4.6 GEOLOGY AND SOILS

This section discusses existing geologic and/or soils related conditions including seismicity, liquefaction potential, slope stability, and expansive soils that may affect the proposed project. The majority of this section is based on a Preliminary Geotechnical Report prepared for the project by Fugro in 2009. The report focused on the levee raise component of the project and included surface and subsurface geologic investigations and laboratory analysis of sample material taken from the levee embankments and the subgrade. The report characterizes material properties and provides recommendations for addressing local geologic conditions and potential geologic hazards. The conclusions and recommendations (Chapter 6 of the report) have been included in Appendix E. The complete report is available for review with the San Luis Obispo County Flood Control and Water Conservation District (District).

4.6.1 Existing Conditions

4.6.1.1 General Site Conditions

The project area includes a portion of the Arroyo Grande Valley. The valley is a broad, flat plain spreading from north to south/southwest. The southern and western ends of the valley terminate at the Oceano Dunes. The northern end of the valley pinches out where Arroyo Grande Creek flows under Highway 101. Surface soils in the area have been continually disturbed by agricultural activities in the valley.

Los Berros Creek channel flows into the Arroyo Grande Creek channel approximately 2,000 feet north of Highway 1. The project elevations range from approximately 11 feet near the Oceano dunes to approximately 65 feet at Century Lane. The channel bottoms are mostly sand and gravel.

Review of the original United States Department of Agriculture (USDA) levee plans by Fugro indicates that the initial levee construction included embankments of approximately 15 feet wide. External slopes were constructed at 1.5h:1v or 2h:1v and internal slopes were designed to be approximately 3h:1v. Review of the as-built plans and recent topographic data indicate the interior slopes are as steep as 2h:1v. The levees were designed to have interior heights of approximately 11 to 14 feet. Existing heights may be somewhat less than this, although portions of the channel upstream of Highway 1 are incised below that depth, potentially due to bank erosion. Exterior slope heights were designed to be approximately 5 to 12 feet above existing grades, although they are generally less pronounced upstream of Highway 1.

In 2003 the levees were damaged by the San Simeon earthquake. Damage to the southern levee was noted by the County near Creek Road. According to the United States Geological Survey (USGS) report prepared after the earthquake, damage was most likely due to liquefaction.

4.6.1.2 Geologic Setting

Based on published geologic maps used in the Fugro report, the entire project site is located on recent alluvial deposits (Qal on Figure 4.6-1). Subsurface exploration and laboratory testing identified five variations of this formation (Qal1 through Qal5) within the project area. These variations are described in detail in the Fugro report. Adjacent formations include the older sand dune deposits that make up the Oceano Dunes and Nipomo Mesa. It should be noted that a portion of the site along the creek was part of what is known as the “pre-settlement Estero”.

According to the USGS the area was "subdivided and turned into developable lots by leveling dunes and filling in swamp areas with dune sand in March 1927". The alignment of Arroyo Grande Creek downstream of Creek Road may have been altered by this development as well. During field explorations, groundwater was encountered anywhere from 3 to 14 feet below ground level. Fugro notes that groundwater levels in the area could fluctuate considerably given rainfall, tidal influences, runoff, and irrigation schedules.

The area of the Union Pacific Railroad (UPRR) bridge raise was not specifically evaluated in the Fugro report. However based on maps in the report, the underlying soils are similar to those in the rest of the project area.

Regional Faulting and Seismicity

Fugro identified nine active and potentially active faults in the vicinity of the project site. The closest are associated with the San Luis Range Fault System. This system includes the Oceano and Wilmar Avenue faults, which are considered active. These faults do not cross the project site. The project site is in a seismically active portion of California and has been subject to various seismic events, including ones in 1830, 1857, 1913, 1916, 1917, 1952, 1966, 1980, and 2003. The San Simeon Earthquake (2003) did result in damage to the levees.

Existing Levee Slope Stability

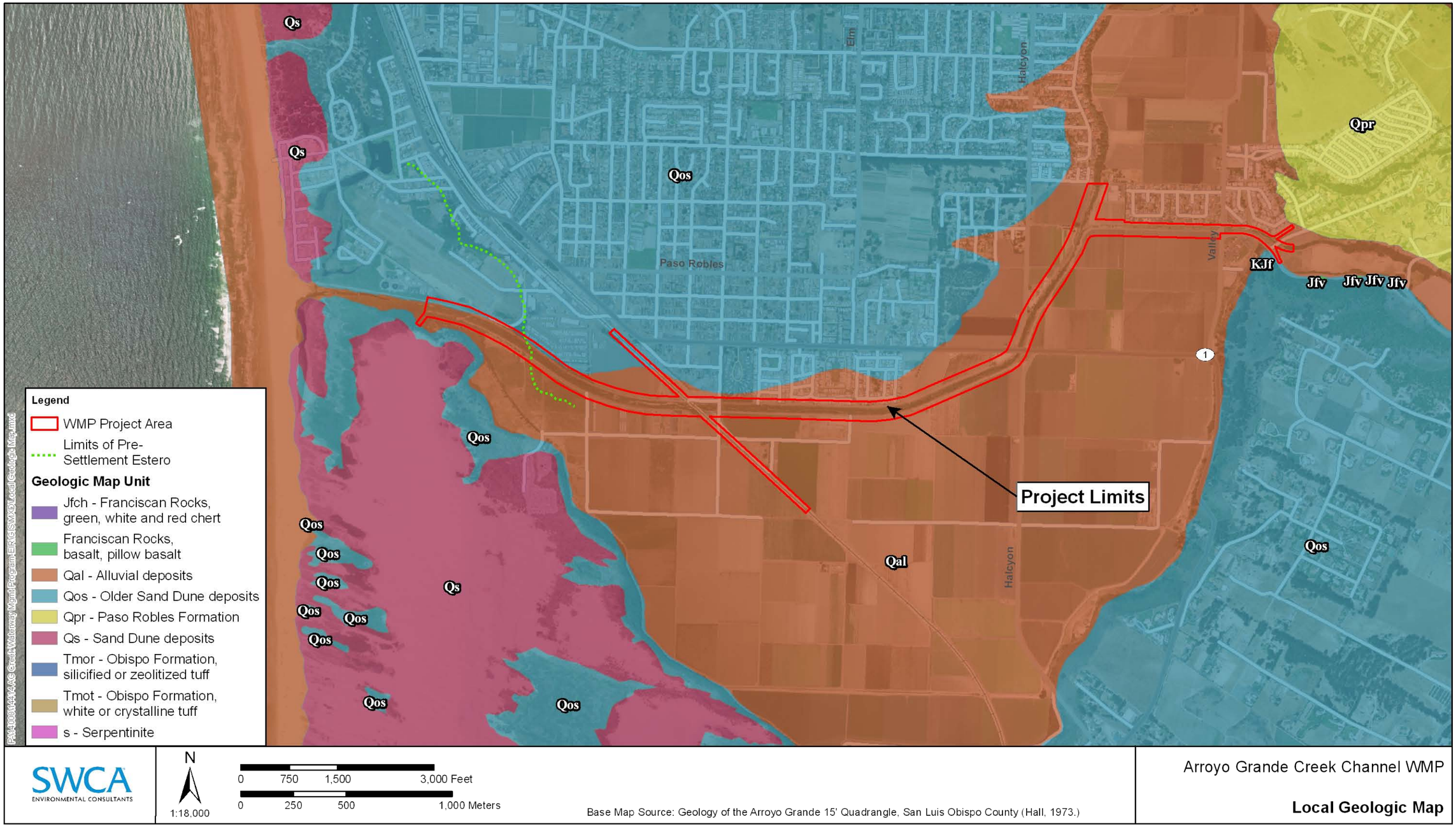
Fugro performed slope stability analysis at two locations along the existing levee. The analysis considered static loading, psuedostatic (earthquake) loading, and post-liquefaction conditions. The results of the analysis are summarized in Table 4.6-1. Generally a factor of safety of 1.1 or higher is considered stable under County guidelines. The analysis concludes that the southern levee downstream of Creek Road may be unstable once earthquake-induced liquefaction occurs. This is consistent with the damage that occurred after the 2003 San Simeon earthquake.

Table 4.6-1. Existing Levee Slope Stability

Location	Levee Slope	Existing Factor of Safety		
		Static	Earthquake	Post-liquefaction
North Levee upstream of 22nd Street (Sta 72)	Interior	2.5	1.5	2.5
	Exterior	1.7	1.2	1.7
South Levee downstream of Creek Road (Sta 30)	Interior	2.6	1.5	0.8
	Exterior	1.9	1.3	1.1

Source: Fugro 2009 (See Appendix E)

Figure 4.6-1. Geologic Map



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Liquefaction

Liquefaction is the rapid transformation of saturated, loose, fine-grained sediment (such as silt and sand) to a fluid-like state, often caused by an earthquake. During the shaking the soil loses its bearing strength and it may spread laterally, undergo settlement, and/or form fissures. Liquefaction can result in substantial damage to property, roads, and infrastructure. The southern levee near Creek Road was affected by liquefaction during the 2003 San Simeon earthquake. Potential for liquefaction is highest where alluvial deposits and high water tables underlie the ground surface, which is the case in much of the project area.

Soil Conditions

Erosion and Scour

Soils in the County are mapped by the Natural Resources Conservation Service (NRCS) and documented in the Soil Surveys for San Luis Obispo County. Tests performed on those soils help engineers determine their characteristics (i.e., permeability, strength, composition, etc.). Typically, erosive factors are used to predict the erodibility of a soil and its tolerance to erosion in relation to specific kinds of land use and treatment. Erosive factors are influenced by factors such as plant cover, grade and length of slope, management practices, and climate.

Erosion outside of the levees is relatively limited due to the flat topography. Erosion of levee slopes has been noted on the interior and exterior levee slopes in some places. An evaluation of erosion along Arroyo Grande Creek performed by Central Coast Salmon Enhancement (CCSE) identified approximately 10 sites with relatively significant erosion problems that are also located within the project area (CCSE 2009).

The existing levee slopes are subject to sheet or rill erosion during rainfall, although the slopes are generally well-vegetated, which minimizes damage caused by stormwater runoff. The County does periodically maintain levee slopes affected by runoff. Levee embankments are also subject to an erosional feature known as piping, wherein a tunnel-like void is eroded in the levee due to seepage daylighting from the interior of the levee to the exterior. The Fugro report notes that piping is possible due to the sandy material which makes up the existing levee. The levees are also subject to mass erosion and have failed catastrophically during flooding events when the levee is breached. This occurred most recently in 2001. Hundreds of acres of farmland and several residences were flooded due to that event (Swanson 2006).

Scour is the hole left behind when sediment (sand and rocks) is washed away from the bottom of a river. Although scour may occur at any time, it may be especially strong during floods. Swiftly flowing water has more energy than calm water to lift and carry sediment down river. If sediment or rock on which bridge supports rest is scoured by a river, the bridge could become unsafe for travel. The Fugro report notes areas of scour upstream of the Highway 1 bridge identified during field visits in 2008.

Subsidence

Subsidence is the sinking or downward settling of the ground surface relative to the surrounding area, with little or no horizontal movement. Significant land subsidence in California is generally related to dewatering or withdrawal of oil or gas from the soil, hydrocompaction of dry, loose, clayey soils, or oxidation of organic materials, although groundwater withdrawal may also result in subsidence. In the project area, groundwater is relatively close to the surface.

Expansive Soils

The project site is dominated by sandy soils, although finer grained and some clay soils do exist, according to the Fugro report. The levees are constructed of sandy material which has a low potential for expansion.

Landslide and Rockfall Hazard

A landslide is defined as downslope movement, under gravitational influence, of soil and rock materials en masse. Rockfall is precipitous movement of rocks or newly detached segments of bedrock down the face of a steep slope or cliff. Landslide and rockfall conditions do not exist at the project site given the flat topographic conditions of the Arroyo Grande Valley.

4.6.2 Regulatory Setting

4.6.2.1 Federal and State Polices and Regulations

Alquist-Priolo Earthquake Hazards Zone Act

The Alquist-Priolo Earthquake Hazard Zone Act (originally the Alquist-Priolo Special Studies Zone Act of 1972) requires that zones along sufficiently active and well-defined faults be established. The zones vary in width, but are in general approximately one quarter mile wide. Development is limited in areas defined as Earthquake Hazard Zones and structures for human occupancy are generally not permitted. The act regulates structures with human occupancy or usage of 2,000 person-hours per year or more. The project site is not in or adjacent to an Alquist-Priolo Zone.

Uniform Building Code and California Building Code

The Uniform Building Code (UBC) and the California Building Code dictate seismic design parameters for structures in California. The UBC provides a standard for building laws. Published by the International Conference of Building Officials, the UBC is a widely adopted model building code in the United States. The 1997 UBC is considered the latest edition and is adopted and used by most cities and counties. The California Building Code incorporates by reference the UBC with necessary California amendments. The California Building Code is codified in the California Code of Regulations (CCR) Title 24 Part 2, commonly known as the California Building Standards Code. Title 24 is assigned to the California Building Standards Commission, which, by law, is responsible for coordinating all building standards. Under state law, all building standards must be centralized in Title 24 or they are not enforceable. About one-third of the text within the California Building Code has been tailored for California earthquake conditions.

4.6.2.2 Local Policies and Regulations

Government Code Sections 65302.1 requires a safety element for the protection of the community from geologic hazards that must include features to minimize risks associated with these hazards. San Luis Obispo County adopted its Safety Element of the General Plan in 1999. In accordance with this regulation, the proposed project shall be designed to comply and be consistent with the Safety Element of the San Luis Obispo County General Plan.

Also applicable to the project are Chapter 22 of the County of San Luis Obispo Land Use Ordinance (LUO), 2002 edition, and Title 19, Building and Construction Ordinance of the San Luis Obispo County Code. Article 5, Chapter 22.52 of the LUO establishes standards for

grading and excavation activities. Grading, sedimentation, and erosion control are addressed in Section 19.20.090 of Title 19, Building and Construction Ordinance of the San Luis Obispo County Code.

4.6.3 Thresholds of Significance

The thresholds of significance are based on the criteria set forth in Appendix G of the CEQA Guidelines. According to that criteria, a project would result in a significant geology and soils-related impact if it would:

1. Expose people or structures to potential substantial adverse effects, including risk of loss, injury, or death involving earthquake rupture, strong seismic ground shaking, seismic related ground failure including liquefaction, and landslides;

2. Result in substantial soil erosion or the loss of topsoil;

3. Be located on a geologic unit or soil that is unstable that could potentially result in landslide, lateral spreading, subsidence, liquefaction or collapse; or

4. Be located on expansive soil creating substantial risks to like or property.

4.6.4 Impact Assessment and Methodology

Soils, geologic, and seismic hazards and impacts, were evaluated based upon a review of the Fugro report, the Halcyon Road Master Environmental Impact Report (EIR) (Morro Group 2007), and a site reconnaissance. The report includes twenty potential hazards that could affect the project. The potential of those hazards to impact the existing levee was compared to their potential to impact the levee after implementation of the proposed project. A table of the conclusions is included in Appendix E.

4.6.5 Project-Specific Impacts and Mitigation Measures

Impacts in this section are not broken down by project component as they relate only to the levee raise components of the project. In general the impacts would be similar for either the Alternative 3a or 3c levee raise, but would perhaps be more intensive for the 3c levee raise as it requires the most substantial changes to existing conditions. It should also be noted that prior to grading associated with the levee components and UPRR bridge raise, additional subsurface analysis and specific geotechnical recommendations would be made by an engineer. This is a requirement of local building code and therefore not identified as a specific mitigation measure below.

4.6.5.1 Faulting and Seismicity

No active faults cross the project area but the project site is subject to seismic activity due to its proximity to numerous faults, including local faults associated with the San Luis Range fault system which are less than 2 miles from the project area, and the San Andreas fault, located approximately 42 miles from the project site.

Seismic activity can induce liquefaction, resulting in settlement or cracking of the levees, or result in failure of the levee slopes. Based on the project location, local geologic conditions and recent experience with seismic events, the proposed project may be impacted by all three

issues. Based on information in the Fugro report, settlement could reach as much as 2 to 9 inches along the levees depending upon the location, with the greatest settlement located in the "pre Estero" area downstream of Creek Road.

Failure of the levee slopes may also occur due to seismic activity and subsequent liquefaction of local soils. The Fugro analysis considered static loading, psuedostatic (earthquake) loading, and post-liquefaction conditions on the proposed project. The results of the analysis are summarized in Table 4.6-2. Generally a factor of safety of 1.1 or higher is considered stable under County guidelines.

Table 4.6-2. Alternative 3c Levee Slope Stability

Location	Levee Slope	Proposed Factor of Safety		
		Static	Earthquake	Post-liquefaction
North Levee upstream of 22nd Street (Sta 72)	Interior	1.9	1.3	1.8
	Exterior	1.7	1.2	1.7
South Levee downstream of Creek Road (Sta 30)	Interior	1.9	1.3	0.5
	Exterior	1.9	1.3	0.8

Source: Fugro 2009 (See Appendix E)

Table 4.6-2 indicates that the Alternative 3c levees would be stable under static and earthquake "loads." It also indicates that in areas downstream of Creek Road the factor of safety may fall well below 1.1 and the levees may be unstable. This is due to the liquefaction that would occur in the soils underlying the levee. This instability exists currently as well, but to a lesser extent.

Two potential mitigation strategies for potential slope instability are discussed in the Fugro report. One includes over-excavating liquefaction prone soils and backfilling the excavation with soils not prone to liquefaction. However given that potential excavation could reach 13 feet in some places, and the lengths which excavation would need to occur, this strategy may be infeasible.

Another approach for mitigation is to acknowledge that liquefaction and instability may occur, and to prepare for it accordingly. This may include identifying those areas most prone to liquefaction and developing an emergency response repair plan so that the levee embankments could be repaired as soon as possible. Without quick repairs, the integrity of the flood control channel would be compromised and the level of flood protection offered would be reduced.

GS Impact 1 **The proposed Alternative 3a and 3c levee improvements may become unstable when a seismic event results in liquefaction of the underlying soils.**

Mitigation Measures

GS/mm-1 *Prior to construction of Alternative 3a and 3c a design-level geotechnical report for the levee improvements shall be prepared by the District. The report shall provide ground motion parameters, for use in geotechnical analyses, such as for evaluating slope stability, liquefaction, and seismic settlement.*

GS/mm-2 *Prior to construction of Alternative 3a and 3c an Emergency Response Plan shall be prepared by the District to address seismic hazards. The plan shall recognize the potential for liquefaction and seismic impacts to the levee, and delineate specific high-hazard areas that should be inspected for damage immediately following an earthquake.*

Residual Impact

In the event that liquefaction produces instability during a flooding event GS/mm-2 would be ineffective at addressing the impacts. As a result there is some residual impact; however, the likelihood of a high-flow event coinciding with a significant earthquake event is quite low. Therefore with implementation of these measures, the impact would be *less than significant*.

4.6.5.2 Soil Conditions

Seepage

Soils conditions of the project area and levees described by Fugro indicate that the integrity of the channels may be compromised due to erosion of the levee slopes, and seepage through the levee embankments or foundation. Other impacts identified include the potential of expansive soils or collapsible soils to affect the levee stability, although standard geotechnical practices required by ordinance would mitigate these impacts.

During high flow events, water seeping through the levee embankments may daylight on the exterior of the levee slopes, resulting in localized erosion. Continued seepage could lead to piping and increased erosion. Foundation seepage may also occur when a higher water level in creeks infiltrates the creekbed and flows beneath the levee to a lower water level. If uncontrolled, piping or seepage could erode foundation materials destabilizing the embankment. Seepage could be accelerated during the vegetation management as shrubs and root-intensive plants would be removed from the levee embankments.

GS Impact 2 **Foundation and/or embankment seepage may result in localized destabilization of the levees.**

Mitigation Measures

GS/mm-3 *Prior to construction of Alternative 3a and 3c a design level geotechnical report shall be prepared by the District to address seepage conditions. It should include mitigation strategies such as cutoff walls, impervious blankets, or drainage systems, for example, that control or reduce gradients.*

Residual Impact

With implementation of mitigation, this impact would be considered *less than significant*.

Erosion

Construction activities associated with the vegetation management, the levee raise components and the UPRR bridge raise would all result in exposed slopes subject to erosion. As proposed, the project components would be implemented during the dry season, minimizing the potential for erosion to occur during construction. Over the long term, the graded fill slopes would be subject to sheet and rill erosion and scour. Currently, erosion of the interior levee slopes is minimized due to the relative flat slope angles (roughly 3h;1v) and the relatively heavy vegetative cover. However this cover would be removed under the vegetation management component of the proposed project.

Erosion would be accelerated where soils are directly exposed to concentrated stormwater runoff such as at culverts and areas where floodwaters overtop the levees. Floodwaters overtopping the levee may result in mass erosion and catastrophic failure of the levee system as witnessed in the 2001 flooding event. This may be more likely on the southern levee as it is lower relative to the northern levee and would overtop first.

GS Impact 3 **Soils disturbed during the vegetation and sediment management, construction of Alternative 3a and 3c, and the UPRR bridge raise would be subject to erosion and scour from stormwater, high flow events in the channel, and flooding events.**

Mitigation Measures

GS/mm-4 *Prior to initiation of any project components an erosion control plan shall be implemented by the District. The plan shall address short and long-term erosion control and scour which may result from the project components. Vegetation used for erosion control shall be compatible with vegetation management efforts to reduce channel roughness coefficients, and any biological resources mitigation measures.*

GS/mm-5 *Prior to initiation of any project components the District shall prepare and submit to the SWRCB for approval a Notice of Intent and Storm Water Pollution Prevention Plan (SWPPP) in accordance with the requirements of the State General Order related to construction projects. The SWPPP shall identify the selected stormwater management procedures, pollution control technologies, spill response procedures, and other means that will be used to minimize erosion and sediment production and the release of pollutants to surface water during construction. The SWPPP shall also describe procedures and be consistent with biological resources mitigation.*

GS/mm-6 *On-going maintenance of the levee embankments by the District should include removal of debris and dead vegetation which could concentrate flows, and repair of holes and other disturbances resulting from the initial and annual vegetation management activities.*

GS/mm-7 *Prior to implementation of Alternative 3a and 3c the District shall identify areas adjacent to the south levee where levee overtop and flooding may least affect public safety and property value and consider construction of a permanent spillway at these location(s). The spillway shall be designed to accommodate flood events in a manner that would reduce the potential for mass erosion and catastrophic failure of the levees.*

Residual Impact

There is always the potential that the levees would erode during a major flood event resulting in massive failure. This possibility is decreased by the proposed project due to its design in accordance with modern building codes and the mitigation measures included in this section of the EIR. Impacts associated with erosion and scour would be *less than significant*. No additional mitigation would be required.

Secondary Impacts

In the event that implementation of GS/mm-7 results in construction of spillways, floodwaters could be concentrated on adjacent agricultural lands, reducing short-term productivity; however, those areas are currently subject to floods from five-year events and therefore the proposed project, even after implementation of GS/mm-7 would result in fewer flooding impacts to the properties adjacent to the spillways. Spillway construction shall be performed consistent with the biological resource and other mitigation included in this EIR, although based on the specific size and design of the improvements, subsequent environmental review may be required.

4.6.5.3 Landslide and Rockfall

The potential for impacts to the project related to landslide and rockfall, are considered *less than significant* due to the absence of site conditions that would create a significant potential for such occurrences. No mitigation is required.

4.6.6 Cumulative Impacts

Potential impacts related to geologic, soils, and seismic hazards are all site-specific, and mitigation measures are applied to each project to minimize the potential for significant geologic impacts. All development projects are required to comply with State and local regulations regarding grading and construction; therefore, cumulative impacts related to these issues would be *less than significant*. No mitigation is required.

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