4.3.5 Geology and Seismicity

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*, in Appendix A of this RDEIR/SDEIS, 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*, in Appendix A of this RDEIR/SDEIS. 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 (Appendix 3B, *Environmental Commitments*, in Appendix A of this RDEIR/SDEIS). 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 (Appendix 3B, *Environmental Commitments*, in Appendix A of this RDEIR/SDEIS). 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 execution of these environmental commitments to minimize potential risks would result in no increased likelihood of loss of property, personal injury or death due to construction of Alternative 4A. 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

The potential for ground settlement under Alternative 4A would be identical to that under Alternative 4. The geologic units in the area of the Alternative 4A modified pipeline/tunnel alignment are the same as those shown for Alternative 4 in Figure 9-3 and summarized in Table 9-26 of the Draft EIR/EIS. The characteristics of each unit would affect the potential for settlement during geotechnical investigation and tunneling operations. Segments 1 and 3, located in the Clarksburg area and the area west of Locke, respectively, contain higher amounts of sand than the other segments, so they pose a greater risk of settlement.

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

NEPA Effects: The potential effect could be substantial because ground settlement could occur during geotechnical investigations and the tunneling operation. During detailed project design, a site-specific subsurface geotechnical evaluation would be conducted along the modified pipeline/tunnel alignment to verify or refine the findings of the preliminary geotechnical investigation. These effects would be reduced with implementation of DWR's Environmental Commitments and Avoidance and Minimization Measures (Appendix 3B in Appendix A of this RDEIR/SDEIS). As required by DWR's Environmental Commitments, the results of the site-specific evaluation and the California-registered civil engineer or California-certified engineering geologist's recommendations would be documented in a detailed geotechnical report prepared in accordance with state guidelines, in particular *Guidelines for Evaluating and Mitigating Seismic Hazards in California* (California Geological Survey 2008).

As described in Section 9.3.1*, Methods for Analysis,* the measures would conform to applicable design and building codes, guidelines, and standards, such as USACE design measures. See Alternative 4 for a specific list of applicable codes and standards DWR has made this conformance and monitoring process an environmental commitment (Appendix 3B, *Environmental Commitments*, in Appendix A of this RDEIR/SDEIS).

Generally, the applicable codes require that facilities be built so that they are designed for a landside slope stability and seepage/underseepage factors of safety greater than 1.0 (i.e., stable) and would therefore be less impacted in the event of ground settlement. 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 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 ground settlement. Therefore, there would be no adverse effect.

***CEQA Conclusion*:** Ground settlement above the tunneling operation 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 as described under Alternative 4. DWR has made conformance to geotechnical design recommendations and monitoring an environmental commitment (Appendix 3B, *Environmental Commitments*, in Appendix A of this RDEIR/SDEIS). Hazards to workers and project structures would be controlled at safe levels and there would be no increased likelihood of loss of property, personal injury or death due to construction of Alternative 4A. 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

Excavation of borrow material could result in failure of cut slopes and application of temporary spoils and RTM at storage sites could cause excessive settlement in the spoils, potentially causing injury of workers at the construction sites. The potential for slope failure under Alternative 4A would be identical to that under Alternative 4.

NEPA Effects: The potential effect could be substantial because excavation of borrow material and the resultant cutslopes and potential failure of spoils/RTM fill slopes could cause injury of workers at the construction sites. The potential for slope failure under Alternative 4A would be identical to that under Alternative 4.

During design, the potential for native ground settlement below the spoils would be evaluated by a geotechnical engineer using site-specific geotechnical and hydrological information. The use of shoring, seepage cutoff walls, and ground modifications to prevent slope instability, soil boiling, or excessive settlement would be considered in the design. As described in Section 9.3.1, *Methods for Analysis,* the measures would conform to applicable design and building codes, guidelines, and standards.

In addition to the risk of slope failure at borrow sites and spoils and RTM sites, there are also potential impacts on levee stability resulting from construction of Alternative 4A water conveyance facilities. All levee reconstruction/building pad construction would conform to applicable state and federal flood management engineering and permitting requirements.

DWR would ensure that the geotechnical design recommendations are included in the design of project facilities and construction specifications and are properly executed during construction to minimize the potential effects from failure of excavations. Conformance with relevant codes and standards would reduce the potential risk for increased likelihood of loss of property or personal injury from settlement/failure of cutslopes of borrow sites and failure of soil or RTM fill slopes during construction. The worker safety codes and standards specify protective measures that must be taken at construction sites to minimize the risk of injury or death from structural or earth failure (e.g., utilizing personal protective equipment, practicing crane and scaffold safety measures). The relevant codes and standards represent performance standards that must be met by contractors and these measures are subject to monitoring by state and local agencies. DWR has made this conformance and monitoring process an environmental commitment (Appendix 3B, *Environmental Commitments*, in Appendix A of this RDEIR/SDEIS).

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 slope failure at borrow sites and spoils and RTM storage sites.

The reconstruction of levees would improve levee stability over existing conditions due to improved side slopes, erosion countermeasures (geotextile fabrics, rock revetments, riprap, or other material), seepage reduction measures, and overall mass. Therefore, there would be no adverse effect.

CEQA Conclusion: Settlement/failure of cutslopes of borrow sites and failure of soil/RTM fill slopes could result in loss of property or personal injury during construction. However, because DWR would conform with Cal-OSHA and other state code requirements and conform to applicable geotechnical design guidelines and standards, such as USACE design measures, the hazard would be controlled to a safe level and there would be no increased likelihood of loss of property, personal injury or death due to construction of Alternative 4A at borrow sites and spoils and RTM storage sites. The reconstruction of levees would improve levee stability over existing conditions due to improved side slopes, erosion countermeasures, seepage reduction measures, and overall mass. The impact would be less than significant. No mitigation is required.

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

Pile driving and other heavy equipment operations would cause vibrations that could initiate liquefaction and associated ground movements in places where soil and groundwater conditions are present to allow liquefaction to occur. The consequences of liquefaction could result in damage nearby structures and levees. The potential for liquefaction under Alternative 4A would be identical to that under Alternative 4.

NEPA Effects: The potential effect could be substantial because construction-related ground motions could initiate liquefaction, which could cause failure of structures during construction, which could result in injury of workers at the construction sites. The potential for liquefaction under Alternative 4A would be identical to that under Alternative 4.

During design, the facility-specific potential for liquefaction would be investigated by a geotechnical engineer. The investigations are an environmental commitment (Appendix 3B, *Environmental Commitments*, in Appendix A of this RDEIR/SDEIS). In areas determined to have a potential for liquefaction, the California-registered civil engineer or California-certified engineering geologist would develop design strategies and construction methods to ensure that pile driving and heavy equipment operations do not cause liquefaction which otherwise could damage facilities under construction and surrounding structures, and could threaten the safety of workers at the site.

Design measures to avoid pile-driving induced levee failure may include predrilling or jetting, using open-ended pipe piles to reduce the energy needed for pile penetration, using CIDH piles/piers that do not require driving, using pile jacking to press piles into the ground by means of a hydraulic system, or driving piles during the drier summer months. Field data collected during design also would be evaluated to determine the need for and extent of strengthening levees, embankments, and structures to reduce the effect of vibrations. These construction methods would conform with current seismic design codes and requirements, as described in Appendix 3B, *Environmental Commitments*, in Appendix A of this RDEIR/SDEIS. Such design standards include USACE's *Engineering and Design—Stability Analysis of Concrete Structures* and *Soil Liquefaction during Earthquakes,* by the Earthquake Engineering Research Institute.

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

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

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 to construction method recommendations and other applicable specifications would ensure that construction of Alternative 4A would not create an increased likelihood of loss of property, personal injury or death of individuals due to construction-related ground motion and resulting potential liquefaction in the work area. Therefore, there would be no adverse effect.

CEQA Conclusion**:** Construction-related ground motions could initiate liquefaction, which could cause failure of structures during construction. However, because DWR would conform to Cal-OSHA and other state code requirements and conform to applicable design guidelines and standards, such as USACE design measures, the hazard would be controlled to a level that would protect worker safety (see Appendix 3B, *Environmental Commitments*, in Appendix A of this RDEIR/SDEIS). Further, DWR has made an environmental commitment (see Appendix 3B, *Environmental Commitments*, in Appendix A of this RDEIR/SDEIS) that the construction methods recommended by the geotechnical engineer are included in the design of project facilities and construction specifications to minimize the potential for construction-induced liquefaction. DWR also has committed to ensure that these methods are followed during construction. Proper execution of these environmental commitments would result in no increased likelihood of loss of property, personal injury or death due to construction of Alternative 4A. The impact would be less than significant. No mitigation is required.

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

NEPA Effects: Alternative 4A would include the same physical/structural components as Alternative 4, and therefore, the effects of Alternative 4A would be the same as Alternative 4. The effect would not be adverse because like Alternative 4, no active faults extend into the Alternative 4A alignment. Additionally, although the Thornton Arch and West Tracy blind thrusts occur beneath the Alternative 4A alignment, they do not present a hazard of surface rupture based on available information, including the AP Earthquake Fault Zone Map showing faults capable of surface rupture (Figure 9-5 of the Draft EIR/EIS).

However, because there is limited information regarding the depths of the Thornton Arch and West Tracy blind thrusts, seismic surveys would be performed on the blind thrust during the design phase to determine the depths to the top of the faults. More broadly, design-level geotechnical studies would be prepared by a geotechnical engineer licensed in the state of California during project design. Consistent with the environmental commitments (see Appendix 3B, *Environmental Commitments*, in Appendix A of this RDEIR/SDEIS), DWR would ensure that the geotechnical engineer's recommended measures to address adverse conditions would conform to applicable design codes, guidelines, and standards, would be included in the project design and construction specifications, and would be properly executed during construction. 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). As described in Section 9.3.1, *Methods for Analysis* in Chapter 9*, Geology and Seismicity*, of the Draft EIR/EIS*,* such conformance with design codes, guidelines, and standards are considered environmental commitments by DWR (see Appendix 3B, *Environmental Commitments*, in Appendix A of this RDEIR/SDEIS).

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

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).

Conformance to these and other applicable design specifications and standards would ensure that operation of Alternative 4 would not create an increased likelihood of loss of property, personal injury or death of individuals in the event of ground movement in the vicinity of the project. There would be no adverse effect.

***CEQA Conclusion*:** There are no active faults capable of surface rupture that extend into the Alternative 4A modified pipeline/tunnel alignment. Design-level geotechnical studies would be prepared by a geotechnical engineer licensed in the state of California during project design. The studies would further assess site-specific conditions at and near all the project facility locations, including seismic activity, soil liquefaction, and other potential geologic and soil-related hazards. This information would be used to verify assumptions and conclusions included in the EIR/EIS. Consistent with the project's environmental commitments (see Appendix 3B, *Environmental Commitments*, in Appendix A of this RDEIR/SDEIS), DWR would ensure that the geotechnical engineer's recommended measures to address adverse conditions would conform to applicable design codes, guidelines, and standards, would be included in the project design and construction specifications, and would be properly executed during construction. Conformance to these and other applicable design specifications and standards would ensure that operation of Alternative 4 would not create an increased likelihood of loss of property, personal injury or death of individuals in the event of ground movement in the vicinity of the project. Therefore, such ground movements would not jeopardize the integrity of the surface and subsurface facilities along the Alternative 4A conveyance alignment or the proposed expanded Clifton Court Forebay and associated facilities adjacent to the existing Clifton Court Forebay. There would be no impact. No mitigation is required.

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

Earthquake events may occur on the local and regional seismic sources during operation of the Alternative 4A water conveyance facilities. The ground shaking could damage pipelines, tunnels, intake facilities, pumping plants, and other facilities disrupting the water supply through the conveyance system. In an extreme event of strong seismic shaking, uncontrolled release of water from damaged pipelines, tunnels, intake facilities, pumping plant, and other facilities could cause flooding, disruption of water supplies to the south, and inundation of structures. These effects are discussed more fully in Appendix 3E, *Potential Seismicity and Climate Change Risks to SWP/CVP Water Supplies*, of the Draft EIR/EIS.

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

The structure of the underground conveyance facility would decrease the likelihood of loss of property or personal injury of individuals from structural shaking of surface and subsurface facilities along the Alternative 4A conveyance alignment in the event of strong seismic shaking.

In accordance with the DWR's environmental commitments (see Appendix 3B, *Environmental Commitments*, in Appendix A of this RDEIR/SDEIS), design-level geotechnical studies would be conducted by a licensed civil engineer who practices in geotechnical engineering. The California-registered civil engineer or California-certified engineering geologist's recommended measures to address this hazard would conform to applicable design codes, guidelines, and standards.

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

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).

Conformance to these and other applicable design specifications and standards would ensure that operation of Alternative 4A would not create an increased likelihood of loss of property, personal injury or death of individuals from structural shaking of surface and subsurface facilities along the Alternative 4A conveyance alignment in the event of strong seismic shaking. Therefore, there would be no adverse effect.

***CEQA Conclusion*:** The impacts of Alternative 4A would be identical to Alternative 4. Seismically induced strong ground shaking could damage pipelines, tunnels, intake facilities, pumping plant, and other facilities. The damage could disrupt the water supply through the conveyance system. In an extreme event, an uncontrolled release of water from the damaged conveyance system could cause flooding and inundation of structures. (Please refer to Chapter 6, *Surface Water*, of the Draft EIR/EIS for a detailed discussion of potential flood impacts.) However, through the final design process, which would be supported by geotechnical investigations required by DWR's environmental commitments (see Appendix 3B, *Environmental Commitments*, in Appendix A of this RDEIR/SDEIS), measures to address this hazard would be required to conform to applicable design codes, guidelines, and standards. Conformance with these codes and standards is an environmental commitment by DWR to ensure that ground shaking risks are minimized as the water conveyance features are operated. The hazard would be controlled to a safe level and there would be no increased likelihood of loss of property, personal injury or death due to operation of Alternative 4A. The impact would be less than significant. No mitigation is required.

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

NEPA Effects: The potential effect could be substantial because seismically induced ground shaking could cause liquefaction, and damage pipelines, tunnels, intake facilities, pumping plant, and other facilities. The damage could disrupt the water supply through the conveyance system. In an extreme event, an uncontrolled release of water from the damaged conveyance system could cause flooding and inundation of structures. The effects of Alternative 4A would be identical to Alternative 4. Please refer to Appendix 3E, *Potential Seismicity and Climate Change Risks to SWP/CVP Water Supplies*, of the Draft EIR/EIS for a detailed discussion of potential flooding effects.

In the process of preparing final facility designs, site-specific geotechnical and groundwater investigations would be conducted to identify and characterize the vertical (depth) and horizontal (spatial) extents of liquefiable soil. During final design, site-specific potential for liquefaction would be investigated by a geotechnical engineer. In areas determined to have a potential for liquefaction, a California-registered civil engineer or California-certified engineering geologist would develop design measures and construction methods to meet design criteria established by building codes and construction standards to ensure that the design earthquake does not cause damage to or failure of the facility. Such measures and methods include removing and replacing potentially liquefiable soil, strengthening foundations (for example, using post-tensioned slab, reinforced mats, and piles) to resist excessive total and differential settlements, and using *in situ* ground improvement techniques (such as deep dynamic compaction, vibro-compaction, vibro-replacement, compaction grouting, and other similar methods). The results of the site-specific evaluation and California-registered civil engineer or California-certified engineering geologist's recommendations would be documented in a detailed geotechnical report prepared in accordance with state guidelines, in particular *Guidelines for Evaluating and Mitigating Seismic Hazards in California* (California Geological Survey 2008). Conformance with these design requirements is an environmental commitment by DWR to ensure that liquefaction risks are minimized as the water conveyance features are operated (see Appendix 3B, *Environmental Commitments*, in Appendix A of this RDEIR/SDEIS).

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

Additionally, any modification to a federal levee system would require USACE approval under 33 USC 408 (a 408 Permit).

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). Conformance to these and other applicable design specifications and standards would ensure that the hazard of liquefaction and associated ground movements would not create an increased likelihood of loss of property, personal injury or death of individuals from structural failure resulting from seismic-related ground failure along the Alternative 4A conveyance alignment during operation of the water conveyance features. Therefore, the effect would not be adverse.

CEQA Conclusion**:** The impacts of Alternative 4A would be identical to Alternative 4. Seismically induced ground shaking could cause liquefaction. Liquefaction could damage pipelines, tunnels, intake facilities, pumping plant, and other facilities, and thereby disrupt the water supply through the conveyance system. In an extreme event, flooding and inundation of structures could result from an uncontrolled release of water from the damaged conveyance system. (Please refer to Chapter 6, *Surface Water*, of the Draft EIR/EIS for a detailed discussion of potential flood impacts.) However, through the final design process, measures to address the liquefaction hazard would be required to conform to applicable design codes, guidelines, and standards. Conformance with these design standards is an environmental commitment by DWR to ensure that liquefaction risks are minimized as the water conveyance features are operated. See Appendix 3B, *Environmental Commitments*, in Appendix A of this RDEIR/SDEIS. The hazard would be controlled to a safe level and there would be no increased likelihood of loss of property, personal injury or death due to operation of Alternative 4A. The impact would be less than significant. No mitigation is required.

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

Alternative 4A would involve excavation that creates new cut-and-fill slopes and construction of new embankments and levees. As a result of ground shaking and high soil-water content during heavy rainfall, existing and new slopes that are not properly engineered and natural stream banks could fail and cause damage to facilities. The effects of Alternative 4A would be identical to Alternative 4.

NEPA Effects: The potential effect could be substantial because levee slopes and stream banks may fail, either from high pore-water pressure caused by high rainfall and weak soil, or from seismic shaking. Structures built on these slopes could be damaged or fail entirely as a result of slope instability. As discussed in Impact SW-2 in Chapter 6, *Surface Water*, of the Draft EIR/EIS, operation of the water conveyance features under Alternative 4A would not result in an increase in potential risk for flood management compared to existing conditions. Peak monthly flows under Alternative 4A in the locations considered were similar to or less than those that would occur under existing conditions. Since flows would not be substantially greater, the potential for increased rates of erosion or seepage are low. For additional discussion on the possible exposure of people or structures to impacts from flooding due to levee failure, please refer to Impact SW-6 in Chapter 6, *Surface Water*, of the Draft EIR/EIS.

During project design, a geotechnical engineer would develop slope stability design criteria (such as minimum slope safety factors and allowable slope deformation and settlement) for the various anticipated loading conditions. The design criteria would be documented in a detailed geotechnical report prepared in accordance with state guidelines, in particular *Guidelines for Evaluating and Mitigating Seismic Hazards in California* (California Geological Survey 2008).

Site-specific geotechnical and hydrological information would be used, and the design would conform with the current standards and construction practices. The design requirements would be presented in a detailed geotechnical report. Conformance with these design requirements is an environmental commitment by DWR to ensure that slope stability hazards would be avoided as the water conveyance features are operated. See Appendix 3B, *Environmental Commitments*, in Appendix A of this RDEIR/SDEIS. DWR would ensure that the geotechnical design recommendations are included in the design of cut and fill slopes, embankments, and levees to minimize the potential effects from slope failure. DWR would also ensure that the design specifications are properly executed during construction.

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

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). Conformance to the above and other applicable design specifications and standards would ensure that the hazard of slope instability would not create an increased likelihood of loss of property, personal injury of individuals along the Alternative 4A conveyance alignment during operation of the water conveyance features. Therefore, the effect would not be adverse.

***CEQA Conclusion*:** Unstable levee slopes and natural stream banks may fail, either from high pore-water pressure caused by high rainfall and weak soil, or from seismic shaking. Structures constructed on these slopes could be damaged or fail entirely as a result of slope instability.

However, during the final project design process, as required by DWR's environmental commitments (see Appendix 3B, *Environmental Commitments*, in Appendix A of this RDEIR/SDEIS), a geotechnical engineer would develop slope stability design criteria (such as minimum slope safety factors and allowable slope deformation and settlement) for the various anticipated loading conditions during facility operations.

DWR would also ensure that measures to address this hazard would be required to conform to applicable design codes, guidelines, and standards. Conformance with these codes and standards is an environmental commitment by DWR to ensure cut and fill slopes and embankments will be stable as the water conveyance features are operated and there would be no increased likelihood of loss of property, personal injury or death due to operation of Alternative 4A. The impact would be less than significant. No mitigation is required.

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

The effects of Alternative 4A would be identical to Alternative 4.

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

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

However, design-level geotechnical studies would be conducted by a licensed civil engineer who practices in geotechnical engineering. The studies would determine the peak ground acceleration caused by movement of the West Tracy fault and the maximum probable seiche wave that could be generated by the ground shaking. The California-registered civil engineer or California-certified engineering geologist's recommended measures to address this hazard, as well as the hazard of a seiche overtopping the expanded Clifton Court Forebay embankment, would conform to applicable design codes, guidelines, and standards. Conformance with these codes and standards is an environmental commitment by DWR to ensure that the adverse effects of a seiche are controlled to an acceptable level while the forebay facility is operated. See Appendix 3B, *Environmental Commitments*, in Appendix A of this RDEIR/SDEIS.

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

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

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). Conformance to these and other applicable design specifications and standards would ensure that the embankment for the expanded portion of the Clifton Court Forebay would be designed and constructed to contain and withstand the anticipated maximum seiche wave height and would not create an increased likelihood of loss of property, personal injury or death of individuals along the Alternative 4A conveyance alignment during operation of the water conveyance features. Therefore, the effect would not be adverse.

***CEQA Conclusion*:** The height of a tsunami wave reaching the Suisun Marsh and the Delta 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 most parts of the Plan Area is considered low because the seismic hazard and the geometry of the water bodies (i.e., wide and shallow) near conveyance facilities are not favorable for a seiche to occur. However, assuming the West Tracy fault is potentially active, a potential exists for a seiche to occur in the expanded Clifton Court Forebay (Fugro Consultants 2011).

However, design-level geotechnical studies would be conducted by a licensed civil engineer who practices in geotechnical engineering. The studies would determine the peak ground acceleration caused by movement of the West Tracy fault and the maximum probable seiche wave that could be generated by the ground shaking. The California-registered civil engineer or California-certified engineering geologist's recommended measures to address this hazard, as well as the hazard of a seiche overtopping the expanded Clifton Court Forebay embankment, would conform to applicable design codes, guidelines, and standards. Conformance with these codes and standards is an environmental commitment by DWR to ensure that the adverse effects of a seiche are controlled to an acceptable level while the forebay facility is operated. DWR would ensure that the geotechnical design recommendations are included in the design of project facilities and construction specifications to minimize the potential effects from seismic events and consequent seiche waves. DWR would also ensure that the design specifications are properly executed during construction.

The effect would not be adverse because the expanded Clifton Court 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, as required by DWR's environmental commitments (see Appendix 3B, *Environmental Commitments*, in Appendix A of this RDEIR/SDEIS). There would be no increased likelihood of loss of property, personal injury or death due to operation of Alternative 4A from seiche or tsunami. The impact would be less than significant. No additional 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 4A 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 adverse effect.

***CEQA Conclusion*:** Alternative 4A 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. The impact would be less than significant. 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

According to the available AP Earthquake Fault Zone Maps, only the Suisun Marsh ROA could be affected by rupture of an earthquake fault. The active Green Valley fault crosses the southwestern corner of the ROA. The active Cordelia fault extends approximately 1 mile into the northwestern corner of the ROA. Rupture of these faults could damage levees and berms constructed as part of the restoration, which could result in failure of the levees and flooding of otherwise protected areas. Under Alternative 4A, no Environmental Commitments would occur in the Suisun Marsh ROA.

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

NEPA Effects: Effects related to rupture of a known earthquake fault within an ROA under Alternative 4A would be similar in mechanism to those described for Alternative 4, but to a substantially smaller magnitude based on the conservation activities proposed under Alternative 4A (and as described in Section 4.1, *Introduction*, of this RDEIR/SDEIS).

Because there is limited information regarding the depths of the blind faults mentioned above, seismic surveys would be performed in the vicinity of the faults as part of final design. These surveys would be used to verify fault depths where levees and other features would be constructed. Collection of this depth information would be part of broader, design-level geotechnical studies conducted by a geotechnical engineer licensed in the state of California to support all aspects of site-specific project design. The studies would assess site-specific conditions at and near all the project facility locations, including the nature and engineering properties of all soils and underlying geologic strata, and groundwater conditions. The geotechnical engineers' information would be used to develop final engineering solutions to any hazardous condition, consistent with the code and standards requirements of federal, state and local oversight agencies. Conformance with these design standards is an environmental commitment by the project proponents to ensure that risks from a fault rupture are minimized as levees for habitat restoration areas are constructed and maintained (see Appendix 3B, *Environmental Commitments*, in Appendix A of this RDEIR/SDEIS). The hazard would be controlled to a safe level by following the proper design standards.

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

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

***CEQA Conclusion*:** As noted above, effects related to rupture of a known earthquake fault within an ROA under Alternative 4A would be similar in mechanism to those described for Alternative 4, but to a substantially smaller magnitude based on the restoration activities proposed under Alternative 4A. 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. Environmental Commitments under Alternative 4A would not occur in the Suisun Marsh area.

However, through the final design process for conservation activities in the ROAs and because there is limited information regarding the depths of the blind faults mentioned above, seismic surveys would be performed in the vicinity of the faults as part of final designs. These surveys would be used to verify fault depths where levees and other features would be constructed. Collection of this depth information would be part of broader, design-level geotechnical studies conducted by a geotechnical engineer licensed in the state of California to support all aspects of site-specific project design. The studies would assess site-specific conditions at and near all the project facility locations, including the nature and engineering properties of all soils and underlying geologic strata, and groundwater conditions. The geotechnical engineer's information would be used to develop final engineering solutions and project designs to any hazardous condition, consistent with DWR's environmental commitments (see Appendix 3B, *Environmental Commitments,* in Appendix A of this RDEIR/SDEIS).

Additionally, measures to address the fault rupture hazard would be required to conform to applicable design codes, guidelines, and standards. Conformance with these design codes, guidelines, and standards is an environmental commitment by the project proponents to ensure that fault rupture risks are minimized as the conservation activities 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

Effects related to strong seismic shaking within an ROA under Alternative 4A would be similar in mechanism to those described for Alternative 4, but to a substantially smaller magnitude based on the conservation activities proposed under Alternative 4A (and as described in Section 4.1, *Introduction*, of this RDEIR/SDEIS).

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

Among all the ROAs, the Suisun Marsh ROA would be most subject to ground shaking because of its proximity to active faults. The Suisun Marsh ROA is subject to a PGA of approximately 0.31–0.35 g for 200-year return interval, while the PGA for the other ROAs ranges from approximately 0.11–0.26 g. The ground shaking could damage levees and other structures, and in an extreme event cause levees to fail such that protected areas flood. However, Environmental Commitments under Alternative 4A would not occur in the Suisun Marsh area.

NEPA Effects: All temporary facilities would be designed and built to meet the safety and collapse-prevention requirements for the above-anticipated seismic loads. Therefore, this effect is considered not adverse. No additional mitigation measures are required.

Site-specific geotechnical information would be used to further assess the effects of local soil on the OBE and MDE ground shaking and to develop design criteria that minimize the potential of damage. Design-level geotechnical studies would be prepared by a geotechnical engineer licensed in the state of California during project design. The studies would assess site-specific conditions at and near all the project facility locations and provide the basis for designing the levees and other features to withstand the peak ground acceleration caused by fault movement in the region. The geotechnical engineer's recommended measures to address this hazard would conform to applicable design codes, guidelines, and standards. Conformance with these design standards is an environmental commitment by the project proponents to ensure that strong seismic shaking risks are minimized as the conservation activities are implemented (see Appendix 3B, *Environmental Commitments*, in Appendix A of this RDEIR/SDEIS).

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

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

***CEQA Conclusion*:** 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. However, Environmental Commitments under Alternative 4A would not occur in the Suisun Marsh area. Damage to these features could result in their failure, causing flooding of otherwise protected areas. Conformance with these design standards is an environmental commitment by the project proponents to ensure that strong seismic shaking risks are minimized as the conservation activities are operated and there would be no increased likelihood of loss of property, personal injury or death in the ROAs (see Appendix 3B, *Environmental Commitments*, in Appendix A of this RDEIR/SDEIS). The impact would be less than significant. No mitigation is required.

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

Effects related to seismic-related ground failure beneath an ROA under Alternative 4A would be similar in mechanism to those described for Alternative 4, but to a substantially smaller magnitude based on the conservation activities proposed under Alternative 4A (and as described in Section 4.1, *Introduction*, of this RDEIR/SDEIS).

New structural features are proposed at the ROAs, such as levees as part of Environmental Commitment 4, setback levees as part of Environmental Commitment 6. However, the amount of restoration being proposed under Alternative 4A is much smaller in breadth than under Alternative 4. Earthquake induced ground shaking could cause liquefaction, resulting in damage to or failure of these levees and other features constructed at the restoration areas. The consequences of liquefaction are manifested in terms of compaction or settlement, loss of bearing capacity, lateral spreading (horizontal soil movement), and increased lateral soil pressure. Failure of levees and other structures could result in flooding of otherwise protected areas in Suisun Marsh and behind new setback levees along the Sacramento and San Joaquin Rivers and in the South Delta ROA

The ROAs vary with respect to their liquefaction hazard (Figure 9-6 of the Draft EIR/EIS). All of the levees in the Suisun Marsh ROA have a medium vulnerability to failure from seismic shaking and resultant liquefaction. The liquefaction vulnerability among the other ROAs in which seismically-induced levee failure vulnerability has been assessed (Figure 9-6 of the Draft EIR/EIS) (i.e., in parts or all the Cache Slough Complex and South Delta ROAs) is medium or high.

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

During final design of conservation facilities, site-specific geotechnical and groundwater investigations would be conducted by a geotechnical engineer to identify and characterize the vertical (depth) and horizontal (spatial) extent of liquefiable soil.

In areas determined to have a potential for liquefaction, the engineer would develop design parameters and construction methods to meet the design criteria established to ensure that design earthquake does not cause damage to or failure of the facility. Conformance with these design standards is an environmental commitment by the project proponents to ensure that liquefaction risks are minimized as the conservation activities are implemented.

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

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). As required by the environmental commitments (see Appendix 3B, *Environmental Commitments*, in Appendix A of this RDEIR/SDEIS), the project proponents would ensure that the geotechnical design recommendations are included in the design of levees and construction specifications to minimize the potential effects from liquefaction and associated hazard. The project proponents would also ensure that the design specifications are properly executed during implementation and would not create an increased likelihood of loss of property, personal injury or death of individuals in the ROAs. This effect would not be adverse.

***CEQA Conclusion*:** Earthquake induced ground shaking could cause liquefaction, resulting in damage to or failure of levees, berms, and other features constructed at the restoration areas. Failure of levees and other structures could result in flooding of otherwise protected areas. As required by the environmental commitments (see Appendix 3B, *Environmental Commitments*, in Appendix A of this RDEIR/SDEIS), site-specific geotechnical and groundwater investigations would be conducted to identify and characterize the vertical (depth) and horizontal (spatial) extent of liquefiable soil. The project proponents would ensure that the geotechnical design recommendations are included in the design of levees and construction specifications to minimize the potential effects from liquefaction and associated hazard. The project proponents would also ensure that the design specifications are properly executed during implementation and would not create an increased likelihood of loss of property, personal injury or death of individuals in the ROAs. Further, through the final design process, measures to address the liquefaction hazard would be required to conform to applicable design codes, guidelines, and standards. Conformance with these design standards is an environmental commitment by the project proponents to ensure that liquefaction risks are minimized as the water conservation features are implemented 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-15: Loss of Property, Personal Injury, or Death from Landslides and Other Slope Instability at Restoration Opportunity Areas

Effects related to landslides and slope instability at an ROA under Alternative 4A would be similar in mechanism to those described for Alternative 4, but to a substantially smaller magnitude based on the conservation activities proposed under Alternative 4A (and as described in Section 4.1, *Introduction*, of this RDEIR/SDEIS).

Implementation of Environmental Commitments 3, 4, 6, and 7 could involve breaching, modification or removal of existing levees and construction of new levees and embankments. Levee modifications, including levee breaching or lowering, may be performed to reintroduce tidal exchange, reconnect remnant sloughs, restore natural remnant meandering tidal channels, encourage development of dendritic channel networks, and improve floodwater conveyance.

Levee modifications could involve the removal of vegetation and excavation of levee materials. Excess earthen materials could be temporarily stockpiled, then re-spread on the surface of the new levee slopes where applicable or disposed of offsite. Any breaching or other modifications would be required to be designed and implemented to maintain the integrity of the levee system and to conform to flood management standards and permitting processes. This would be coordinated with the appropriate flood management agencies. Those agencies may include USACE, DWR, CVFPB, and other flood management agencies. For more detail on potential modifications to levees as a part of conservation activities, please refer to Chapter 3, *Conservation Strategy*, of the Draft BDCP, and Appendix D, *Substantive BDCP Revisions*, of this RDEIR/SDEIS

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

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

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

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

As outlined in Appendix 3B, *Environmental Commitments*, in Appendix A of this RDEIR/SDEIS, erosion protection measures and protection against related failure of adjacent levees would be taken where levee breaches were developed. Erosion protection measures would also be taken where levee lowering is done for the purposes of allowing seasonal or periodic inundation of lands during high flows or high tides to improve habitat or to reduce velocities and elevations of floodwaters. Neighboring levees could require modification to accommodate increased flows or to reduce effects of changes in water elevation or velocities along channels following inundation of tidal marshes. Hydraulic modeling would be used during subsequent analyses to determine the need for such measures.

New levees would be constructed to separate lands to be inundated for tidal marsh from non-inundated lands, including lands with substantial subsidence. Levees could be constructed as described for the new levees at intake locations. Any new levees would be required to be designed and implemented to conform to applicable flood management standards and permitting processes.

Additionally, during project design, a geotechnical engineer would develop slope stability design criteria (such as minimum slope safety factors and allowable slope deformation and settlement) for the various anticipated loading conditions.

Site-specific geotechnical and hydrological information would be used, and the design would conform with the current standards and construction practices, as described in Appendix 3B, *Environmental Commitments*, in Appendix A of this RDEIR/SDEIS.

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

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

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

***CEQA Conclusion*:** Unstable new and existing levee and embankment slopes could fail as a result of seismic shaking and as a result of high soil-water content during heavy rainfall and cause flooding of otherwise protected areas. However, during project design and as required by the project proponents' environmental commitments (see Appendix 3B, *Environmental Commitments*, in Appendix A of this RDEIR/SDEIS), a geotechnical engineer would develop slope stability design criteria (such as minimum slope safety factors and allowable slope deformation and settlement) for the various anticipated loading conditions. The project proponents would ensure that the geotechnical design recommendations are included in the design of embankments and levees to minimize the potential effects from slope failure. The project proponents would also ensure that the design specifications are properly executed during implementation.

Additionally, as required by the project proponents' environmental commitments (see Appendix 3B, *Environmental Commitments*, in Appendix A of this RDEIR/SDEIS), site-specific geotechnical and hydrological information would be used to ensure conformance with applicable design guidelines and standards, such as USACE design measures. Through implementation of these environmental commitments, 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. Therefore, no mitigation is required.

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

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

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