would entail two fewer intakes. These differences would present a lower hazard of slope
38 failure at borrow and spoils storage sites but would not substantially change the hazard of loss of
39 property, personal injury, or death during construction compared to Alternative 4. The effects of
40 Alternative 5A would, therefore, be similar to those of Alternative 4. See the description and findings
41 under Alternative 4. 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
 3 would conform to Cal-OSHA and other state code requirements and conform to applicable
 4 geotechnical design guidelines and standards, such as USACE design measures, the hazard would be
 5 controlled to a safe level and there would be no increased likelihood of loss of property, personal
 6 injury or death due to construction of Alternative 5A. The impact would be less than significant. No
 7 mitigation is required.

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

11 **NEPA Effects:** Alternative 5A would include the same physical/structural components as Alternative
 12 4, but would entail two fewer intakes. These differences would present a slightly lower hazard of
 13 structural failure from construction-related ground motions but would not substantially change the
 14 hazard of loss of property, personal injury, or death during construction compared to Alternative 4.
 15 The effects of Alternative 5A would, therefore, be similar to those of Alternative 4. See the
 16 description and findings under Alternative 4. There would be no adverse effect.

17 **CEQA Conclusion:** Construction-related ground motions and traffic effects could initiate
 18 liquefaction, which could cause failure of structures during construction. The impact could be
 19 significant. However, because DWR would conform to Cal-OSHA and other state code requirements
 20 and conform to applicable design guidelines and standards, such as USACE design measures, in
 21 addition to implementation of Mitigation Measures TRANS-2a and TRANS-2b, as well as the
 22 maintenance and reconstruction of levees through Mitigation Measure TRANS-2c, the hazard would
 23 be controlled to a level that would protect worker safety (see Appendix 3B, *Environmental*
 24 *Commitments, AMMs, and CMs*) and there would be no increased likelihood of loss of property,
 25 personal injury or death due to construction of Alternative 5A. The impact would be less than
 26 significant.

27 **Mitigation Measure TRANS-2a: Prohibit Construction Activity on Physically Deficient**
 28 **Roadway Segments**

29 Please refer to Mitigation Measure TRANS-2a in Alternative 1A, Impact TRANS-2, in Chapter 19,
 30 *Transportation*.

31 **Mitigation Measure TRANS-2b: Limit Construction Activity on Physically Deficient**
 32 **Roadway Segments**

33 Please refer to Mitigation Measure TRANS-2b in Alternative 1A, Impact TRANS-2, in Chapter 19,
 34 *Transportation*.

35 **Mitigation Measure TRANS-2c: Improve Physical Condition of Affected Roadway Segments**
 36 **as Stipulated in Mitigation Agreements or Encroachment Permits**

37 Please refer to Mitigation Measure TRANS-2c in Alternative 1A, Impact TRANS-2, in Chapter 19,
 38 *Transportation*.

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 5A would include the same physical/structural components as Alternative
 4 4, but would entail two fewer intakes. These differences would present a slightly lower hazard from
 5 an earthquake fault rupture but would not substantially change the hazard of loss of property,
 6 personal injury, or death during construction compared to Alternative 4. The effects of Alternative
 7 5A would, therefore, be similar to those of Alternative 4. See the description and findings under
 8 Alternative 4. There would be no adverse effect.

9 **CEQA Conclusion:** There are no active faults capable of surface rupture that extend into the
 10 Alternative 5A alignment. Facilities lying directly on or near active blind faults, such as the concrete
 11 batch plants and fuel stations near Twin Cities Road and Interstate 5 and at the expanded Clifton
 12 Court Forebay, as well as the expanded forebay itself for Alternative 5A, may have an increased
 13 likelihood of loss of property or personal injury at these sites in the event of seismically induced
 14 ground movement. However, DWR would conform to Cal-OSHA and other state code requirements,
 15 such as shoring, bracing, lighting, excavation depth restrictions, required slope angles, and other
 16 measures, to protect worker safety. Conformance with these standards and codes is an
 17 environmental commitment of the project (see Appendix 3B, *Environmental Commitments, AMMs,*
 18 *and CMs*). Conformance with these health and safety requirements and the application of accepted,
 19 proven construction engineering practices would reduce this risk and there would be no increased
 20 likelihood of loss of property, personal injury or death due to construction of Alternative 5A. This
 21 impact would be less than significant. 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 5A would include the same physical/structural components as Alternative
 25 4, but would entail two fewer intakes. These differences would present a slightly lower hazard from
 26 seismic shaking but would not substantially change the hazard of loss of property, personal injury,
 27 or death during construction compared to Alternative 4. The effects of Alternative 5A would,
 28 therefore, be similar to those of Alternative 4. See the description and findings under Alternative 4.
 29 There would be no adverse effect.

30 **CEQA Conclusion:** Seismically induced strong ground shaking could damage pipelines, tunnels,
 31 intake facilities, pumping plant, and other facilities. The damage could disrupt the water supply
 32 through the conveyance system. In an extreme event, an uncontrolled release of water from the
 33 damaged conveyance system could cause flooding and inundation of structures. (Please refer to
 34 Chapter 6, *Surface Water*, for a detailed discussion of potential flood impacts.) However, through the
 35 final design process, which would be supported by geotechnical investigations required by DWR's
 36 environmental commitments (see Appendix 3B, *Environmental Commitments, AMMs, and CMs*),
 37 measures to address this hazard would be required to conform to applicable design codes,
 38 guidelines, and standards. Conformance with these codes and standards is an environmental
 39 commitment by DWR to ensure that ground shaking risks are minimized as the water conveyance
 40 features are operated (see Appendix 3B). The hazard would be controlled to a safe level and there
 41 would be no increased likelihood of loss of property, personal injury or death due to operation of
 42 Alternative 5A. The impact would be less than significant. No mitigation is 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 **NEPA Effects:** Alternative 5A would include the same physical/structural components as Alternative
 5 4, but would entail two fewer intakes. These differences would present a slightly lower hazard of
 6 structural failure from ground failure but would not substantially change the hazard of loss of
 7 property, personal injury, or death during construction compared to Alternative 4. The effects of
 8 Alternative 5A would, therefore, be similar to those of Alternative 4. See the description and findings
 9 under Alternative 4. There would be no adverse effect.

10 **CEQA Conclusion:** Seismically induced ground shaking could cause liquefaction. Liquefaction could
 11 damage pipelines, tunnels, intake facilities, pumping plant, and other facilities, and thereby disrupt
 12 the water supply through the conveyance system. In an extreme event, flooding and inundation of
 13 structures could result from an uncontrolled release of water from the damaged conveyance system.
 14 (Please refer to Chapter 6, *Surface Water*, for a detailed discussion of potential flood impacts.)
 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, AMMs, and CMs*, such
 18 design codes, guidelines, and standards include USACE's *Engineering and Design—Stability Analysis*
 19 *of Concrete Structures and Soil Liquefaction during Earthquakes*, by the Earthquake Engineering
 20 Research Institute. Conformance with these design standards is an environmental commitment by
 21 DWR to ensure that liquefaction risks are minimized as the water conveyance features are operated
 22 (see Appendix 3B). The hazard would be controlled to a safe level and there would be no increased
 23 likelihood of loss of property, personal injury or death due to operation of Alternative 5A. The
 24 impact would be less than significant. No mitigation is required.

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

27 **NEPA Effects:** Alternative 5A would include the same physical/structural components as Alternative
 28 4, but would entail two fewer intakes. These differences would present a slightly lower hazard from
 29 landslides and other slope instability but would not substantially change the hazard of loss of
 30 property, personal injury, or death during construction compared to Alternative 4. The effects of
 31 Alternative 5A would, therefore, be similar to those of Alternative 4. See the description and findings
 32 under Alternative 4. There would be no adverse effect.

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
 35 constructed on these slopes could be damaged or fail entirely as a result of slope instability.
 36 However, through the final design process, measures to address this hazard would be required to
 37 conform to applicable design codes, guidelines, and standards. As described in Section 9.3.1, and in
 38 Appendix 3B, *Environmental Commitments, AMMs, and CMs*, a geotechnical engineer would develop
 39 slope stability design criteria (such as minimum slope safety factors and allowable slope
 40 deformation and settlement) for the various anticipated loading conditions during facility
 41 operations. DWR would also ensure that measures to address this hazard would be required to
 42 conform to applicable design codes, guidelines, and standards. Such design codes, guidelines, and
 43 standards include the California Building Code and resource agency and professional engineering
 44 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
 2 DWR to ensure cut and fill slopes and embankments would be stable as the water conveyance
 3 features are operated and there would be no increased likelihood of loss of property, personal injury
 4 or death due to operation of Alternative 5A (see Appendix 3B). The impact would be less than
 5 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 5A would include the same physical/structural components as Alternative
 9 4, but would entail two fewer intakes. These differences would present a slightly lower hazard of a
 10 seiche or tsunami but would not substantially change the hazard of loss of property, personal injury,
 11 or death during construction compared to Alternative 4. The effects of Alternative 5A would,
 12 therefore, be similar to those of Alternative 4. See the description and findings under Alternative 4.
 13 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
 16 inundation maps prepared by the California Department of Conservation (2009), the height of a
 17 tsunami wave reaching the Suisun Marsh and the Delta would be small because of the distance from
 18 the ocean and attenuating effect of the San Francisco Bay. Similarly, the potential for a significant
 19 seiche to occur in most parts of the project area is considered low because the seismic hazard and
 20 the geometry of the water bodies (i.e., wide and shallow) near conveyance facilities are not
 21 favorable for a seiche to occur. However, assuming the West Tracy fault is potentially active, a
 22 potential exists for a seiche to occur in the expanded Clifton Court Forebay (Fugro Consultants
 23 2011). The impact would not be significant because the expanded Clifton Court Forebay
 24 embankment would be designed and constructed according to applicable design codes, guidelines,
 25 and standards to contain and withstand the anticipated maximum seiche wave height, as required
 26 by DWR's environmental commitments (see Appendix 3B, *Environmental Commitments, AMMs, and*
 27 *CMs*). There would be no increased likelihood of loss of property, personal injury or death due to
 28 operation of Alternative 5A from seiche or tsunami. The impact would be less than significant. No
 29 additional mitigation is required.

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

32 *NEPA Effects:* Alternative 5A would not involve construction of unlined canals; therefore, there
 33 would be no increase in groundwater surface elevations and consequently no effect caused by canal
 34 seepage. There would be no effect.

35 *CEQA Conclusion:* Alternative 5A would not involve construction of unlined canals; therefore, there
 36 would be no increase in groundwater surface elevations and consequently no impact caused by
 37 canal seepage. There would be no impact. No mitigation is required.

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

40 *NEPA Effects:* Implementation of Environmental Commitments 3, 4, 6-12, 15, and 16 would be
 41 similar under Alternative 5A as under Alternative 4A, but would involve up to approximately 12,724

1 acres of restoration, as described in Section 9.3.4.2. The effect would be similar to that of Alternative
2 4A. See Impact GEO-12 under Alternative 4A. There would be no adverse effect.

3 **CEQA Conclusion:** According to the available AP Earthquake Fault Zone Maps, only the Suisun Marsh
4 ROA could be affected by rupture of an earthquake fault. The active Green Valley fault crosses the
5 southwestern corner of the ROA. The active Cordelia fault extends approximately 1 mile into the
6 northwestern corner of the ROA. Rupture of the Cordelia and Green Valley faults could occur at the
7 Suisun Marsh ROA and damage ROA facilities, such as levees and berms. Damage to these features
8 could result in their failure, causing flooding of otherwise protected areas. However, Alternative 5A
9 would not include implementation of Environmental Commitments in the Suisun Marsh area.

10 The impact would be less than significant. No mitigation is required.

11 **Impact GEO-13: Loss of Property, Personal Injury, or Death from Structural Failure Resulting** 12 **from Strong Seismic Shaking at Restoration Opportunity Areas**

13 **NEPA Effects:** Implementation of Environmental Commitments 3, 4, 6–12, 15, and 16 would be
14 similar under Alternative 5A as under Alternative 4A but would involve up to approximately 12,724
15 acres of restoration, as described in Section 9.3.4.2. See Impact GEO-13 under Alternative 4A. There
16 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
19 to active faults. Damage to these features could result in their failure, causing flooding of otherwise
20 protected areas. However, conformance with design standards is an environmental commitment by
21 the project proponents to ensure that any remaining strong seismic shaking risks are minimized as
22 the conservation activities are operated and there would be no increased likelihood of loss of
23 property, personal injury or death in the ROAs (see Appendix 3B, *Environmental Commitments*,
24 *AMMs*, and *CMs*). As described in Section 9.3.1, *Methods for Analysis*, and in Appendix 3B, design
25 codes, guidelines, and standards, including the California Building Code and resource agency and
26 professional engineering specifications, such as DWR's Division of Flood Management *FloodSAFE*
27 *Urban Levee Design Criteria* and USACE's *Engineering and Design—Earthquake Design and*
28 *Evaluation for Civil Works Projects* would be used for final design of conservation features. The
29 impact would be less than significant. No mitigation is required.

30 **Impact GEO-14: Loss of Property, Personal Injury, or Death from Structural Failure Resulting** 31 **from Seismic-Related Ground Failure (Including Liquefaction Beneath Restoration** 32 **Opportunity Areas)**

33 **NEPA Effects:** Implementation of Environmental Commitments 3, 4, 6–12, 15, and 16 would be
34 similar under Alternative 5A as under 4A but would involve up to approximately 12,724 acres of
35 restoration, as described in Section 9.3.4.2. See Impact GEO-14 under Alternative 4A. There would
36 be no adverse effect.

37 **CEQA Conclusion:** Earthquake-induced ground shaking could cause liquefaction, resulting in
38 damage to or failure of levees, berms, and other features constructed at the restoration areas.
39 Failure of levees and other structures could result in flooding of otherwise protected areas.
40 However, through the final design process, measures to address the liquefaction hazard would be
41 required to conform to applicable design codes, guidelines, and standards. As described in Appendix
42 3B, *Environmental Commitments*, *AMMs*, and *CMs*, such design codes, guidelines, and standards

1 include USACE's *Engineering and Design—Stability Analysis of Concrete Structures and Soil*
 2 *Liquefaction during Earthquakes*, by the Earthquake Engineering Research Institute. Conformance
 3 with these design standards is an environmental commitment by the project proponents to ensure
 4 that liquefaction risks are minimized as the water conservation features are implemented. The
 5 hazard would be controlled to a safe level and would not create an increased likelihood of loss of
 6 property, personal injury or death of individuals in the ROAs. The impact would be less than
 7 significant. No mitigation is required.

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

10 **NEPA Effects:** Implementation of Environmental Commitments 3, 4, 6–12, 15, and 16 would be
 11 similar under Alternative 5A as under Alternative 4A but would involve up to approximately 12,724
 12 acres of restoration, as described in Section 9.3.4.2. See Impact GEO-15 under Alternative 4A. There
 13 would be no adverse effect.

14 **CEQA Conclusion:** Unstable new and existing levee and embankment slopes could fail as a result of
 15 seismic shaking and as a result of high soil-water content during heavy rainfall and cause flooding of
 16 otherwise protected areas. However, because the project proponents would conform to applicable
 17 design guidelines and standards, such as USACE design measures, the hazard would be controlled to
 18 a safe level and would not create an increased likelihood of loss of property, personal injury or death
 19 of individuals in the ROAs (see Appendix 3B, *Environmental Commitments, AMMs, and CMs*). The
 20 impact would be less than significant. No mitigation is required.

21 **Impact GEO-16: Loss of Property, Personal Injury, or Death from Seiche or Tsunami at**
 22 **Restoration Opportunity Areas as a Result of Implementing the Environmental Commitments**

23 **NEPA Effects:** Implementation of Environmental Commitments 3, 4, 6–12, 15, and 16 would be
 24 similar under Alternative 5A as under Alternative 4A but would involve up to approximately 12,724
 25 acres of restoration, as described in Section 9.3.4.2. The distance from the ocean and attenuating
 26 effect of the San Francisco Bay would likely allow only a low tsunami wave height to reach the
 27 Suisun Marsh and the Delta. Conditions for a seiche to occur at the ROAs are not favorable.
 28 Therefore, the effect would not be adverse.

29 **CEQA Conclusion:** Based on recorded tsunami heights at the Golden Gate Bridge (Contra Costa
 30 Transportation Agency 2009) and in the interior of the San Francisco Bay and on tsunami
 31 inundation maps prepared by the California Department of Conservation (2009), the height of a
 32 tsunami wave reaching the ROAs 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 the ROAs that would cause loss of property, personal injury, or death at the ROAs is considered low
 35 because conditions for a seiche to occur at the ROAs are not favorable. The impact would be less
 36 than significant. No mitigation is required.

37 **9.3.5 Cumulative Analysis**

38 The cumulative effects analysis for geology and seismicity considers the effects of BDCP/California
 39 WaterFix implementation in combination with other past, present, and reasonably foreseeable
 40 projects or programs. The analysis focuses on projects and programs within the Plan Area, in
 41 particular those that could create a cumulatively significant geologic or seismic risk to people or

1 structures, including the risk of loss of property, personal injury, or death. The principal programs
 2 and projects considered in the analysis are listed in Table 9-31. This list has been drawn from a
 3 more substantial compilation of past, present, and reasonably foreseeable programs and projects
 4 included in Appendix 3D, *Defining Existing Conditions, the No Action Alternative, No Project*
 5 *Alternative, and Cumulative Impact Conditions.*

6 **Table 9-31. Effects on Geology and Seismicity from Plans, Policies, and Programs Considered for**
 7 **Cumulative Analysis**

Agency	Program/Project	Status	Description of Program/Project	Effects on Geology and Seismicity
U.S. Army Corps of Engineers	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/California WaterFix 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/California WaterFix construction locations from earthquakes, groundshaking, liquefaction, slope instability, seiche or tsunami.
West Sacramento Area Flood Control Agency and U.S. Army Corps of Engineers	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/California WaterFix construction locations from earthquakes, groundshaking, liquefaction, slope instability, seiche or tsunami.
California Department of Water Resources	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/California WaterFix construction locations from earthquakes, groundshaking, liquefaction, slope instability, seiche or tsunami.

Agency	Program/Project	Status	Description of Program/Project	Effects on Geology and Seismicity
California Department of Water Resources	Delta Levees Flood Protection Program	Ongoing	Levee rehabilitation projects in the Delta.	No direct effect on increased risks at BDCP/California WaterFix construction locations from earthquakes, groundshaking, liquefaction, slope instability, seiche or tsunami.
California Department of Water Resources	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/California WaterFix construction locations from earthquakes, groundshaking, liquefaction, slope instability, seiche or tsunami.
Sacramento Area Flood Control Agency, Central Valley Flood Protection Board, U.S. Army Corps of Engineers	Flood Management Program	Ongoing	South Sacramento Streams Project component consists of levee, floodwall, and channel improvements.	No direct effect on increased risks at BDCP/California WaterFix construction locations from earthquakes, groundshaking, liquefaction, slope instability, seiche or tsunami.
Bureau of Reclamation, California Department of Water Resources	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/California WaterFix construction locations from earthquakes, groundshaking, liquefaction, slope instability, seiche or tsunami.
Bureau of Reclamation, California Department of Water Resources	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/California WaterFix construction locations from earthquakes, groundshaking, liquefaction, slope instability, seiche or tsunami.

Agency	Program/Project	Status	Description of Program/Project	Effects on Geology and Seismicity
California Department of Water Resources, Bureau of Reclamation, and Contra Costa Water District	Los Vaqueros Expansion Investigation	Final EIR certified by Contra Costa Water District in March 2010	The existing Los Vaqueros Reservoir would be expanded up to a total of 275,000 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/California WaterFix construction locations from earthquakes, groundshaking, liquefaction, slope instability, seiche or tsunami.
California Department of Water Resources	FloodSAFE California	Ongoing Program	Promotes public safety through integrated flood management while protecting environmental resources; emphasizes action in the Delta. This program is very broad, but is designed to improve flood safety throughout the state while encouraging sound conservation actions that benefit California's native fish and wildlife and promote wildlife-friendly agricultural practices.	No direct effect on increased risks at BDCP/California WaterFix construction locations from earthquakes, groundshaking, liquefaction, slope instability, seiche or tsunami.
Semitropic Water Storage District	Delta Wetlands Projects	Semitropic Water Storage District issued a Draft EIR in 2010 and a Final EIR in 2012.	Under the current proposal, the project would: 1) provide water to Semitropic WSD to augment its water supply, 2) bank water within the Semitropic Groundwater Storage Bank and Antelope Valley Water Bank, and 3) provide water to other places, including the service areas of the Golden State Water Company and Valley Mutual Water Company.	No direct effect on increased risks at BDCP/California WaterFix construction locations from earthquakes, groundshaking, liquefaction, slope instability, seiche or tsunami.
State and Federal Contractors Water Agency, California Department of Water Resources and MOA Partners	Lower Yolo Restoration Project		The goal of this project is to provide important new sources of food and shelter for a variety of native fish species at the appropriate scale in strategic locations in addition to ensuring continued or enhanced flood protection.	No direct effect on increased risks at BDCP/California WaterFix construction locations from earthquakes, groundshaking, liquefaction, slope instability, seiche or tsunami.

Agency	Program/Project	Status	Description of Program/Project	Effects on Geology and Seismicity
State Water Resources Control Board	Bay-Delta Water Quality Control Plan Update	Ongoing development	The State Water Board is updating the 2006 Bay-Delta Water Quality Control Plan (WQCP) in four phases: Phase I: Modifying water quality objectives (i.e., establishing minimum flows) on the Lower San Joaquin River and Stanislaus, Tuolumne, and Merced Rivers to protect the beneficial use of fish and wildlife and (2) modifying the water quality objectives in the southern Delta to protect the beneficial use of agriculture; Phase II: Evaluating and potentially amending existing water quality objectives that protect beneficial uses and the program of implementation to achieve those objectives. Water quality objectives that could be amended include Delta outflow criteria; Phase III: Requires changes to water rights and other measures to implement changes to the WQCP from Phases I and II; Phase IV: Evaluating and potentially establishing water quality criteria and flow objectives that protect beneficial uses on tributaries to the Sacramento River.	No direct effect on increased risks at BDCP/California WaterFix construction locations from earthquakes, groundshaking, liquefaction, slope instability, seiche or tsunami.
U.S. Army Corps of Engineers	CALFED Levee Stability Program		The California Bay-Delta Program's (CALFED) levee stability program provides for long-term protection of resources in the Delta by maintaining and improving the integrity of the area's extensive levee system.	Possible reduced risk in vicinity of BDCP/California WaterFix construction locations of seismically induced levee failure.
San Joaquin County	General Plan Update		The general plan provides guidance for future growth in a manner that preserves the county's natural and rural assets. Most of the urban growth is directed to existing urban communities.	No direct effect on increased risks at BDCP/California WaterFix construction locations from earthquakes, groundshaking, liquefaction, slope instability, seiche or tsunami.

Agency	Program/Project	Status	Description of Program/Project	Effects on Geology and Seismicity
California State Administration	Sites Reservoir/ North of the Delta Offstream Storage		Determine the viability of a proposed off-stream storage project that could improve water supply, water reliability, support enhanced survival of anadromous fish and other aquatic species	No direct effect on increased risks at BDCP/California WaterFix construction locations from earthquakes, groundshaking, liquefaction, slope instability, seiche or tsunami.
Department of Water Resources	California Water Action Plan	Initiated in January 2014	This plan lays out a roadmap for the next 5 years for actions that would fulfill 10 key themes. In addition, the plan describes certain specific actions and projects that call for improved water management throughout the state.	No direct effect on increased risks at BDCP/California WaterFix construction locations from earthquakes, groundshaking, liquefaction, slope instability, seiche or tsunami.
Delta Conservancy	California EcoRestore	Initiated in 2015	This program will accelerate and implement a suite of Delta restoration actions for up to 30,000 acres of fish and wildlife habitat by 2020.	No direct effect on increased risks at BDCP/California WaterFix construction locations from earthquakes, groundshaking, liquefaction, slope instability, seiche or tsunami.
Department of Water Resources	North Bay Aqueduct Alternative Intake	Notice of Preparation issued on December 2, 2009. CEQA documentation under preparation.	Plan to construct and operate an alternative intake on the Sacramento River, generally upstream of the Sacramento Regional Wastewater Treatment Plant, and connect it to the existing North Bay Aqueduct system by a new pipeline. The proposed alternative intake would be operated in conjunction with the existing North Bay Aqueduct intake at Barker Slough.	No direct effect on increased risks at BDCP/California WaterFix construction locations from earthquakes, groundshaking, liquefaction, slope instability, seiche or tsunami.

Agency	Program/Project	Status	Description of Program/Project	Effects on Geology and Seismicity
California Department of Fish and Wildlife	San Joaquin River Restoration Program: Salmon Conservation and Research Facility and Related Management Actions Project	Final EIR certified in June 2014	<p>The Proposed Project entails five primary actions:</p> <ol style="list-style-type: none"> 1. Construct and operate the Salmon Conservation and Research Facility; 2. Reintroduce Chinook salmon to the Restoration Area (including donor stock collection, broodstock development, and/or direct translocation); 3. Manage Chinook salmon runs in the Restoration Area; 4. Conduct fisheries research and monitoring in the Restoration Area; and 5. Manage and support recreation within the Restoration Area. 	<p>The EIR for this project indicated that the soils underlying the proposed Salmon Conservation and Research Facility site have a low expansive potential, and that the proposed project is not likely to be affected by lateral spreading. However, the variable and loose consistency of the alluvium found in some borings makes it unsuitable for direct support of additional fill or building improvements in its existing condition and that the fill material that the project site overlies may impact soil and thus structure stability. Additionally, relatively shallow groundwater levels could potentially affect the stability of soils beneath the proposed project, which could result in subsidence and collapse.</p>
Natural Resources Agency, Salton Sea Authority, California Department of Fish and Wildlife, California Department of Water Resources	Salton Sea Species Conservation Habitat Project	Ongoing	<p>The Natural Resources Agency, in partnership with the Salton Sea Authority, will coordinate state, local and federal restoration efforts and work with local stakeholders to develop a shared vision for the future of the Salton Sea. Restoration will include construction of 600 acres of near shore aquatic habitat to provide feeding, nesting and breeding habitat for birds. This project is permitted to increase to 3,600 acres and could be scaled even greater with additional resources. Additional restoration projects may follow.</p>	<p>No direct effect on increased risks at BDCP/California WaterFix construction locations from earthquakes, groundshaking, liquefaction, slope instability, seiche or tsunami.</p>

1 9.3.5.1 Cumulative Effects of the No Action Alternative

2 The cumulative effect of the No Action Alternative is anticipated to result in the current hazard
 3 resulting from earthquake-induced ground shaking from regional and local faults persisting. It is
 4 also anticipated that the current hazard of earthquake-induced liquefaction triggered by regional
 5 and local faults would persist. Slope instability associated with non-engineered levees would
 6 continue to present a risk of levee failure and subsequent flooding of Delta islands, with a
 7 concomitant influx of seawater into the Delta, thereby adversely affecting water quality and water
 8 supply. Ongoing and reasonably foreseeable future projects in parts of the Delta are expected to
 9 upgrade the levees to a “flood-safe” condition under the 100-year return flood elevation. However,
 10 these projects would provide very little levee foundation strengthening and improvements directed
 11 at improving the stability of the levees to better withstand ground shaking, liquefaction, and slope
 12 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
 15 events increasing over time. Based on the location, extent and non-engineered nature of many
 16 existing levee structures in the Delta area, the potential for significant damage to, or failure of, these
 17 structures during a major local seismic event is generally moderate to high. In the instance of a large
 18 seismic event, levees constructed on liquefiable foundations are expected to experience large
 19 deformations (in excess of 10 feet) under a moderate to large earthquake in the region. There would
 20 potentially be loss, injury or death resulting from ground rupture, ground shaking and liquefaction,
 21 (See Appendix 3E, *Potential Seismic and Climate Change Risks to SWP/CVP Water Supplies* for more
 22 detailed discussion). While similar risks would occur under implementation of the action
 23 alternatives, these risks may be reduced by project-related levee improvements along with those
 24 projects identified for the purposes of flood protection in Table 9-31.

25 9.3.5.2 Concurrent Project Effects

26 Construction of the water conveyance facilities under all action alternatives has the potential to
 27 result in the loss of property, personal injury, or death due to structural failure from strong seismic
 28 shaking, settlement or collapse caused by dewatering, ground settlement, slope failure, or structural
 29 failure due to ground motions. In addition, operation of the water conveyance facilities under all
 30 action alternatives could potentially result in the loss of property, personal injury, or death from
 31 structural failure resulting from strong seismic shaking or seismic-related ground failure (including
 32 liquefaction), landslides and other slope instability, seiche or tsunami, or groundwater surface
 33 elevations from unlined canal seepage. These potential effects would be limited to the locations of
 34 the construction and the operations activities of the action alternatives. Implementation of the
 35 conservation measures in the restoration opportunity areas under Alternatives 1A–2C, 3, 4, 5, and
 36 6A–9, could result in similar geologic- and seismic-related risks.

37 The Delta and vicinity is within a highly active seismic area, with a generally high potential for major
 38 future earthquake events along nearby and/or regional faults, and with the probability for such
 39 events increasing over time. Construction activities for water conveyance facilities and CM2–CM7
 40 and CM16 under Alternatives 1A–2C, 3, 4, 5, and 6A–9, could overlap in time, with CM1 construction
 41 concluding after approximately 10 years. Similarly, in the long-term, operation of the water
 42 conveyance facilities and the habitat areas would occur concurrently. However, there would be little,
 43 if any, overlap in location. Therefore, it is unlikely that the potential geologic and seismic hazards
 44 resulting from these activities under Alternatives 1A–2C, 3, 4, 5, and 6A–9 would combine to

1 increase the overall risks of loss, injury or death at any one locality in the Plan Area. Environmental
 2 commitments to design and manage all active construction sites to meet safety and collapse
 3 prevention requirements of the relevant state codes and standards (described in Appendix 3B,
 4 *Environmental Commitments, AMMs, and CMs*) and conformance with Cal-OSHA and other state code
 5 requirements such as shoring, bracing, lighting, excavation depth restrictions, required slope angles,
 6 and other measures, to protect worker safety would act to reduce the severity of the geologic- and
 7 seismic-related hazards. Concurrent geologic and seismicity effects under Alternatives 4A, 2D, and
 8 5A would be similar to, but less than, those described under the BDCP alternatives.

9 9.3.5.3 Cumulative Effects of the Action Alternatives

10 Impact GEO-1: Cumulative Impacts Related to Geology and Seismicity Hazards

11 **NEPA Effects:** Implementation of the action alternatives and other local and regional projects as
 12 presented in Table 9-31, could contribute to regional impacts and hazards associated with geology
 13 and seismicity. The geologic and seismic hazards that would exist and the potential adverse effects
 14 that could occur to structures and persons in association with construction and operation of any
 15 action alternative would be restricted to the locations of the construction and the operational
 16 activities of these alternatives. Depending on which alternative is chosen, the location of these
 17 impacts would vary slightly. These impacts include the potential for loss, injury or death as a result
 18 of strong seismic shaking, settlement or collapse caused by dewatering, ground settlement, slope
 19 failure (including decreased levee stability from construction and operation activities), seismic-
 20 related ground failure (including liquefaction), ground shaking, fault rupture, seiche or tsunami. All
 21 of the impacts are mitigated by incorporating standard construction and structural measures into
 22 project design and construction. No impacts related to construction or operation of any of the action
 23 alternatives or from implementation of the conservation measures were identified for this resource
 24 area. These cumulative impacts would result from construction activities and development of
 25 additional structures that may be subject to geologic, seismic, or slope failure and could be reduced
 26 by implementing measures similar to those described for proposed project. However, these projects
 27 would not increase the risks to structures and people at the specific locations affected by the action
 28 alternatives. Therefore, the risks of loss of property, personal injury, or death associated with the
 29 alternatives would not combine with the geologic and seismic risks from other projects or programs
 30 to create a cumulatively adverse effect at any one locality in the Plan Area. There would be no
 31 cumulative adverse effect.

32 **CEQA Conclusion:** The geologic and seismic hazards that would exist and the potential adverse
 33 effects that could occur in association with construction and operation of any action alternative
 34 would be restricted to the locations of the construction and the operational activities of these
 35 alternatives. Other past, present and probable future projects and programs in the Plan Area that
 36 are identified in Table 9-31 would not increase the risks of loss, injury or death at the specific
 37 locations affected by project alternatives. Therefore, the risks of loss, injury or death associated with
 38 the project alternatives would not combine with the geologic and seismic risks from other projects
 39 or programs to create a substantial cumulative effect at any one locality in the Plan Area. This
 40 cumulative impact is considered less than significant. No mitigation is required.

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