Long-Term Operation – Final Environmental Impact Statement

# Chapter 20 – Geology and Soils

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# Contents

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# Chapter 20 Geology and Soils

This chapter is based on the background information and technical analysis documented in Appendix W, *Geology and Soils Technical Appendix*, which includes additional information on geology and soil quality conditions and technical analysis of the effects of each alternative.

## 20.1 Affected Environment

### 20.1.1 Trinity River

Soils in the southern region of the Klamath Mountain Geomorphic Province, including the Trinity River watershed are generally composed of gravelly loam with some alluvial areas with dredge tailings, river wash, and xerofluvents, which is a gravelly soil. Soils along the lower Klamath River are generally composed of gravelly clay loam and gravelly sandy loam with sand and gravels within the alluvial deposits. Throughout the Trinity River and lower Klamath River watersheds, large, dormant, deep-seated landslides occur where low shear strength soils are located. In most cases, slope movement occurs in geologic units known as mélanges found in the Franciscan Complex.

### 20.1.2 Central Valley

The Sacramento River flows from Shasta Reservoir to the Sacramento–San Joaquin Delta (Delta). The area along the Sacramento River from Shasta Reservoir to downstream of Red Bluff is characterized by loosely consolidated deposits of sandstone, shale, and gravel. Downstream of Red Bluff to the Delta, the river flows through Quaternary-age alluvium, lake, playa, and terrace deposits that are unconsolidated or poorly consolidated. The active river channel maintains roughly constant dimensions as it migrates across the floodplain within the limits of the meander belt. The area along the American River downstream of Folsom Reservoir and Nimbus Dam is in the Great Valley Geomorphic Province. The alluvial plains in the American River watershed include older Quaternary deposits. River flood plains and channel deposits lay along the American River.

The Stanislaus River downstream of New Melones Reservoir flows through the Great Valley Geomorphic Province. Tertiary sedimentary formations were deposited along the Stanislaus River from an area east of Knights Ferry to Oakdale. The lower San Joaquin River is a low-gradient, single-channel, generally sand-bedded, meandering river downstream of Millerton Reservoir. There are large sections of the riverbanks that have been armored with large rocks to reduce bank erosion and channel migration. Land subsidence throughout the Central Valley occurs to varying degrees primarily due to aquifer-system compaction as groundwater elevations decline because of groundwater overdraft (i.e., groundwater withdrawals at rates greater than groundwater recharge rates) typically used for irrigation. Throughout the Central Valley, agricultural lands are subject to erosional processes when land cover is reduced or lost.

### 20.1.3 Bay-Delta

The San Francisco Bay/Sacramento–San Joaquin Delta Estuary (Bay-Delta) Region is a northwest-trending structural basin, separating the primarily granitic rock of the Sierra Nevada from the primarily Franciscan Formation rock of the California Coast Ranges. The historical delta at the confluence of the Sacramento River and San Joaquin River is referred to as the Sacramento–San Joaquin Delta, or Delta. The soils of this region are as diverse as the landscapes but typically are fine textured with locally high organic content (e.g., peat). The flatter landscapes of this region are not conducive for mass wasting processes, and surficial erosion is typically localized in response to storm runoff events and tidal influences. Subsidence in the region is associated with groundwater overdraft in the southern Santa Clara Valley. Land subsidence on some islands in the central and western Delta and Suisun Marsh may be a function of changes in tidal influence on these island landscapes because of levee construction and subsequent development.

### 20.1.4 Additional Central Valley Project and State Water Project Service Areas

In San Luis Obispo County, Morro Bay, Pismo Beach, and Oceano along the coast have soils that range from sands and loamy sands in areas near the shoreline to shaley loams, clay loams, and clays in the terraces and foothills located along the eastern boundaries of these communities. In Santa Barbara County, the Santa Maria, Vandenberg Air Force Base, Santa Ynez, Goleta, Santa Barbara, and Carpinteria areas are in alluvial plains, along stream channels with alluvium deposits, along the shoreline, or along marine terrace deposits above the Pacific Ocean.

## 20.2 Effects of the Alternatives

The impact analysis considers changes in geological and soils conditions related to changes in CVP and SWP operation under the alternatives as compared with the No Action Alternative.

Changes in releases to prioritize deliveries or storage may result in changes in reservoir water surface elevations that could influence shoreline erosion rates throughout the extent of the reservoir as water surface elevations fluctuate on an annual and interannual basis. For discussion purposes, the term *drawdown* is used to describe these changes in water surface elevations.[1] While shoreline rock content and slope directly influence shoreline erodibility, the extent of time and surface area exposed to wave and surficial erosion are also key factors in the loss of soil resources along reservoir shorelines. Changes in surface water deliveries could also result in modification of flow regimes that could affect stream channel erosion. Changes in water deliveries and the extent of irrigated acreage have the potential to result in soil erosion on crop-idled lands over the long-term average condition and in dry and critically dry years. Changes in water delivery amounts may also result in increased use of groundwater resources to maintain crops, which could affect land subsidence.

[1] In surface water hydrology and civil engineering, *drawdown* refers to the lowering of the surface elevation of a body of water where the shoreline is exposed to the atmosphere due to water-level fluctuations.

The No Action Alternative is based on 2040 conditions. The changes to geology and soil resources that are assumed to occur by 2040 under the No Action Alternative conditions would be different than existing conditions because of the following factors:

- Climate change and sea-level rise
- General plan development throughout California, including increased water demands in portions of the Sacramento Valley

Under the No Action Alternative, Reclamation would continue with the current operation of the Central Valley Project (CVP), as described in the 2020 Record of Decision and subject to the 2019 Biological Opinions. The 2020 Record of Decision for the CVP and the 2020 Incidental Take Permit for the State Water Project (SWP) represent current management direction or intensity pursuant to 43 CFR Section 46.30.

Although the No Action Alternative included habitat restoration projects at a programmatic level, the 2020 ROD did not provide environmental coverage for these projects, and all of the habitat projects considered under the No Action required or will require additional environmental documentation. Thus, ground disturbance for habitat restoration projects did not materialize as a result of implementing the No Action Alternative. For the purpose of the analysis, these habitat restoration projects are considered independent projects that will be considered under cumulative effects.

Under the No Action Alternative, land uses in 2040 would occur in accordance with adopted general plans, which could also result in impacts on erosion and subsidence due to ground disturbance and increased water use.

The No Action Alternative is expected to result in potential changes in soil erosion and rate of land subsidence for geology and soils resources at reservoirs that store CVP water, tributaries, and agricultural land. These changes were described and considered in the 2020 LTO Record of Decision and associated documents.

## 20.2.1 Potential Changes in Soil Erosion

### *20.2.1.1 Trinity River*

#### Reservoir Shoreline Erosion

*Alternative 1*

During dry periods, there may be increases in shoreline erosion associated with the operation of the Trinity Reservoir. Changes in shoreline erosion associated with operation of Trinity Reservoir under Alternative 1 in wet periods are negligible.

*Alternative 2*

During dry and wet periods, for all phases of Alternative 2 at Trinity Reservoir, the drawdown values are negligible.

*Alternative 3*

During dry periods, Alternative 3 has the largest drawdown for Trinity Reservoir compared with the No Action Alternative; therefore, shoreline erosion would increase relative to the No Action Alternative. During wet periods, the potential for shoreline erosion would be negligible.

*Alternative 4*

During Alternative 4, dry and wet periods in Trinity Reservoir would have negligible changes in drawdown relative to the No Action Alternative.

**Riverine Erosion**

*Alternative 1*

Erosion associated with high flows are not expected in the Trinity River below Lewiston under Alternative 1 because the drawdown values would be negligible.[2,3,4]

*Alternative 2*

Changes in high flows during wet periods would be negligible in the Trinity River below Lewiston Dam under all phases of Alternative 2. During dry periods, as all phases of Alternative 2 in the Trinity River are negative (-3.6 thousand acre-feet [TAF]), indicating less erosion and mass wasting than the No Action Alternative.

*Alternative 3*

During releases from Trinity Reservoir during dry periods, Alternative 3 would have an increase in flow that would likely result in an increase in erosion of the bed and banks of the Trinity River when compared with the No Action Alternative. During wet periods, Alternative 3 would result in a decreased potential for erosion compared with the No Action Alternative.

*Alternative 4*

During releases from Trinity Reservoir, Alternative 4's increase in flow would be negligible relative to the No Action Alternative in both dry and wet periods.

**Agricultural Land Erosion**

The steep, mountainous terrain associated with much of Trinity River watershed has precluded development of irrigated agriculture; therefore, erosion of irrigable lands is excluded from consideration in this discussion for all action alternatives.

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[2] High flows are defined as flows from the CalSim3 model that exceed the No Action Alternative and thus cause more impacts than NAA conditions.

[3] For a reservoir, Alternative drawdown values > No Action Alternative drawdown values imply a larger erosional surface exposed for the alternative than the No Action Alternative possibly resulting in surface erosion and mass-wasting. For river releases, Alternative drawdown values > No Action Alternative drawdown values implies more releases into the river and possibly results in flooding with subsequent bank failures.

[4] As defined in Appendix W, negligible drawdown values are those whose changes from the No Action Alternative are between -5% and 5%.

### *20.2.1.2 Sacramento Valley*

#### Reservoir Mass Wasting

*Alternative 1*

Shoreline erosion associated with changes in Shasta Reservoir storage is negligible under Alternative 1 compared with the No Action Alternative. Under Alternative 1, Folsom Reservoir drawdowns for dry periods is more (24% change) than the No Action Alternative. Therefore, there is a greater likelihood for shoreline erosion in Folsom Reservoir to occur for Alternative 1 during dry periods relative to the No Action Alternative. Change in shoreline erosion in Folsom Reservoir would be negligible in wet periods.

*Alternative 2*

During dry periods in Shasta Reservoir, all phases of Alternative 2 have positive drawdown values (ranging from 7% to 22% change) that indicate the likelihood for shoreline erosion is greater relative to the No Action Alternative. For wet periods, all phases of Alternative 2 would have negligible drawdown changes relative to No Action Alternative. Changes in shoreline erosion in Folsom Reservoir would be negligible in both dry and wet periods for all phases of Alternative 2.

*Alternative 3*

During dry periods, Alternative 3 has a positive drawdown value (32% change) for Shasta Reservoir storage. Therefore, there is a greater potential for shoreline erosion relative to the No Action Alternative for Alternative 3. For wet periods, the potential for shoreline erosion would be negligible relative to the No Action Alternative. Changes in shoreline erosion in Folsom Reservoir would be negligible in both dry and wet periods for Alternative 3.

*Alternative 4*

Under Alternative 4, dry periods in Shasta Reservoir would have an increased potential for shoreline erosion at Shasta Reservoir relative to the No Action Alternative due to the increased drawdown (8% change). For wet periods, the potential for shoreline erosion is negligible relative to the No Action Alternative. Changes in shoreline erosion in Folsom Reservoir would have an increased potential for shoreline erosion at Folsom Reservoir relative to the No Action Alternative due to the increased drawdown (9% change). For wet periods, the potential for shoreline erosion would be negligible Alternative 4.

#### Riverine Erosion

*Alternative 1*

Under Alternative 1, flow-related riverine erosion in the Sacramento River for both dry and wet periods would be negligible. Alternative 1 would likely result in decreased riverine erosion in the American River relative to the No Action Alternative (-43% change). During wet periods, conditions are equal to those in the No Action Alternative, and therefore riverine erosion in the American River would be comparable to the No Action Alternative. The potential for riverine erosion through the Yolo Bypass under Alternative 1 is negligible given the low channel gradient, large cross-sectional area for flow, and low flow velocities at the margins of the bypass.

*Alternative 2*

Under all phases of Alternative 2, the potential for riverine erosion in the Sacramento River for both dry and wet periods would be negligible. All phases of Alternative 2 would release less flow during dry periods to at the American River and would result in decreased riverine erosion in the American River relative to the No Action Alternative (-14% - -33% change). During wet periods, conditions are equal to those in the No Action Alternative. The minor anticipated increase in winter flood flows through the Yolo Bypass under Alternative 2 Without TUCP Without VA and Alternative 2 With TUCP Without VA would result in negligible increases in riverine erosion. However, under Alternative 2 Without TUCP With Delta VA and Alternative 2 Without TUCP All VA, riverine erosion through the Yolo Bypass would result in negligible decreases relative to the No Action Alternative.

*Alternative 3*

Under Alternative 3, the potential for riverine erosion in the Sacramento River for both dry and wet periods would be negligible. Under dry periods in the American River, Alternative 3 would result in decreased riverine erosion relative to the No Action Alternative (-20% change). During wet periods, riverine erosion in the American River would be comparable to the No Action Alternative. Riverine erosion in the Yolo Bypass under Alternative 3 would be negligible.

*Alternative 4*

Under Alternative 4, releases to the Sacramento River for both dry and wet periods are negligible. Alternative 4 would release less during dry periods at American River and would likely result in decreased riverine erosion in the American River relative to the No Action Alternative (-13%). During wet periods, conditions are equal to those in the No Action Alternative, and therefore riverine erosion would be comparable to the No Action Alternative. The minor anticipated increase in riverine erosion through the Yolo Bypass under Alternative 4 would be negligible.

**Agricultural Land Erosion**

*Alternative 1*

When compared with the No Action Alternative, Alternative 1 lands subject to fallowing in the Sacramento River Region would be decreased by 0.05% during average years and by an average of 0.22% during critical and dry water year types, reducing the potential for wind erosion.

*Alternative 2*

When compared with the No Action Alternative, Alternative 2 would increase land subject to fallowing in the Sacramento River Region during average years from 0.23% to 0.44%, increasing the potential for wind erosion. During the average of critical and dry water year types, land subject to fallowing would increase by 0.25% to 0.59%, increasing the potential for wind erosion.

*Alternative 3*

When compared with the No Action Alternative, Alternative 3 lands subject to fallowing in the Sacramento River Region would be increased during average (1.11%) and the average of critical, and dry water year types (1.03%), increasing the potential for wind erosion.

*Alternative 4*

When compared with the No Action Alternative, Alternative 4 lands subject to fallowing in the Sacramento River Region would be decreased during average water years (0.06%) and increased during the average critical and dry water year types (0.09%). The potential for erosion would therefore decrease under Alternative 4 during average water year types and would increase during critical and dry water year types.

### *20.2.1.3 San Joaquin Valley*

**Reservoir Shoreline Erosion**

*Alternative 1*

Under Alternative 1, changes in shoreline erosion at New Melones Reservoir would be negligible in both dry and wet periods.

*Alternative 2*

Under all phases of Alternative 2, changes in shoreline erosion at New Melones Reservoir would be negligible in both dry and wet periods.

*Alternative 3*

Under Alternative 3, changes in shoreline erosion at New Melones Reservoir would be negligible in both dry and wet periods.

*Alternative 4*

Under Alternative 4, changes in shoreline erosion at New Melones Reservoir would be negligible in both dry and wet periods.

Under Alternatives 1 through 4, there would be no changes in shoreline erosion at Millerton Reservoir under either dry or wet periods. In addition, shoreline erosion at Millerton Reservoir would not be affected by changes elsewhere in the CVP.

**Riverine Erosion**

*Alternative 1*

Alternative 1 has larger drawdowns during both dry and wet periods (13% change and 7% change) through releases on the Stanislaus River relative to the No Action Alternative and has a slightly higher potential for riverine erosion during both dry and wet periods relative to the No Action Alternative. This may be caused by noise in the CalSim 3 model and is discussed further in Appendix W.

*Alternative 2*

Alternative 2 has larger drawdowns during dry periods (6%-7% change) through releases on the Stanislaus River relative to the No Action Alternative. Therefore, under all phases of Alternative 2 during dry periods, the potential for riverine erosion would increase slightly relative to the No Action Alternative. Changes in riverine erosion during wet periods would be negligible relative to the No Action Alternative.

*Alternative 3*

Alternative 3 has larger drawdowns during wet periods (10% change) through releases on the Stanislaus River relative to the No Action Alternative. Under Alternative 3, riverine erosion would slightly increase in the Stanislaus River during wet periods relative to the No Action Alternative. During dry periods, riverine erosion would be negligible relative to the No Action Alternative.

*Alternative 4*

Releases to the Stanislaus River would be positive during dry periods (7% change) and negligible during wet periods under Alternative 4. Under Alternative 4, riverine erosion would therefore slightly increase in the Stanislaus River during dry periods relative to the No Action Alternative. During wet periods, riverine erosion would be negligible relative to the No Action Alternative.

There would be no change in riverine erosion in in the San Joaquin River under any action alternative.

**Agricultural Land Erosion**

*Alternative 1*

When compared with the No Action Alternative, lands subject to fallowing in the San Joaquin River Region would be decreased during average years (2.88% change) and during the average of dry and critical water years (3.01%) under Alternative 1, decreasing the potential for erosion of fallowed land.

*Alternative 2*

When compared with the No Action Alternative, lands subject to fallowing in the San Joaquin River Region would increase (1.13%) during average water years and would increase (1.85%) during the average of critical and dry water year types under Alternative 2 With TUCP Without VA. This would increase the potential for erosion of fallowed lands during all water year types.

When compared with the No Action Alternative, lands subject to fallowing in the San Joaquin River Region would increase (0.12%) during average water years and increase (0.69%) during the average of critical dry water years under Alternative 2 Without TUCP Without VA. This would increase the potential for erosion of fallowed lands during all water year types.

When compared with the No Action Alternative, lands subject to fallowing in the San Joaquin River Region would increase (1.20%) during average water years and increase (1.38%) during the average of critical dry water years under Alternative 2 Without TUCP Delta VA. This would increase the potential for erosion of fallowed lands during all water year types.

When compared with the No Action Alternative, lands subject to fallowing in the San Joaquin River Region would increase (1.04%) during average water years and increase (1.35%) during the average of critical dry water years under Alternative 2 Without TUCP Systemwide VA. This would increase the potential for erosion of fallowed lands during all water year types.

*Alternative 3*

When compared with the No Action Alternative, lands subject to fallowing in the San Joaquin River Region would decrease (9.56%) during average water years and increase (6.63%) during the average of critical dry water years under Alternative 3. Therefore, the potential for erosion would decrease during average water years and increase during critical and dry water year types.

*Alternative 4*

When compared with the No Action Alternative, lands subject to fallowing in the San Joaquin River Region would decrease (0.89%) during average water years and increase (0.07%) during the average of critical dry water years under Alternative 4. Therefore, the potential for erosion would decrease during average water years and increase during critical and dry water year types.

#### 20.2.1.4 Bay-Delta Operations

**Riverine Erosion**

*Alternative 1*

No changes in riverine erosion would occur in the Bay-Delta Region under Alternative 1 relative to the No Action Alternative. No changes in riverine erosion would occur in the Suisun Marsh or the San Francisco Bay under Alternative 1 relative to the No Action Alternative.

*Alternative 2*

No changes in riverine erosion would occur in the Bay-Delta Region under any phase of Alternative 2 relative to the No Action Alternative. No changes in riverine erosion would occur in the Suisun Marsh or the San Francisco Bay under any phase of Alternative 2 relative to the No Action Alternative.

*Alternative 3*

As discussed previously, a minor increase in flow under Alternative 3 is expected through the Bay-Delta Region during January; however, this increase is within the range of high flows through the Bay-Delta Region during winter flood events through the Bay-Delta; therefore, riverine erosion is not a substantial concern in this area.

*Alternative 4*

No changes in flows are expected in the Bay-Delta Region under Alternative 4 compared with the No Action Alternative; therefore, riverine erosion would not occur in this area. No changes in flows are expected in the Suisun Marsh or the San Francisco Bay under Alternative 4; therefore, there is no expected change in riverine erosion.

**Agricultural Land Erosion**

No conversion of agricultural land or crop idling is anticipated, and erosion of fallowed land would not change compared with the No Action Alternative. Under all phases of Alternative 2 and Alternative 3, agricultural flows to the San Francisco Bay Area would decrease, which could result in erosion of fallowed land. Under Alternative 4, agricultural flows to the San Francisco Bay Area would increase, which could decrease erosion of fallowed land.

#### 20.2.1.5 Additional CVP and SWP Service Areas

There are no Reclamation storage reservoirs or affected stream reaches in the CVP and SWP service areas; therefore, erosion of fallowed land would not change relative to the No Action Alternative.

### 20.2.2 Potential Changes in Rate of Land Subsidence

Land subsidence occurs for different reasons throughout the Central Valley. Land subsidence in the Sacramento and San Joaquin valleys occurs primarily due to aquifer-system compaction as groundwater elevations decline because of groundwater overdraft (i.e., groundwater withdrawals at rates greater than groundwater recharge rates) typically used for irrigation.

#### 20.2.2.1 Trinity River

As described in Appendix I, *Groundwater Technical Appendix*, the area along the Trinity River is not known to be susceptible to subsidence, and groundwater pumping is not expected to increase in this region; therefore, subsidence is not a concern in this area.

#### 20.2.2.2 Central Valley

Land subsidence is caused by the consolidation of certain subsurface soils when the pore pressure in those soils is reduced. In the Sacramento and San Joaquin valleys, that reduction in pore pressure is usually caused by groundwater pumping that causes groundwater levels to fall below historical low levels. The location and amount of subsidence is highly dependent on the local soil conditions and historical low groundwater levels in the area. Given that groundwater levels are generally expected to increase or remain unchanged due to Alternative 1, it is unlikely that Alternative 1 would cause additional subsidence relative to the No Action Alternative.

Average simulated groundwater levels decrease up to approximately 13 to 14 feet for Alternative 2 With TUCP Without VA and Alternative 2 Without TUCP Without VA in some water year types relative to the No Action Alternative. Groundwater levels may decrease by as much as 19 to 20 feet for Alternative 2 Without TUCP Delta VA and Alternative 2 Without TUCP Systemwide VA relative to the No Action Alternative. The largest decreases in simulated groundwater levels would occur along the western portion of the Central Valley in the Sacramento Valley and in the San Joaquin Valley. Portions of these areas are known to have historic subsidence, and further reductions in groundwater level may cause additional subsidence. All phases of Alternatives 2 result in larger decreases in groundwater levels than the No Action Alternative and, thus, have a higher likelihood of additional subsidence.

Average simulated groundwater levels indicate that Alternative 3 may decrease groundwater levels by as much as 160 feet in some water year types relative to the No Action Alternative. The largest decreases in groundwater levels are simulated to occur along the western portion of the Sacramento and San Joaquin valleys. Additional areas of decreased groundwater levels appear north of Modesto and south of Fresno. Given the relatively large decreases in simulated groundwater elevations and the fact that portions of these areas are known to have historic subsidence, the potential for additional subsidence is high.

In the Sacramento and San Joaquin valleys, average simulated groundwater levels are generally expected to decrease up to 7 feet in certain water year types under Alternative 4 relative to the

No Action Alterative. The largest decreases in these simulated groundwater levels occur along the western portion of the Sacramento Valley. The relatively small decreases in groundwater levels are not expected to cause large amounts of additional subsidence.

#### *20.2.2.3 Southern California Region*

The Southern California region is not known to be highly susceptible to subsidence, as noted in Appendix I, Section I.2.3.1.4, *Southern California Region*. Groundwater pumping is not expected to increase in this region, suggesting that subsidence will not be a concern in this area.

## 20.3 Mitigation Measures

No avoidance and minimization measures or mitigation measures have been identified for geology and soils.

## 20.4 Cumulative Impacts

The No Action Alternative would continue with the current operation of the CVP and may result in potential changes in soil erosion and rate of land subsidence at reservoirs that store CVP water, tributaries, and agricultural land. The action alternatives will result in changes to soil erosion and rate of land subsidence at reservoirs that store CVP water, tributaries, and agricultural land. The magnitude of the changes is dependent on alternative and water year type. Therefore, the No Action Alternative and action alternatives may contribute to cumulative changes to geology and soils resources as described in *Appendix W*, *Geology and Soils Resources* and *Appendix Y*, *Cumulative Impacts Technical Appendix.*