8. Fluvial Geomorphology and Riparian Habitat

8.1 Introduction

This chapter describes the fluvial geomorphological setting for the Extended, Secondary, and Primary study areas. Descriptions and maps of these three study areas are provided in Chapter 1 Introduction.

Fluvial geomorphology is concerned with the origins, evolution, and ongoing processes underlying a river's shape, geometry (width and depth), and planform pattern (as viewed from above). Geomorphic processes resulting from the actions of streamflow and related erosion actions, including transport and sedimentation, are driven by geology, climate, biological interactions, and human-induced changes. These physical relationships affect the associated riparian vegetation, habitat, and wildlife that evolved and adapted to the cycle of erosion, deposition, and changing channel pattern. The health and productivity of the fluvial system depend on the periodic rejuvenation associated with large storm events and channel movements.

Permits and authorizations for fluvial geomorphology and riparian habitat are presented in Chapter 4 Environmental Compliance and Permit Summary. The regulatory setting for fluvial geomorphology and riparian habitat is presented in Appendix 4A Environmental Compliance.

This chapter focuses primarily on the Sacramento River between Keswick Dam and the Pacific Ocean (a portion of the Secondary Study Area) because geomorphic and riparian habitat changes would primarily occur along the Sacramento River due to changes in diversion patterns at the Tehama-Colusa Canal and Glenn-Colusa Irrigation District (GCID) Main Canal intakes and at the new intake and discharge location for the Delevan Pipeline. Impacts along the Sacramento River were analyzed quantitatively (Appendix 8A Sedimentation and River Hydraulics Modeling and Appendix 8B Sacramento River Ecological Flows Tool). Impacts along the Trinity and Lower Klamath rivers were evaluated and discussed qualitatively because the flows in these rivers would be similar under Alternatives A, B, C, and D and the Existing Conditions/No Project/No Action Condition, as discussed in Chapter 6 Surface Water Resources. Impacts along the Feather, and American rivers were also evaluated and discussed qualitatively because the numerical model used for the Sacramento River did not address these rivers. Potential local and regional impacts from constructing, operating, and maintaining the alternatives were described and compared to applicable significance thresholds. Mitigation measures are provided throughout this Environmental Impact Report (EIR)/Environmental Impact Statement (EIS) for impacts identified as potentially significant, where appropriate; however, because no potentially significant impacts to fluvial geomorphology or riparian habitat were identified, no mitigation measures are included in this chapter.

8.2 Environmental Setting/Affected Environment

8.2.1 Overview of the Analysis of Fluvial Geomorphology and Related Riparian Habitat in the Study Area

An overview of surface waters in the Study Areas is presented in Section 6.2 of Chapter 6 Surface Water Resources (Extended, Secondary, and Primary Study Areas are explained in Chapter 1 Introduction), including surface water bodies in the Central Valley, Trinity River basin, San Francisco Bay Area, Central Coast, and Southern California. The Central Valley includes three major drainage areas:

Sacramento River Basin, San Joaquin River Basin, and the Tulare Lake Basin. The Sacramento and San Joaquin rivers join in the Sacramento-San Joaquin Delta (Delta) and flow through the Suisun, San Pablo, and San Francisco bays to the Pacific Ocean. The southernmost portion of the Central Valley, the Tulare Lake Basin, is an inland drainage area that receives flows from four rivers and several smaller streams. The portion of the San Francisco Bay Area affected by deliveries within the service areas of Central Valley Project (CVP) and State Water Project (SWP) are located within multiple watersheds of rivers and streams that flow through San Pablo and San Francisco bays to the Pacific Ocean. The portion of the Central Coast and Southern California served within the service area of the SWP includes multiple watersheds of rivers and streams that flow either through bays or directly into the Pacific Ocean.

Implementation of the action alternatives could result in changes in the Sacramento River watershed and the Delta as compared to the Existing Conditions/No Project/No Action Condition. It is anticipated that reservoir operations and related flow conditions in the San Joaquin River watershed upstream from the Delta (as defined at Vernalis) would not be affected by implementation of the action alternatives as compared to the Existing Conditions/No Project/No Action Condition. Surface water conditions in the San Francisco Bay Area, Central Coast, and Southern California regions also would not be affected by implementation of the action alternatives as compared to the Existing Conditions/No Project/No Action Condition because the surface water streams generally are not affected by imported water deliveries or supplies. Therefore, fluvial geomorphology and riparian habitat conditions are not discussed in this chapter for the San Joaquin River upstream from Vernalis and streams in the San Francisco Bay Area, Central Coast, and Southern California regions.

Changes in operations of Shasta Lake, Trinity Lake, Lake Oroville, and Folsom Lake under the action alternatives as compared to the Existing Conditions/No Project/No Action Condition could change stream flow in the rivers downstream of these CVP and SWP storage reservoirs. The stream flow changes could affect river processes, such as erosion and meandering, and related ecological processes, such as plant recruitment, succession, and habitat conditions. Operations of all non-CVP and non-SWP reservoirs, the CVP New Melones Reservoir, and the CVP Millerton Lake also would be consistent between the Existing Conditions/No Project/No Action Condition and all of the action alternatives. Therefore, fluvial geomorphology and riparian habitat conditions are not discussed in this chapter for the San Joaquin River upstream from Vernalis; streams located upstream from Shasta Lake, Trinity Lake, Lake Oroville, and Folsom Lake; and on streams associated with operations of non-CVP and non-SWP reservoirs.

Changes in reservoir storage would occur at San Luis Reservoir, which is used by both the CVP and SWP. However, the changes in reservoir storage would result in changes in flows in canals and pipelines, and there would be no changes in releases from San Luis Reservoir to streams or rivers. Therefore, fluvial geomorphology and riparian habitat conditions are not discussed in this chapter related to changes in San Luis Reservoir operations.

8.2.2 Extended Study Area

The Extended Study Area includes the service areas of the CVP, operated and maintained by the Bureau of Reclamation (Reclamation), and the SWP, operated and maintained by the California Department of Water Resources (DWR), that are not included in the Secondary and Primary study areas. As described in Section 8.2.1, there are many CVP and SWP water facilities in the Extended Study Area; however, operations of most of these facilities would continue to be consistent with historical operations under the Existing Conditions, No Project/No Action Condition, and action alternatives. Therefore, there would not be any geomorphologic or riparian habitat condition changes related to those facilities. There also would not be any changes in geomorphologic or riparian habitat conditions related to modifications in San Luis Reservoir storage, as discussed in Section 8.2.1. Overall, there would not be any geomorphologic or riparian habitat changes in the Extended Study Area.

8.2.3 Secondary Study Area

The Secondary Study Area is defined as the CVP and SWP reservoirs, rivers, creeks, and associated floodplains that could be affected by Sites Reservoir Project (Project) operations. As previously described, the Project operations under the action alternatives would not affect all of the reservoirs and streams in the Secondary Study Area. The following CVP and SWP facilities and associated water bodies could be affected (listed from north to south):

- Trinity Lake and Lewiston Reservoir operations could affect downstream portions of the Trinity River to the confluence of the Klamath River, and the Klamath River downstream of the Trinity River confluence to the Pacific Ocean.
- Whiskeytown Lake operations could affect downstream portions from Clear Creek and Spring Creek.
- Shasta Lake and Keswick Reservoir operations could affect downstream portions of the Sacramento River.
- Lake Oroville and Thermalito Complex (Thermalito Diversion Pool, Thermalito Forebay, and Thermalito Afterbay) operations could affect downstream portions of the Feather River.
- Folsom Lake and Lake Natoma operations could affect downstream portions of the American River.
- Operations of upstream reservoirs could affect flows in the Sacramento-San Joaquin Delta, Suisun Bay, San Pablo Bay, and San Francisco Bay.

8.2.3.1 Trinity and Klamath Rivers

The Trinity River is linked to the Sacramento River by cross-basin diversions from Lewiston Reservoir through the Clear Creek Tunnel to Whiskeytown Lake on Clear Creek. Trinity River and Clear Creek water is then diverted to Keswick Reservoir on the Sacramento River through the Spring Creek Tunnel to Spring Creek and then the Sacramento River. These diversions affect streamflow in the Trinity River, Clear Creek, Spring Creek, and the Sacramento River. Trinity Lake provides water to meet instream temperature objectives for the Trinity and Upper Sacramento rivers, and minimum instream flow requirements downstream of Lewiston Dam on the Trinity River as stipulated in the 2000 Trinity River Record of Decision (ROD) (U.S. Department of the Interior, 2000), as described in Chapter 6 Surface Water Resources.

The Trinity and Klamath rivers are predominately bedrock streams, incised into older metamorphic rocks that generally constrain the channel into narrow gorges and canyons, with riparian vegetation confined to narrow bands along both banks of the river. Wider valley reaches occur near Weaverville and Hoopa where gravel bars form a wider river corridor for riparian vegetation. Operations of Trinity Lake and Lewiston Reservoir affect the downstream sediment supply by trapping all of the coarse bedload material (gravels and coarser materials) and most of the suspended material (silts, sands, and clay). As a result, the river immediately downstream of Lewiston Reservoir is sediment starved, which results in a lack of finer mineral soils that are important for riparian vegetation growth. The loss of the finer mineral soils also results in a coarsening of the spawning riffles, which include gravel sizes that range from small diameters to cobbles that make portions of the river unusable for salmonid spawning. Downstream, the decrease in sediment mobilizing flows (also known as "flushing flows") due to operations of Trinity Lake has resulted in deposition of fine sediment from the abundant supplies of tributary streams. This effect constricts the channel and encourages riparian growth that "overstabilizes" the channel due to a lack of erosional disturbances that creates pools, riffles, and multispecies/multi-age riparian vegetation.

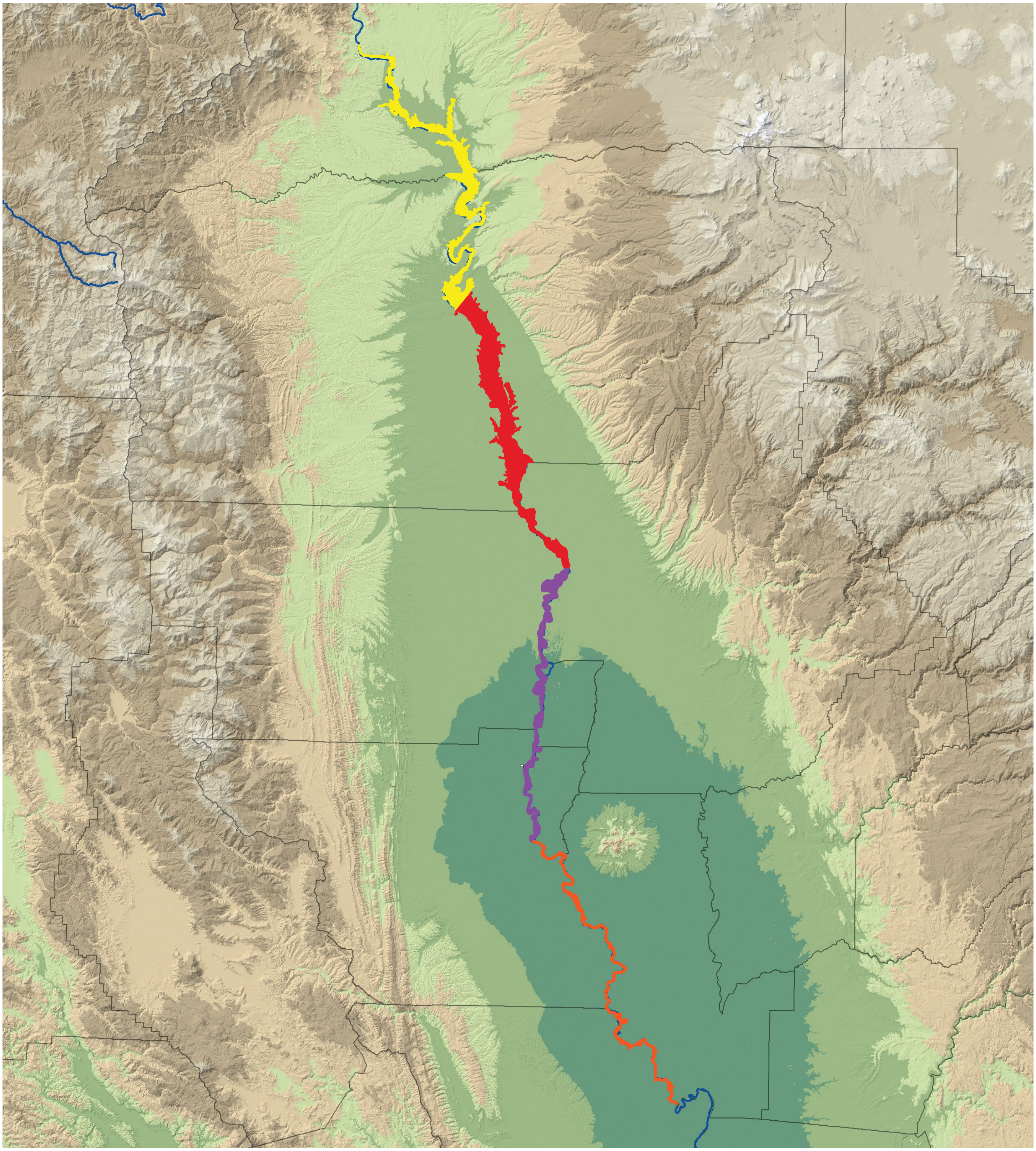
Instream woody material (IWM) also is a key component of healthy riverine aquatic ecosystems. The IWM also captured in Trinity Lake and Lewiston Reservoir, resulting in diminishing pool and island habitats downstream of the reservoirs. The geomorphic effects of the Trinity Lake and Lewiston Reservoir operations on aquatic and riparian ecosystems becomes less prevalent with distance as the Trinity River flows into the Klamath River, and the Klamath River continues as tributary inflows containing sediment and IWM enter the rivers and flow toward the Pacific Ocean.

Following adoption of the Trinity River ROD, the Trinity River Restoration Program (TRRP) (a partnership of federal, State, tribal entities, and Trinity County) was established to guide implementation of the ROD (TRRP, 2016). The TRRP is focused on flow management, mechanical channel rehabilitation, sediment management, watershed restoration, infrastructure improvement, adaptive environmental assessment and monitoring, and environmental compliance and mitigation. The mechanical channel rehabilitation has been initiated and will provide treatment of 44 channel rehabilitation sites and 3 side channel sites along the Trinity River to create and maintain riparian and fish habitat. As of 2015, 33 projects were completed. The sediment management actions focus on gravel augmentation below Lewiston Reservoir and reduction in fine sediments that degrade fish habitat. The watershed restoration actions also focus on reduction of fine sediments and improvement of fish habitat connectivity within the tributaries and with the mainstem river. Infrastructure improvements are being developed to allow for increased peak flows in the Trinity River.

8.2.3.2 Sacramento River to the Sacramento-San Joaquin Delta

This section describes fluvial geomorphology along the Sacramento River from the Upper Sacramento River to the confluence with the San Joaquin River. The Sacramento River fluvial geomorphology is influenced by natural terrain, geologic history, hydrology, and human activity (e.g., diversions and discharges) that cause changes in flow, temperature, sediment transport, and other factors. The Sacramento River conditions and related fluvial geomorphology in the reach upstream of Keswick Reservoir would not be affected by the Project and is presented for information only.

The diversions for this Project are located between Keswick Reservoir and Verona. Therefore, the highest potential for changes would occur between Keswick Reservoir and Verona. The Sacramento River between Keswick Reservoir and Verona is further divided into three sub-reaches: Keswick Reservoir to Red Bluff, Red Bluff to Colusa, and Colusa to Verona. The Keswick Reservoir to Red Bluff reach includes flows upstream of diversions that would be implemented under the action alternatives. The Red Bluff to Colusa reach includes all of the diversions that would be implemented under the action alternatives. The Colusa to Verona reach is located downstream of the diversions and the discharges that would be implemented under the action alternatives. All three of these reaches have different geological characteristics, as described below. The Keswick Reservoir to Red Bluff reach flows through bedrock canyons and alluvial valleys formed during tectonic mountain uplift and volcanism. Between Red Bluff and Colusa, the river flows through alluvial plains with numerous oxbows upstream of Chico Landing and natural levees, historical flood overflows, and constructed levees and flood bypasses are common characteristics downstream of Chico Landing. Between Colusa and Verona, the river becomes narrow and deep, and flows between natural and constructed levees. The overall reaches from Keswick Reservoir to Verona are presented in Figure 8-1.



Legend

Sacramento River Reaches

- Keswick Dam to Red Bluff Diversion Dam
- Red Bluff Diversion Dam to Chico Landing (RM 193)
- Chico Landing (RM 193) to Colusa Bridge
- Colusa Bridge to Verona (Confluence with the Feather River)
- Rivers

0 5 10 20 30 Miles

N

FIGURE 8-1
Sacramento River Reaches for Geomorphology Analysis

Sites Reservoir Project EIR/EIS

Path: W:\NODOS\MapFiles\Chapters\Geomorph\Figure8-1.mxd

The Sacramento River continues from Verona and through the Delta to the confluence with the San Joaquin River.

Upper Sacramento River

The Sacramento River headwaters originate on the east slope of Mt. Eddy in the vicinity of Mt. Shasta. Mt. Shasta provides much of the snowmelt that feeds the Upper Sacramento River during early spring months. From Mt. Shasta, the river flows within narrow canyons between the Cascade Range on the east and the Klamath Mountains on the west. The river flows into the 4.5-million-acre-foot Shasta Lake. Shasta Dam is located on the Upper Sacramento River, approximately 9 miles northwest of Redding.

Keswick Dam and Reservoir are located approximately 9 miles downstream of Shasta Dam and 5 miles west of Redding. All releases from Keswick Reservoir are made to the Sacramento River from Keswick Dam.

Overview of Sacramento River between Keswick Reservoir and San Joaquin River

Downstream of Keswick Reservoir, the Sacramento River flows through the Sacramento Valley to the Delta. The flows are influenced by tributary stream runoff from precipitation and snowmelt; diversions for agricultural, municipal, and industrial purposes; agricultural and municipal discharges; and a flood damage reduction system that includes levees, floodplains (including the Yolo, Sutter, and Colusa bypasses), and weirs (flood relief structures with a controlled elevation). Major tributary streams downstream of Keswick Reservoir include Clear, Cottonwood, Thomes, Stony, and Cache creeks, which flow in an eastward direction from the Cascade Range; and Stillwater, Battle, Mill, Deer, Big Chico and Butte creeks and the Feather, Yuba, Bear, American, Cosumnes, and Mokelumne rivers, which flow in a westward direction from the Sierra Nevada Mountains. The Sacramento River joins the San Joaquin River in the Delta, and then flows through Suisun, San Pablo, and San Francisco bays before flowing into the Pacific Ocean.

The fluvial geomorphology of the Sacramento River between Keswick Reservoir and the Delta varies with the degree of natural geologic confinement. Between Keswick Reservoir and Redding, the river flows within erosionally resistant geologic formations. Geologic activity related to tectonic mountain uplift and volcanism resulted in mountainous terrain with rivers incised into bedrock canyons and narrow alluvial valleys from Redding to Red Bluff. Downstream of Red Bluff, the river enters the tectonically down-dropping Central Valley Basin, and confinement gradually gives way to the more open floodplains and an alluvial river meander corridor from Redding to Red Bluff. Below Red Bluff to Colusa, the Sacramento Valley widens, and the meander belt of the Sacramento River becomes wider between large alluvial fans on either side of the river. Downstream of Colusa to Verona (near the confluence of the Feather River), the river opens further and meandering occurs within a well-defined belt bounded by natural levees.

Flows remain in the Sacramento River except at high flows when water overflows the natural levees on the right bank (looking downstream) into the Colusa Basin between Ord Ferry and Colusa (DWR, 2013). High flows also are conveyed through flood relief weirs along the right bank, downstream of Chico Landing, into the Butte Basin Overflow Area. On the left bank from Ord Ferry and Verona, portions of high flows in the Sacramento River would flow over the Moulton, Colusa, and Tisdale weirs into the Sutter Bypass, which also receives natural runoff from adjacent areas. The Sutter Bypass meets the Feather River upstream from the confluence with the Sacramento River near the Fremont Weir where floodwaters flow into the Yolo Bypass. Downstream of Verona, the main Sacramento River channel is surrounded by flood management levees and the river is perched topographically above the surrounding flood basins; the meander belt narrows significantly until flow reaches the Delta downstream of the city of Sacramento. The flood management levees continue along the Sacramento River through the Delta to around Rio Vista; however, the adjacent sloughs are contained by natural levees in many portions of the Delta.

In 1986, California Senate Bill 1086 called for an "Upper Sacramento River Fisheries and Riparian Habitat Management Plan," to "*protect, restore, and enhance wild strains of salmon and steelhead and maximize habitat restoration for naturally spawning salmon and steelhead, as well as preserve remaining riparian habitat and reestablish a continuous riparian ecosystem along the Sacramento River between the mouth of the Feather River and Keswick Dam.*" The federal Central Valley Project Improvement Act (CVPIA) (Public Law 102-575) and CALFED programs also identified improvements in Sacramento River fluvial geomorphology, meander migration, fishery, and ecosystem health as important issues. The *Flow Regime Requirements for Habitat Restoration along the Sacramento River between Colusa and Red Bluff, 2000* prepared by CALFED and the DWR summarized information about the Upper Sacramento River. One of the goals of the report was to provide some initial environmental guidelines for the proposed Sites Reservoir alternatives. However, the results of the study indicated that the overall flow regime requirements for the Sacramento River could not be determined without further long-term studies of flow regime requirements between Red Bluff and Colusa to maintain or rehabilitate riparian and riverine habitat with respect to the capability and constraints of infrastructure (CALFED, 1999). With respect to Sites Reservoir operations, the report suggested that Sacramento River flows in excess of 55,000 cubic feet per second (cfs) would not be substantially reduced because channel migration was initiated at approximately 55,000 cfs. However, the report indicated that this suggestion was not necessarily based on available quantitative analysis and would require additional data collection analysis prior to preparation of final recommendations.

Sacramento River between Keswick Reservoir and Red Bluff Between Keswick Reservoir and Redding, the river flows through volcanic and sedimentary formations in a narrow canyon with little floodplain and a narrow riparian corridor (Resources Agency, 2003). Downstream of Redding to Cow Creek, the river begins to meander through a broad floodplain of alluvium, and it continues to Red Bluff across the Plio-Pleistocene sedimentary deposits of the Tehama Formation and volcanic-sedimentary deposits of Tuscan Formation. Between Cow Creek and Red Bluff, portions of the channel are located within a narrow and deep canyon between the Tuscan Formation outcrops, including the Table Mountain plateau and steep-sloped Iron Canyon. These two formations are generally erosion resistant, with only minor lateral and vertical river channel movement and limited alluvial floodplain development. The river reach between Keswick Reservoir and Red Bluff is still considered mostly a bedrock stream with limited modern alluvial sediments bounding the river. To a large degree this reach is not affected by changes in streamflow or sediment. Boulders and cobbles are the most common bed material, because finer material has been eroded from the bed, and replacement material is being trapped by upstream dams. Several large bends occur in the lower section of this reach, with one near Jellys Ferry and another in the Bend area.

Geological Characteristics of the Keswick Reservoir to Red Bluff Reach

Volcanic basalts and andesites originating from past eruptions in the Cascade Ranges to the east, show evidence of damming the river for short periods of time in the past (Association of Engineering Geologists, 2005). Horizontal layers of red gravelly deposits of the Pleistocene Red Bluff Formation (greater than 400,000 years old) are exposed along the river above the older Tehama-Tuscan formations. The sources of these gravels were glacial outwash streams from the surrounding Cascades and Coast ranges. Terrace deposits that abut the river corridor occur in several locations, indicating past levels of the river. These flat benches approximately align with the gradient of the river and are inset into the older deposits. Four terrace levels are generally present, with the older terraces being higher than the younger terraces. Terraces indicate the recent geologic history of the river down cutting through tectonically uplifted terrain and through large post-glacial gravel outwash and alluvial fan deposits. These are Pleistocene terraces (2.1 to 0.012 million years before present) and reflect multiple periods of sedimentation and erosion. Over the past 12,000 years (Holocene Epoch) and during the current interglacial period, the river has experienced generally less and less natural sediment supply, even before construction of reservoirs in the past 100 years.

This portion of the river provides the vast majority of the available spawning habitat in the Sacramento River for salmonids. Much of the streambed has coarsened as a result of sediment supply loss to the point where original spawning areas are no longer usable. Artificial spawning gravel suitable for salmon is trucked in annually and placed at selected locations below Keswick Dam as part of the Sacramento River Spawning Habitat Restoration Project to bolster spawning gravel availability between Keswick and Redding.

Major Tributaries in the Keswick Reservoir to Red Bluff Reach

Three larger and several smaller tributaries join the Sacramento River in the Keswick Reservoir to Red Bluff reach of the Sacramento River and provide additional spawning habitat for salmonids. The three large tributaries, Clear Creek, Cottonwood Creek, and Battle Creek, are described below.

Clear Creek drains the metamorphic and igneous rocks west of Redding and flows into the Sacramento River downstream of Keswick Reservoir. Clear Creek is entrenched in a canyon downstream of Whiskeytown Reservoir consisting of erosion-resistant metamorphic rocks. Substantial modifications of the Clear Creek stream channel occurred due to placer mining activities from the mid-1800s through the early 1900 and several irrigation diversions including the McCormick-Saeltzer Dam constructed in 1903. Channel modifications occurred in the lower Clear Creek due to gravel extraction activities from the 1950s to 1970s. Construction of Whiskeytown Dam modified the hydraulics, gravel loading, and sediment transport in lower Clear Creek. In response to the loss of fine sediment from the riffles, federal and State requirements have been adopted that require minimum flow releases from Whiskeytown Lake, gravel injection downstream of the dam, reconstruction and revegetation of the floodway, and reduction of watershed erosion. The McCormick-Saeltzer Dam was removed in 2001 to restore Clear Creek geomorphologic processes.

Cottonwood Creek drains flows from the west side of the Valley where the underlying rocks are mostly interbedded sedimentary shales, siltstones, sandstones, and conglomerates of the Great Valley Sequence. Lower Cottonwood Creek flows within modern alluvial sediments and an actively meandering channel system with active sediment transport processes, erosion, and deposition sustaining a relatively broad riparian corridor. Cottonwood Creek soils do not absorb large amounts of rainfall quickly and are prone to flash flooding. Because dams were not constructed on this creek, it provides a substantial amount of coarse sediment into the Sacramento River.

Battle Creek flows drains a large area of permeable volcanic rocks on the Sacramento Valley’s east side. Springs provide a year-round flow of cool water in the upper watershed. Numerous hydroelectric project dams and diversions were constructed in the Battle Creek watershed and have captured sediment behind the dams. Under the ongoing Battle Creek Salmon and Steelhead Restoration Project, five power plants are being decommissioned, and ecological processes are being restored along 42 miles of Battle Creek and 6 miles and along tributaries to Battle Creek to support the upstream migration of salmonids. The Coleman National Fish Hatchery is located on Battle Creek Near the confluence with the Sacramento River.

Riparian Habitat Characteristics in the Keswick Reservoir to Red Bluff Reach

Fall-run Chinook salmon spawn in the Keswick Reservoir to Red Bluff reach. The spawning gravel is generally appropriately sized and clean. Green sturgeon also use this reach.

Sacramento River between Red Bluff and Colusa

The Sacramento River below Red Bluff exits from the canyon and flows onto the broad alluvial plains of the Sacramento Valley. Between Red Bluff and Chico Landing (at the confluence of Big Chico Creek and Sacramento River), the Sacramento River has meandered many oxbows over an area that spanned 9,200 acres between 1896 and 1991 (Resources Agency, 2003). Between Chico Landing and Colusa, the Sacramento River fluvial geomorphology is defined by the meandering river with the gradual downstream development of natural levees and historical flood overflows into the Butte and Colusa basins. The Chico Landing to Colusa reach is defined by the construction of the levees and flood bypass structures at the upstream end of the Sacramento River Flood Control Project constructed by the U.S. Army Corps of Engineers (USACE).

Overview of Geomorphic Processes of the Red Bluff to Colusa Reach

The river bed and the banks along the Sacramento River between Red Bluff and Colusa consist of erodible alluvium. Because of the dynamic nature of the river meander, sediment transport, and plant succession, the Sacramento River in this reach supports an important riparian corridor with large and diverse areas of wildlife habitat for a variety of common and special status terrestrial, botanical, and aquatic species. Bank erosion is a normal, natural, and essential element of this landscape. Fish, wildlife, and riparian vegetation are adapted to the cycle of erosion, deposition, and changing channel pattern in which the river meanders slowly back and forth across a broad meander belt. The health and productivity of the system depends on the periodic rejuvenation associated with these channel movements and disturbance.

Channel bank erosion and meander migration rates vary widely between Red Bluff and Colusa. Changes in bank material composition (stratigraphy and grain sizes), bank height, angle and vegetation cover, and rooting depth are major factors in the variation of meander migration rates. More cohesive, clay-rich banks and coarse gravelly banks are less erodible, and the unconsolidated sandy/silt banks are more erodible. Steeper and higher banks are generally more prone to erosion that can be reduced by increased vegetation cover and/or redesign of the bank size and soil structure. The layering or stratigraphy of river banks can be an important factor if erodible sandy layers underlie cohesive clay-rich layers or coarse sediments. In some places, the river impinges on older geologic formations or bedrock that control the edge of the meander belt and slow or arrest the erosion. New channels have formed across bends in the river which straightens the main Sacramento River channel and can isolate the previous main channel. The isolated sections of the historic river bed in the Red Bluff to Colusa reach have filled with fine sediments in some areas and formed oxbow lakes in other areas.

Erosion is generally associated with the outside (concave side) of the bends where the force of the flow exceeds the resistance of bank materials. Point bars form on the inside (convex side) of channel bends where lower flow velocities allow sediments to deposit. The broad floodplain areas bounding the channel are often zones with low flow velocities, allowing fine sand and silt to deposit. The outside bend is typically a deep pool, and the inside of the bend is shallow; where the meander loops shift the direction of the flow to the next loop and shallow riffles form. The combination of the erosion of outside bends and deposition on point-bars forms the “meander belt.” The Sacramento River channel has moved back and forth, re-working much of the same area, over decades and centuries.

Geological Characteristics of the Red Bluff to Colusa Reach

Between Red Bluff and Chico Landing, the Sacramento River is underlain by sedimentary and volcanic deposits from the Tehama, Tuscan, and Red Bluff formations. Exposed outcroppings of the Tehama Formation are exposed on the vertical banks near Red Bluff, Tehama, Woodson Bridge, and Hamilton City (Resources Agency, 2003). Terrace deposits of the Modesto and Riverbank formations extend away from the river in a “stair-step” manner. These deposits tend to erode at a lower rate than deposits near the river bed and form a geological control point. This reach of the river historically had a high degree of sinuosity. However, since the mid-1900s, vegetation removal on the meander bends has contributed to chute cutoffs, and changes in the flow regime after construction of Shasta Dam have resulted in decreased sinuosity.

The river bed between Chico Landing and Colusa consists primarily of silts and sands as compared to gravels upstream from Chico Landing. Historically between Chico Landing and Colusa, an upstream delta formed where water from the Butte, Sutter, and Colusa basins flowed across the Sacramento River and entered the Yolo Basin. As the waters flowed across the Sacramento River, the flows became slower and sediment was deposited in this area (Resources Agency, 2003). At this location, the Modesto Formation occurred as a terrace deposit on the west side of the river, and Paleo-channel deposits occurred on the east side of the Sacramento River. Natural levees formed as mounds of loamy soils on both sides of the Sacramento River forming natural weirs that maintained the meander channel and provided flood overflow basins. The natural levees on the west side of the river extended from Hamilton City in a discontinuous pattern to south of the confluence with Stony Creek. The formation of the delta deposits in the Sacramento River was reduced following construction of the flood management facilities in the Butte and Colusa basins and the Sutter and Yolo bypasses.

Major Tributaries and Diversions in the Red Bluff to Colusa Reach

Major tributaries that enter this portion of the Sacramento River include Antelope, Elder, Mill, Thomes, Deer, and Big Chico creeks. Flows on these streams generally are either not present or intermittent in the summer months due to upstream irrigation diversions. The Deer and Mill creek watershed conservancies are implementing watershed plans to improve flow regimes to support spring-run Chinook salmon. The Deer, Mill, and Antelope Creek Stabilization Project was implemented to reduce find sediment generation and restore riffles for salmonids. The ongoing Mill Creek Water Exchange Program is focused on implementation of conjunctive use of surface water and groundwater in the watershed to increase instream flows during critical migration periods for spring-run Chinook salmon.

Major water supply diversions in this reach include the Tehama-Colusa Canal Authority canal intake at Red Bluff, the GCID Main Canal Intake upstream from Hamilton City, and the M&T Ranch Intake downstream of Hamilton City. In the vicinity of the GCID Main Canal Intake, bank erosion historically had been high. However, bank protection at the upstream Snaden Island, geologic control exposed on the west bank directly upstream, and a grade control structure (with riprap on both banks) to decrease bank erosion susceptibility were implemented during construction of the new GCID Main Canal Intake. Suspended sediment deposits in the GCID Main Canal Facilities and bedload deposits in the meander loop are removed periodically.

The only major tributary in this reach is Stony Creek. Flows along Stony Creek are controlled by East Park Dam on Little Stony Creek and the Stony Gorge and Black Butte dams on Stony Creek.

Major water supply diversions in this reach include the Provident-Princeton-Codora-Glenn Intake downstream of Ord Ferry, the Reclamation District 1004 Intake near Princeton, and the Maxwell Irrigation District Intake downstream of Princeton.

Geomorphic Characteristics of the Red Bluff to Colusa Reach

The Sacramento River between Red Bluff and Colusa is “graded,” where erosion and deposition are generally in balance and the volume of sediment entering the reach is the same as the volume that exits. However, the notable and unique conditions of the Sacramento River are its “natural levees” that form topographically high boundaries between the river corridor meander belt and the large, valley floor flood basins (Butte, Colusa, Sutter, and Yolo basins) on each side. Natural levees are overtopped or breached during floods, diverting large volumes of flow and sediment away from the river channel. Because flow velocities are reduced as the flood basins fill, sediments deposit and accumulate over time. The volume of overflow from the Sacramento River to the flood basins increases southward. As a result, the size of the river and meander belt decreases significantly, and the river channel, meander belt, and natural levees are perched topographically higher than the flood basins.

Bank protection has been installed along the outside of river bends in many places in the Red Bluff to Colusa reach to protect existing land uses, including agriculture, buildings, pumping plants, bridges, and levees. This bank protection stops bank erosion locally and reduces the average reach-length erosion rate. These “hard points” on Sacramento River often change the rate and pattern of channel movement both upstream and downstream. In some locations, the river has either meandered around or through the bank protection.

Riparian Habitat Characteristics of the Red Bluff to Colusa Reach

There is a wide variety of riparian forest species in the meander belt between Red Bluff and Colusa. The clay-rich soils that developed within old oxbow lake deposits support more marsh and wetland species than woody species. Because of the richness and water-holding capacity of clay-rich soil, trees on these soils grow much taller than in the surrounding areas with drier soils. Willow scrub often develops in dense clumps after germinating in freshly deposited mineral soils along the low-water channel edge point bars. Cottonwoods, sycamore, alder, box elder, and black walnut adjust to floodplain deposition by growing atop continually deepening layers of sediment. As the soils become deeper due to sedimentation, cottonwoods, sycamores, and willows extend their root systems into the groundwater. As older trees die, portions of the riparian forests open and grasslands and savannahs are established until the meander channel changes locations. This process results in a riparian habitat that supports a variety of species due to the shade provided by the tall canopy trees, food and cover in the lower brush vegetation, and open ground for grazing and predation. Birds depend on habitat variability to provide nesting, feeding, and breeding habitats. Fish depend on shade and insect food from streamside riparian vegetation, large woody and tree roots washed into the river for cover, and fresh gravel washed from eroding banks for spawning. Bank swallows construct nests in soft soils of high banks above the eroded channel banks to provide habitat protected from predators.

Sacramento River between Colusa and Verona

The Sacramento River below Colusa becomes narrower and deeper, with less slope and finer bed material. Natural levees are present on both sides of the river between Colusa and Verona. Prior to construction of the flood management levees, the channel meandered in this reach, especially near Grimes, Kirkville, and Knights Landing (Resources Agency, 2003). Historically, high flows during flood events were conveyed in the Butte, Colusa, Sutter, and Yolo basins.

Geological Characteristics of the Colusa to Verona Reach

The natural levees in the Colusa to Verona reach were created from loams, sandy loams, silty loams, and clay loams deposited over clays. The soil materials of the natural levees accumulated along the sloughs that drained the basins and along the Sacramento River. Several natural levees remain, such as the Knights Landing Ridge Cut between the Colusa and Yolo basins along the historic reach of Cache Creek.

Major Tributaries and Diversions of the Colusa to Verona Reach

The Feather River joins the Sacramento River near Verona. The Feather River drainage also includes the Yuba and Bear rivers. Lake Oroville and the Thermalito Complex on the Feather River, Englebright Reservoir on the Yuba River, and New Camp Far West Reservoir on the Bear River control flows and reduce sediment from flowing into the Sacramento River.

Major water supply diversions in this reach of the Sacramento River include intakes from Reclamation Districts 70, 108, 730, 787, 1500, and 1660, and Sutter Mutual Water Company.

A series of flood relief structures, weirs, and bypasses that move excess flood flows out of the Sacramento River and into the adjacent basins are located in this reach. There are three weirs adjusting the flow remaining in the river: Moulton, Colusa, and Tisdale. These weirs divert high flood flows into the Colusa Bypass, Butte Basin, and Sutter Bypass. These overflows and additional high Sacramento River flows at Fremont Weir flow into the Yolo Bypass for continued conveyance to the Delta. Most of the bypass areas are farmed during the agricultural season. However, during floods, much of the bypass areas become spawning and rearing habitat for splittail, and rearing areas for salmonids and other fish species. Some riparian vegetation, sloughs, and wetlands occur in the bypasses, providing habitat for numerous species. The river gradient is low, and the banks contain cohesive clay, resulting in little erosion and meandering. Riprap has been installed in many areas to protect the banks and levees. The river has also been straightened for navigation in places by cutting a new channel across a bend.

Geomorphic Characteristics of the Colusa to Verona Reach

The river channel is a uniform single channel with no islands, point bars, or riffles. The riverbed consists mostly of sand with some gravel. There is very little sediment transport, evidenced by the presence of only a few sand bars.

Riparian Habitat Characteristics of the Colusa to Verona Reach

Riparian habitat is generally sparse, with some vegetation along banks. However, in many places, the bank protection is being maintained by the removal of vegetation. Most of the surrounding land has been converted to farms and urban areas, with only a few isolated remnants of riparian forests and oxbow lakes. Riparian habitat is patchy and does not have the complexity and variety typical of the Red Bluff to Colusa reach.

The river is a migration corridor for Chinook salmon, steelhead, and green and white sturgeon to spawn in the upper two reaches and for fry heading for the Pacific Ocean. Numerous warm water species live in this reach or migrate through it, including the introduced striped bass and American shad.

Sacramento River between Sacramento River between Verona and the Confluence with the San Joaquin River

Downstream of the Feather River near Verona, the Sacramento River widens substantially. Enormous amounts of fine sediment from hydraulic mining on the Feather and American rivers in the 1800s resulted in sediment along the river bed. Flood management levees were constructed along most of this reach of the Sacramento River.

The Sacramento River enters the legal boundary of the Delta (per the 1959 Delta Protection Act) downstream of the confluence with the American River. The Delta is a low-lying region of the Great Central Valley formed by the confluence of the Sacramento and San Joaquin rivers. The Delta region consists of islands surrounded by manmade and natural channels. Most of the islands are surrounded by levees protected with rock riprap. Subsidence, caused by farming, wind erosion, and oxidation of peat soils has occurred on many of the islands in the western Delta near Suisun Bay.

8.2.4 Primary Study Area

Project activities that have the potential to affect geomorphic processes within the Primary Study Area are limited to construction, operation, and maintenance of the Delevan Pipeline Intake/Discharge Facilities, located on the west side of the Sacramento River at River Mile (RM) 158.5. Although the extent of the Sacramento River, including the Red Bluff to Colusa Reach discussed in Section 8.2.3, is regarded as being located within the Secondary Study Area, the Delevan Pipeline Intake/Discharge Facilities and the segment of the Sacramento River immediately adjacent to the proposed facilities are located within the footprint of the Primary Study Area, which includes all project facilities except the Tehama-Colusa Canal Authority Red Bluff Pumping Plant, where an additional pump would be installed. Located approximately 5 miles south of the town of Princeton and immediately downstream of the existing Maxwell Irrigation District diversion pumps and intake, the Delevan Pipeline Intake/Discharge Facilities are the only proposed facilities that would result in potential impacts on/from geomorphologic processes as a result of proposed construction, operation, and maintenance activities. Therefore, potential impacts related to fluvial geomorphology for the remaining Primary Study Area facilities, including along Funks and Stone Corral creeks, are not discussed.

Geomorphic Characteristics near the Proposed Delavan Pipeline Intake/Discharge Facilities

Bank erosion and deposition are active processes at this location. Figure 8-2 shows the Sacramento River channel meander locations upstream of the proposed Delavan Pipeline Intake/Discharge Facilities location since 1896.

Riparian Habitat Characteristics near the Proposed Delavan Pipeline Intake/Discharge Facilities

Disturbed valley foothill riparian occurs along the bank at the Delevan Pipeline Intake/Discharge Facilities location, as described in Chapter 14 Terrestrial Biological Resources. Valley foothill riparian habitat includes woody species in the riparian canopy. The streamside vegetation is dominated by the valley oak with elderberry shrubs. Bank swallows were observed for most years between 2000 and 2009 near the Delevan Pipeline Intake/Discharge Facilities location (see Table 14-4 in Chapter 14 Terrestrial Biological Resources).

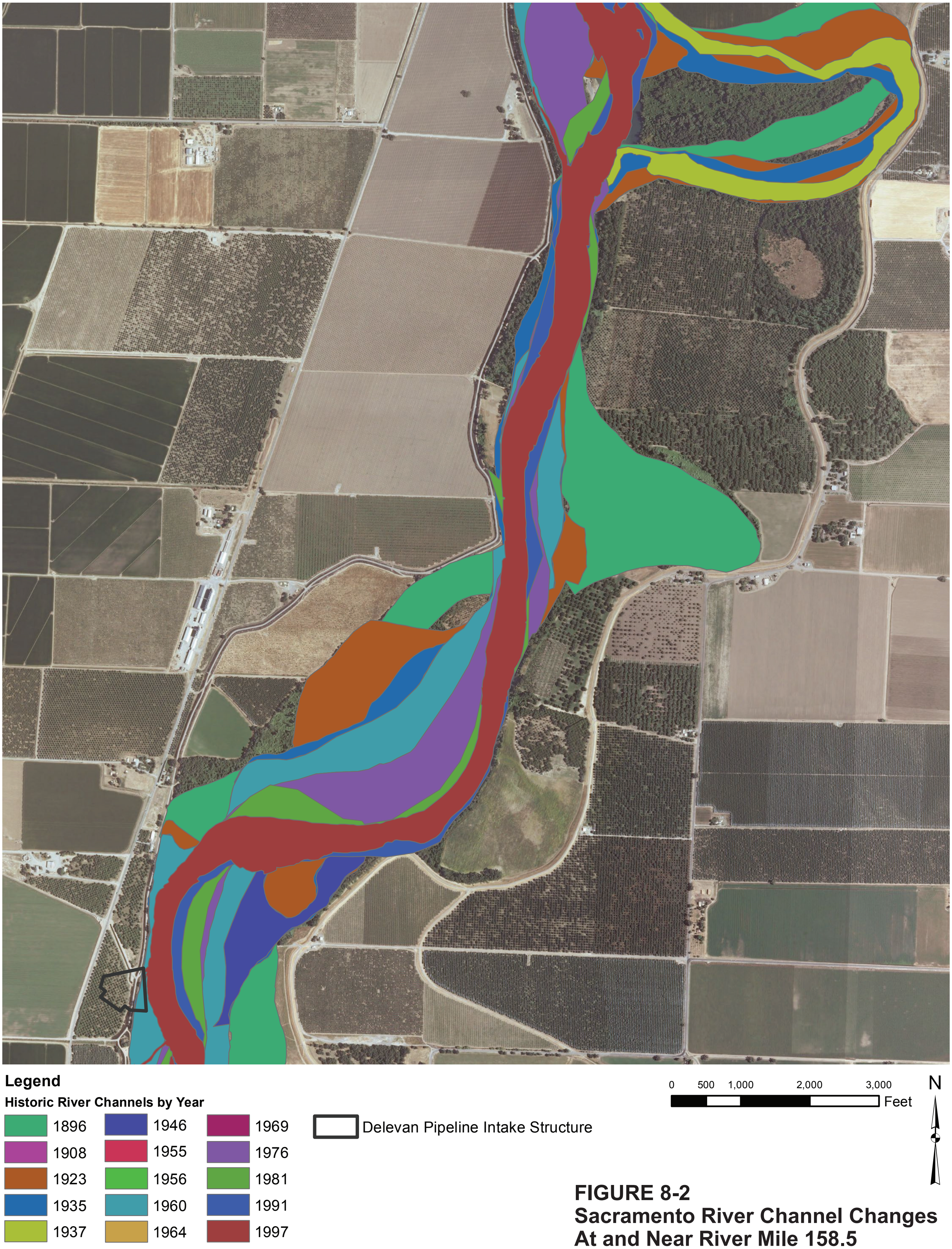


FIGURE 8-2
Sacramento River Channel Changes At and Near River Mile 158.5
Sites Reservoir Project EIR/EIS

Path: W:\NODOS\MapFiles\Chapters\Geomorph\Figure8-2.mxd

8.3 Environmental Impacts/Environmental Consequences

8.3.1 Evaluation Criteria and Significance Thresholds

Significance criteria represent the thresholds that were used to identify whether an impact would be potentially significant. Appendix G of the *CEQA Guidelines* does not include criteria that are specific to fluvial geomorphology. The evaluation criteria used for this impact analysis were based on professional judgment that considers current regulations, standards, and/or consultation with agencies, knowledge of the area, and the context and intensity of the environmental effects, as required pursuant to the National Environmental Policy Act. For the purposes of this analysis, an alternative would result in a potentially significant impact if it would result in any of the following:

- Substantial alteration of natural river geomorphic processes such as bank erosion, sinuosity, gradient, flow velocity, sediment transport, bed coarseness, depth, and width.
- Substantial alteration of natural river meandering, bank erosion, and deposition, with consequent substantial alteration of riparian vegetation regeneration and habitat complexity.
- Substantial alteration of the amount of IWM, boulders, shaded riverine aquatic habitat, or spawning gravel in rivers, resulting in substantial loss of fish rearing, holding, spawning, and feeding habitat.
- Substantial alteration on these geomorphologic parameters was determined by comparing the results from computer models that modeled operational scenarios of the proposed action alternatives, checking the parameters for changes that are larger than normal and natural variations over a long study period, and professional judgement, as described in the following subsection. The modeled changes that were predictable, consistent, and larger than the observable natural variations in the geomorphic parameters were considered to be potentially significant impacts.

8.3.2 Impact Assessment Assumptions and Methodology

Combinations of Project facilities were used to create Alternatives A, B, C, C_1, and D. In all resource chapters, the Sites Project Authority (Authority) and Reclamation described the potential impacts associated with the construction, operation, and maintenance of each of the Project facilities for each of the five action alternatives. Some Project features/facilities and operations (e.g., reservoir size, overhead power line alignments, provision of water for local uses) differ by alternative, and are evaluated in detail within each of the resource areas chapters. As such, the Authority has evaluated all potential impacts with each feature individually, and may choose to select or combine individual features as determined necessary.

Impacts associated with the construction, operation, and maintenance for Alternative C_1 would be the same as Alternative C and are therefore not discussed separately below.

8.3.2.1 Assumptions

The following assumptions were made regarding Project-related construction, operation, and maintenance impacts to river geomorphology:

- Direct Project-related construction, operation, and maintenance activities would occur in the Primary Study Area along the Sacramento River at the location of the proposed Delavan Pipeline Intake/Discharge Facilities.

- Direct Project-related operational effects would occur in the Secondary Study Area along the Sacramento River from Keswick Reservoir to Verona due to changes in diversion patterns at the Tehama-Colusa Canal Authority canal and GCID Main Canal intakes and the proposed Delavan Pipeline Intake/Discharge Facilities. Flows on the tributaries to the Sacramento River, along the Sacramento River upstream of Shasta Lake, and along the Sacramento River downstream of Verona would be similar during higher flow periods when geomorphic changes occur, as presented in Chapter 6 Surface Water Resources.
- The only direct Project-related maintenance activity that would occur in the Secondary Study Area is the sediment removal and disposal at the Tehama-Colusa Canal Authority Red Bluff Pumping Plant Intake, GCID Main Canal Intake, and at the Delevan Pipeline Intake/Discharge Facilities.
- No direct Project-related construction or maintenance activities would occur in the Extended Study Area.
- The existing bank protection located upstream from the proposed Delevan Pipeline Intake/Discharge Facilities would continue to be maintained and remain functional.
- No additional channel stabilization, grade control measures, or dredging in the Sacramento River in the vicinity of or upstream from the Delevan Pipeline Intake/Discharge Facilities would occur that are related to the action alternatives.

8.3.2.2 Methodology

Existing conditions and the future No Project/No Action alternatives were assumed to be similar in the Primary Study Area given the generally rural nature of the area and limited potential for growth and development in Glenn and Colusa counties within the 2030 study period used for this EIR/EIS as further described in Chapter 2 Alternatives Analysis. As a result, within the Primary Study Area, it is anticipated that the No Project/No Action Alternative would not entail material changes in conditions as compared to the existing conditions baseline.

With respect to the Extended and Secondary study areas, the effects of the proposed action alternatives would be primarily related to changes to available water supplies in the Extended and Secondary study areas and the Project’s cooperative operations with other existing large reservoirs in the Sacramento watershed, and the resultant potential impacts and benefits to biological resources, land use, recreation, socioeconomic conditions, and other resource areas. DWR has projected future water demands through 2030 conditions that assume the vast majority of CVP and SWP water contractors would use their total contract amounts, and that most senior water rights users also would fully use most of their water rights. This increased demand in addition to the projects currently under construction and those that have received approvals and permits at the time of preparation of the EIR/EIS would constitute the No Project/No Action Condition. As described in Chapter 2 Alternative Analysis, the primary difference in these projected water demands would be in the Sacramento Valley; and as of the time of preparation of this EIR/EIS, the water demands have expanded to the levels projected to be achieved on or before 2030.

Accordingly, existing conditions and the No Project/No Action alternatives are assumed to be the same for this EIR/EIS and as such are referred to as the Existing Conditions/No Project/No Action Condition, which is further discussed in Chapter 2 Alternatives Analysis. With respect to applicable reasonably foreseeable plans, projects, programs and policies that may be implemented in the future but that have not yet been approved, these are included as part of the analysis of cumulative impacts in Chapter 35 Cumulative Impacts.

Alternatives A, B, and C as Compared to the Existing Conditions/No Project/No Action Condition

The impact assessment used computer simulation models to quantify the effects of the Project relative to the existing conditions and the future No Project/No Action conditions. For this analysis, Reclamation's Sedimentation and River Hydraulics Group conducted computer river hydraulic, sediment, and meander modeling that compared changes in geomorphic processes. Sediment transport models, in conjunction with the USRDOM model, were used to predict sediment transport and changes in bed coarseness, depth, and width. Two sediment transport models were used: one to predict variations in bedload movement, and one for suspended sediment movement.

The USRDOM model simulates daily river flows in the Sacramento River based on the operations specified by the CALSIM II model for each alternative. The CALSIM II model uses hydrologic inputs to represent conditions under the Existing Conditions/No Project/No Action Condition, including water diversion requirements (demands), stream accretions and depletions, rim basin inflows, irrigation efficiencies, return flows, non-recoverable losses, and groundwater operations that will occur under specific level of development. Sacramento Valley and tributary hydrologic conditions are synthesized using a process designed to adjust the historical sequence of monthly stream flows over an 82-year period (1922 to 2003) to represent a sequence of flows that would occur with the level of development assumptions. The model is run with the same level of development assumptions and water supply facilities (e.g., water demands) for all of the 82-year period with different hydrologic conditions included for each of the 82 years. The CALSIM II model results must be used in a comparative manner and cannot be used to predict conditions independently. Therefore, the CALSIM II model results for Alternative A must be compared to the model results for the Existing Conditions/No Project/No Action Condition to determine the trends for changes under Alternative A.

The monthly CALSIM II results are further analyzed using historical daily flow patterns to calculate daily flow projections which are used to simulate daily reservoir operations and river flows over the period of simulation extending from water year 1922 through 2003 (82-year simulation period). The USRDOM model description and results are included in Appendix 6C Upper Sacramento River Daily River Flow and Operations Modeling. Detailed discussion of the CALSIM II model is provided in Appendix 6B Water Resources System Modeling.

The bedload analysis in the USRDOM model (Appendix 8A Sedimentation and River Hydraulics Modeling) investigated the sediment transport capacity of the Sacramento River from Keswick to Colusa Weir. The USRDOM model divided the Sacramento River into 15 reaches based on fluvial geomorphology and hydrology. The USRDOM model daily flows were used to develop flow duration curves. Bedload transport was calculated using several available equations, with one selected that best described the available observational data. The transport of material greater in size than 2 millimeters was calculated in tons per year for each reach. Using this approach, the aggrading and degrading reaches could be identified, as well as changes in streambed composition predicted over the 82-year simulation period.

The suspended sediment transport model (Appendix 8A Sedimentation and River Hydraulics Modeling) investigated the movement of sediment in the Sacramento River and estimated the amount of sediment that would be diverted at the Project diversions for each alternative. The USRDOM model results of simulated daily flows were used in conjunction with actual U.S. Geological Survey gaging station sediment sampling results to develop a flow versus suspended sediment rating curve (see Appendix 8A Sedimentation and River Hydraulics Modeling for list of gage stations). The rating curve was then used to calculate the sediment transport in the Sacramento River and the amount of sediment entrained in the diversion for each alternative.

The effects on natural river meandering, bank erosion, and deposition in the Sacramento River channel between Red Bluff and Colusa, with consequent effects on riparian vegetation, was modeled using the SRH-Meander model (Appendix 8A Sedimentation and River Hydraulics Modeling). Inputs to the model included USRDOM model daily flows, streambank erodibility, and channel hydraulic characteristics.

The SRH-Meander model simulated the bed topography, flow field, and bank erosion rate in a curved channel with an erodible bank and bed. At the end of each time step, it computed the amount of bank erosion and updated the channel centerline alignment. The amount of bank erosion was calculated using the near-bank depth-averaged flow velocity and a method that incorporated a multiple-size sediment transport equation (Appendix 8A Sedimentation and River Hydraulics Modeling). The model was run with all of the existing riprap in place. The model was calibrated by running the model between 1976 and 1999 using Existing Conditions and comparing the actual channel changes with the results of modeling. The model was tuned by adjusting the bank erodibility factors until a best-fit between actual and calculated meandering occurred.

The calibrated SRH-Meander model was run using the USRDOM daily flows from 1980 to 2010 to predict channel meandering from 2010 to 2030. The outputs of the model were a series of maps showing the channel centerline alignment in 2030 for each of the alternatives and graphs showing the accumulated migration distance.

Further, in assessing the impacts to the riparian vegetation along the Sacramento River in the Secondary Study Area, modeling specific to riparian vegetation, including results from the SRH-1DV and SacEFT models, were used. The SacEFT results were also used to analyze impacts to the IWM recruitment on the Sacramento River.

The SRH-1DV model simulates the establishment, growth, and mortality of vegetation, in addition to computing hydraulics and the groundwater elevation in the in the riparian zone near the river. The simulation projects daily vegetation changes through 82 years of simulated flow, within the 107 river miles of Sacramento River from upstream of Red Bluff to Colusa. The SRH-1DV analysis focuses on four key valley foothill riparian vegetation types that are representative of the range of riparian communities of the Sacramento River: cottonwood, mixed forest, Gooding’s black willow, and narrow leaf willow. The detailed description of the SRH-1DV model and the associated alternatives evaluation is provided in Appendix 8A Sedimentation and River Hydraulics Modeling.

The SacEFT decision support tool provides key performance measures for various focal aquatic and terrestrial species, and riparian habitat in the Sacramento River. It specifically includes performance measures for evaluating the effects of various flow scenarios on the initiation success and post-initiation scour risk of the Fremont Cottonwood seedlings, and the amount of IWM recruited to the mainstem Sacramento River. These performance measures are used as a general indicator for assessing the impacts on riparian vegetation and potential habitat quality in the mainstem Sacramento River in Secondary Study Area. The detailed description of the SacEFT model and the associated alternatives evaluation is provided in Appendix 8B Sacramento River Ecological Flows Tool.

Alternative D as Compared to the Existing Conditions/No Project/No Action Condition

As described in detail in Section 8.3.6, the analysis of Alternative D was conducted qualitatively using information presented in the quantitative analyses of Alternatives A, B, and C as compared to the Existing Conditions/No Project/No Action Condition.

8.3.3 Impacts Associated with Alternative A

8.3.3.1 Extended Study Area – Alternative A

As described in Section 8.2.2, there would not be any geomorphologic or riparian habitat changes in the Extended Study Area; therefore, there would be no impact as compared to the Existing Conditions/ No Project/No Action Condition.

8.3.3.2 Secondary Study Area – Alternative A

Construction, Operation, and Maintenance Impacts

Impact Geom-1: Substantial Alteration of Natural River Geomorphic Processes

Construction of the proposed Delevan Intake/Discharge Facilities would be conducted in accordance with the requirements under the Clean Water Act and the Stormwater Pollution Prevention Permit (SWPPP) issued by the Central Valley Regional Water Quality Board and the State Water Resources Control Board, as described in Chapter 3 Description of the Sites Reservoir Project Alternatives. The requirements of the Clean Water Act and SWPPP would address risks of increased discharge of sediment or increased sediment in the receiving waters due to discharges from the construction site or soil erosion or scour along the banks of Sacramento River and include use of erosion control methods, such as sediment traps and silt fences.

Project-related fluvial geomorphology impacts could occur due to changes in operations at the Tehama-Colusa Canal Authority canal and GCID Main Canal intakes and the proposed Delevan Intake/Discharge Facilities. These impacts would occur in the Sacramento River between Red Bluff and Verona.

No construction activities would occur in in the remainder of the Secondary Study Area (including Trinity Lake, Lewiston Reservoir, Trinity River, the Klamath River, Whiskeytown Lake, Spring Creek, Lake Oroville, Thermalito Complex, Feather River, Sutter Bypass, Folsom Lake, Lake Natoma, American River). Changes in flows in these surface waters would be minor and would be associated with modified surface water releases from Sites Reservoir, Shasta Dam Keswick Reservoir and Whiskeytown Dam (Chapter 6 Surface Water Resources); therefore, it is not anticipated that the river processes would be altered due to implementation of Alternative A. Operational changes resulting in alteration of streamflow would be **less than significant**, when compared to the Existing Conditions/No Project/No Action Condition, because stream and water body fluvial geomorphology would not be substantially affected.

Under Alternative A, construction activities associated with the addition of a pump at the Tehama-Colusa Canal Authority Red Bluff Pumping Plant would occur within the existing pumping plant and would not result in changes in geomorphological conditions as compared to the Existing Conditions/No Project/ No Action Alternative.

Sediment removal at the Tehama-Colusa Canal Authority Red Bluff Pumping Plant Intake and the GCID Main Canal Intake would occur during the regularly scheduled maintenance period for these intakes using the same maintenance activities conducted as under the Existing Conditions/No Project/No Action

Condition. Therefore, construction activities at the Red Bluff Pumping Plant, and maintenance activities at the Tehama-Colusa Canal Authority Red Bluff Pumping Plant Intake and the GCID Main Canal Intake are expected to result in **less-than-significant** changes to Sacramento River geomorphology as compared to the Existing Conditions/No Project/No Action Condition.

Modeling results indicate that the effects of operations of facilities under Alternative A on the Sacramento River would include a slight decrease in suspended sediment load and bed load (because of reduced flow and bed mobility) in the Sacramento River downstream of the Tehama-Colusa Canal Authority Red Bluff Pumping Plant Intake, GCID Main Canal Intake, and the Delevan Pipeline Intake/Discharge Facilities, mostly during winter months (Appendix 8A Sedimentation and River Hydraulics Modeling). The expected amount of sediment that would be entrained in these proposed intakes would be less than 1 percent of the existing changes in sediment deposition into the Delta.

The estimated average annual amount of suspended sediment moving in the river past the Bend Bridge gage is approximately 2.01 million tons (USACE, 1983). The average amount of suspended sediment that would be entrained at the Tehama-Colusa Canal Authority Red Bluff Pumping Plant Intake annually under Alternative A is approximately 47,000 tons per year as compared to 40,000 tons estimated under the Existing Conditions/No Project/No Action Condition (Appendix 8A Sedimentation and River Hydraulics Modeling). Therefore, the amount of suspended sediment in the Sacramento River downstream of the Tehama-Colusa Canal Authority Red Bluff Pumping Plant Intake under Alternative A would be reduced by approximately 2.3 percent as compared to the 2.0 percent under the Existing Conditions/No Project/No Action Condition.

The amount of sediment that would be entrained at the GCID Main Canal Intake under Alternative A would approximately 56,000 tons per year (Appendix 8A Sedimentation and River Hydraulics Modeling) as compared to 47,000 tons estimated under the Existing Conditions/No Project/No Action Condition. Therefore, the amount of sediment in the Sacramento River downstream of the GCID Main Canal Intake under Alternative A would be reduced by approximately 1.5 percent as compared to a 1.2 percent decrease under the Existing Conditions/No Project/No Action Condition.

The estimated annual amount of suspended sediment in the Sacramento River approximately 10 miles upstream from the proposed Delevan Pipeline Intake/Discharge Facilities location, is 4.32 million tons (USACE, 1983). Modeling results indicate that the amount of suspended sediment that would be entrained at the Delevan Pipeline Intake/Discharge Facilities intake would be approximately 49,000 tons (Appendix 8A Sedimentation and River Hydraulics Modeling), representing approximately 1.1 percent of the amount of suspended sediment in the Sacramento River at that location. This intake is considered part of the Primary Study Area, but the downstream effects would occur in the Secondary Study Area.

The diverted suspended sediment at the three intake locations would be less than 5 percent of the total suspended sediment moving in this reach of the river under Alternative A as compared to 3 percent under the Existing Conditions/No Project/No Action Condition. However, because the water and sediment would both be diverted, the concentration of the sediment in the water would remain unchanged, the geomorphic changes under Alternative A would be **less than significant** on sediment concentration, turbidity, or water clarity as compared to the Existing Conditions/No Project/No Action Condition.

Impact Geom-2: Substantial Alteration of Natural River Meandering, Bank Erosion, and Deposition, and Substantial Alteration of Riparian Vegetation and Habitat Complexity

The installation of the fish screen at the proposed Delevan Pipeline Intake/Discharge Facilities would be functionally equivalent to bank protection, and may affect meandering downstream of the diversion. However, the bank at this location includes geologic control (an erosion resistant unit). In addition, the existing Maxwell Irrigation District Pumping Plant, located immediately upstream from the proposed Delevan Pipeline Intake/Discharge Facilities location, is in a narrow section of the river and consequently acts as a local flow control point (Reclamation, 2012).

The Reclamation Meander Study (Appendix 8A Sedimentation and River Hydraulics Modeling) produced flow duration curves that indicated similar conditions under Alternative A as under the Existing Conditions/No Project/No Action Condition for flows in excess of 30,000 cfs, which is the flow that the Reclamation Meander model assumed would result in substantial geomorphologic river changes.

The Reclamation Sacramento River Bedload Analysis (Appendix 8A Sedimentation and River Hydraulics Modeling) indicated that the bedload transport capacity of the Sacramento River from immediately upstream of Red Bluff to downstream of Colusa would be similar under Alternative A and the Existing Conditions/No Project/No Action Condition.

Modeling performed using SRH-1DV (Appendix 8A Sedimentation and River Hydraulics Modeling) indicated that the riparian vegetation conditions along the Sacramento River between Red Bluff and Colusa under Alternative A would be similar to conditions under the Existing Conditions/No Project/ No Action Condition.

Modeling performed using SacEFT (Appendix 8B Sacramento River Ecological Flows Tool) indicates that the risk of post-initiation scour (following establishment of seedlings) to Fremont cottonwoods, bank swallow habitat, and IWM recruitment (which effects Western Pond Turtle habitat) along the Sacramento River from Red Bluff to Colusa would be similar under Alternative A and the Existing Conditions/ No Project/No Action Condition. It should be noted that the SacEFT model output considered in this analysis assumed that there would be no change to bank protection (e.g., riprap) under the action alternatives as compared to the Existing Conditions/No Project/No Action Condition.

Therefore, changes in geomorphic conditions in the Sacramento River and in surface water bodies downstream of the confluence of the Sacramento and San Joaquin rivers (including the western Delta, Suisun Bay, San Pablo Bay, and San Francisco Bay) under Alternative A as compared to the Existing Conditions/No Project/No Action Condition would be **less than significant**.

Impact Geom-3: Substantial Alteration of the Amount of Instream Woody Material, Boulders, Shaded Riverine Aquatic Habitat, or Spawning Gravel in Rivers, with Effects on Fish Habitat

Modeling performed using SacEFT (Appendix 8B Sacramento River Ecological Flows Tool) indicates that the IWM recruitment to the Sacramento River would remain similar under Alternative A as compared to the Existing Conditions/No Project/No Action Condition. It is not certain how Alternative A would affect the shaded riverine aquatic habitat that occurs along the banks of a stream (Appendix 8A Sedimentation and River Hydraulics Modeling).

Bedload is the main source of spawning gravel for salmonids, which depend on fresh gravel that is free from fine sediment, to deposit their eggs. Periodic bedload movement is important in maintaining high spawning gravel quality. Bedload deposition is also important in maintaining hydraulic diversity. Islands, point bars, and multiple channels provide a variety of habitat elements for the fish and wildlife. The Reclamation Sacramento River Bedload Analysis (Appendix 8A Sedimentation and River Hydraulics Modeling) indicated that the bedload transport capacity of the Sacramento River from immediately upstream of Red Bluff to downstream of Colusa would be similar under Alternative A and the Existing Conditions/No Project/No Action Condition; and that no bedload sediment would be projected to be entrained in the three Project intakes.

Therefore, changes in geomorphic conditions under Alternative A as compared to the Existing Conditions/No Project/No Action Condition would be **less than significant**.

8.3.3.3 Primary Study Area – Alternative A

Project activities that have the potential to affect geomorphic processes within the Primary Study Area are limited to construction, operation, and maintenance of the Delevan Pipeline Intake/Discharge Facilities, located on the west side of the Sacramento River at RM 158.5. The remaining Primary Study Area facilities do not have the potential to affect geomorphic processes or riparian habitat and are therefore not discussed further.

Construction, Operation, and Maintenance Impacts

Impact Geom-1: Substantial Alteration of Natural Geomorphic River Processes

The proposed Delevan Pipeline Intake/Discharge Facilities fish screen would stabilize a short section of bank. The proposed pump station and afterbay would be located on erosion resistant deposits of the Modesto Formation and not part of the existing meander channel (Figure 8-2). Therefore, construction of the fish screens would result in a **less-than-significant** change under Alternative A as compared to the Existing Conditions/No Project/No Action Condition.

Refer to the **Impact Geom-1** discussion for the Sacramento River within the Secondary Study Area for a discussion of the operation and maintenance impacts under Alternative A associated with the Tehama-Colusa Canal Authority Red Bluff Pumping Plant Intake, GCID Main Canal Intake, and the proposed Delevan Pipeline Intake/Discharge Facilities.

A temporary increase in sediment levels around the proposed Delevan Pipeline Intake/Discharge Facilities would occur during construction under Alternative A as compared to the Existing Conditions/No Project/No Action Condition. These changes in sediment would be temporary and would not affect the local geomorphology in the Sacramento River because the construction activities would be required to be consistent with the SWPPP issued by the Central Valley Regional Water Quality Control Board to avoid increased sediment discharge and increased turbidity. Therefore, conditions under Alternative A would have **no impact** as compared to the Existing Conditions/No Project/No Action Condition.

Impact Geom-2: Substantial Alteration of Natural River Meandering, Bank Erosion, and Deposition, and Substantial Alteration of Riparian Vegetation and Habitat Complexity

Installation of the proposed Delevan Pipeline Intake/Discharge Facilities fish screen would result in the removal of riparian vegetation along a short length of bank. The construction and operation of this facility would reduce habitat complexity as compared to the Existing Conditions/No Project/No Action Condition. However, the changes related to the adjacent vegetation on either side of the river is considered to be **less than significant** with regard to overall stream function and habitat complexity under Alternative A as compared to the Existing Conditions/No Project/No Action Condition.

Impact Geom-3: Substantial Alteration of the Amount of Instream Woody Material, Boulders, Shaded Riverine Aquatic Habitat, or Spawning Gravel in Rivers, with Effects on Fish Habitat

The bank where the proposed Delevan Pipeline Intake/Discharge Facilities fish screens would be constructed consists of geologically stable areas that are generally resistant to erosion.

As previously described, changes in bedload sediment would be **less than significant.** Therefore, changes in spawning gravel and fish habitat associated with both construction and operation of the facility under Alternative A would be **less than significant** with respect to aquatic habitat when compared to the Existing Conditions/No Project/No Action Condition.

8.3.4 Impacts Associated with Alternative B

8.3.4.1 Extended Study Area – Alternative B

As described in Section 8.2.2, there would not be any geomorphologic or riparian habitat changes in the Extended Study Area; therefore, there would be no impact as compared to the Existing Conditions/No Project/No Action Condition.

8.3.4.2 Secondary Study Area – Alternative B

Construction, Operation, and Maintenance Impacts

Operational changes associated with Alternative B as they relate to natural river geomorphic processes (**Impact Geom-1**), riparian vegetation and habitat complexity (**Impact Geom-2**), and fish habitat (**Impact Geom-3**) would be the same as described for Alternative A for Trinity Lake, Lewiston Reservoir, Trinity River, Klamath River downstream of the Trinity River, Whiskeytown Lake, Spring Creek, Shasta Lake, Keswick Reservoir, Clear Creek, Lake Oroville, Thermalito Complex, Feather River, Sutter Bypass, Yolo Bypass, Folsom Lake, Lake Natoma, American River, the Delta, Suisun Bay, San Pablo Bay, and San Francisco Bay. These operational changes under Alternative B would result in changes in geomorphologic conditions that would be **less than significant** as compared to the Existing Conditions/No Project/No Action Condition.

Under Alternative B, construction of the additional pump at the Tehama-Colusa Canal Authority Red Bluff Pumping Plant would occur within the existing pumping plant and would not result in changes in geomorphologic conditions as compared to the Existing Conditions/No Project/No Action Condition.

Operational impacts associated with implementation of Alternative B to the Sacramento River downstream of Keswick Reservoir are discussed in the following sections.

Impact Geom-1: Substantial Alteration of Natural River Geomorphic Processes

The average amount of suspended sediment that would be entrained into the existing Tehama-Colusa Canal Authority Red Bluff Pumping Plant Intake under Alternative B would be approximately 62,000 tons per year as compared to 40,000 tons under the Existing Conditions/No Project/No Action Condition (Appendix 8A Sedimentation and River Hydraulics Modeling). Therefore, the amount of suspended sediment in the in the Sacramento River downstream of the Tehama-Colusa Canal Authority

Red Bluff Pumping Plant Intake under Alternative B would be reduced by approximately 3.0 percent as compared to 2.0 percent under the Existing Conditions/No Project/No Action Condition.

The amount of suspended sediment entrained at the existing GCID Main Canal Intake under Alternative B would be approximately 69,000 tons per year (Appendix 8A Sedimentation and River Hydraulics Modeling) as compared to 47,000 tons per year under the Existing Conditions/No Project/ No Action Condition. Therefore, the amount of sediment in the Sacramento River downstream of the GCID Main Canal Intake under Alternative B would be reduced by approximately 1.8 percent as compared to a 1.2 percent decrease under the Existing Conditions/No Project/No Action Condition.

There would be no changes in suspended sediment downstream of the Delevan Pipeline Discharge Facilities location due to operations of the Project because no water would be diverted at this location.

The diverted suspended sediment at the two intake locations would be 5 percent of the total suspended sediment moving in this reach of the river under Alternative B as compared to 3 percent under the Existing Conditions/No Project/No Action Condition. However, because the water and sediment would both be diverted, the concentration of the sediment in the water would remain unchanged, the geomorphic changes under Alternative B would be **less than significant** on sediment concentration, turbidity, or water clarity as compared to the Existing Conditions/No Project/No Action Condition.

Impact Geom-2: Substantial Alteration of Natural River Meandering, Bank Erosion, and Deposition, and Substantial Alteration of Riparian Vegetation and Habitat Complexity

The installation of the proposed Delevan Pipeline Discharge Facilities would be functionally equivalent to bank protection, and may affect meandering downstream of the diversion. However, the bank at this location includes geologic control (an erosion resistant unit). In addition, the existing Maxwell Irrigation District Pumping Plant, located immediately upstream from the proposed Delevan Pipeline Discharge Facilities location, is in a narrow section of the river and consequently acts as a local flow control point (Reclamation, 2012).

The Reclamation Meander Study (Appendix 8A Sedimentation and River Hydraulics Modeling) produced flow duration curves that indicated similar conditions under Alternative B as under the Existing Conditions/No Project/No Action Condition for flows in excess of 30,000 cfs, which is the flow that the Reclamation Meander model assumed would result in substantial geomorphologic river changes.

The Reclamation Sacramento River Bedload Analysis (Appendix 8A Sedimentation and River Hydraulics Modeling) indicated that the bedload transport capacity of the Sacramento River from immediately upstream of Red Bluff to downstream of Colusa would be similar under Alternative B and the Existing Conditions/No Project/No Action Condition.

Modeling performed using SRH-1DV (Appendix 8A Sedimentation and River Hydraulics Modeling) indicated that the riparian vegetation conditions along the Sacramento River between Red Bluff and Colusa under Alternative B would be similar to conditions under the Existing Conditions/No Project/ No Action Condition.

Modeling performed using SacEFT (Appendix 8B Sacramento River Ecological Flows Tool) indicates that the risk of post-initiation scour (following establishment of seedlings) to Fremont cottonwoods, bank swallow habitat, and IWM recruitment (which effects Western Pond Turtle habitat) along the Sacramento River from Red Bluff to Colusa would be similar under Alternative B and the Existing Conditions/ No Project/No Action Condition. It should be noted that the SacEFT model output considered in this analysis assumed that there would be no change to bank protection (e.g., riprap) under the action alternatives as compared to the Existing Conditions/No Project/No Action Condition.

Therefore, changes in geomorphic conditions in the Sacramento River and in surface water bodies downstream of the confluence of the Sacramento and San Joaquin rivers (including the western Delta, Suisun Bay, San Pablo Bay, and San Francisco Bay) under Alternative B as compared to the Existing Conditions/No Project/No Action Condition would be **less than significant**.

Impact Geom-3: Substantial Alteration of the Amount of Instream Woody Material, Boulders, Shaded Riverine Aquatic Habitat, or Spawning Gravel in Rivers, with Effects on Fish Habitat

Modeling performed using SacEFT (Appendix 8B Sacramento River Ecological Flows Tool) indicates that the IWM recruitment to the Sacramento River would remain similar under Alternative B as compared to the Existing Conditions/No Project/No Action Condition.

It is not certain how Alternative B would affect the shaded riverine aquatic habitat that occurs along the banks of a stream (Appendix 8A Sedimentation and River Hydraulics Modeling).

The Reclamation Sacramento River Bedload Analysis (Appendix 8A Sedimentation and River Hydraulics Modeling) indicated that the bedload transport capacity of the Sacramento River from immediately upstream of Red Bluff to downstream of Colusa would be similar under Alternative B and the Existing Conditions/No Project/No Action Condition; and that no bedload sediment is projected to be entrained in the two Project intakes.

Therefore, changes in geomorphic conditions under Alternative B as compared to the Existing Conditions/No Project/No Action Condition would be **less than significant**.

8.3.4.3 Primary Study Area – Alternative B

Project activities that have the potential to affect geomorphic processes within the Primary Study Area are limited to construction, operation, and maintenance of the Delevan Pipeline Discharge Facilities, located on the west side of the Sacramento River at RM 158.5. The remaining Primary Study Area facilities do not have the potential to affect geomorphic processes or riparian habitat and are therefore not discussed further.

Construction, Operation, and Maintenance Impacts

Impact Geom-1: Substantial Alteration of Natural River Geomorphic Processes

The discharge facility would have no associated fish screens and, therefore, would not extend into the river. The discharge facility would be operated as a release-only facility and, therefore, would not entrain sediment during operation or require the maintenance activity of sediment removal.

The proposed Delevan Pipeline Discharge Facilities would stabilize a short section of bank and located on erosion resistant deposits of the Modesto Formation and not part of the existing meander channel (Figure 8-2). Therefore, construction of the discharge facilities would result in a **less-than-significant** change under Alternative B as compared to The Existing Conditions/No Project/No Action Condition.

Refer to the **Impact Geom-1** discussion for the Sacramento River within the Secondary Study Area for a discussion of the operation and maintenance impacts under Alternative B associated with the Tehama-

Colusa Canal Authority Red Bluff Pumping Plant Intake, GCID Main Canal Intake, and the proposed Delevan Pipeline Discharge Facilities.

A temporary increase in sediment levels around the proposed Delevan Pipeline Discharge Facilities would occur during construction under Alternative B as compared to the Existing Conditions/No Project/No Action Condition. These changes in sediment would be temporary and would not affect the local geomorphology in the Sacramento River because the construction activities would be required to be consistent with the SWPPP issued by the Central Valley Regional Water Quality Control Board to avoid increased sediment discharge and increased turbidity. Therefore, conditions under Alternative B would have **no impact** as compared to the Existing Conditions/No Project/No Action Condition.

Impact Geom-2: Substantial Alteration of Natural River Meandering, Bank Erosion, and Deposition, and Substantial Alteration of Riparian Vegetation and Habitat Complexity

Installation of the proposed Delevan Pipeline Discharge Facilities would result in the removal of riparian vegetation along a short-length of bank. The construction and operation of this facility would reduce habitat complexity as compared to the Existing Conditions/No Project/No Action Condition. However, the changes related to the adjacent vegetation on either side of the river are considered to be **less than significant** with regard to overall stream function and habitat complexity under Alternative B as compared to the Existing Conditions/No Project/No Action Condition.

Impact Geom-3: Substantial Alteration of the Amount of Instream Woody Material, Boulders, Shaded Riverine Aquatic Habitat, or Spawning Gravel in Rivers, with Effects on Fish Habitat

The bank where the proposed Delevan Pipeline Discharge Facilities would be located consists of geologically stable areas that are generally resistant to erosion.

As previously described, changes in bedload sediment would be **less than significant.** Therefore, changes in spawning gravel and fish habitat associated with both construction and operation of the facility under Alternative B would be **less than significant** with respect to aquatic habitat as compared to the Existing Conditions/No Project/No Action Condition.

8.3.5 Impacts Associated with Alternative C

8.3.5.1 Extended Study Area – Alternative C

As described in Section 8.2.2, there would not be any geomorphologic or riparian habitat changes in the Extended Study Area; therefore, there would be no impact as compared to the Existing Conditions/No Project/No Action Condition.

8.3.5.2 Secondary Study Area – Alternative C

Construction, Operation, and Maintenance Impacts

Operational changes associated with Alternative C as they relate to natural river geomorphic processes (**Impact Geom-1**), riparian vegetation and habitat complexity (**Impact Geom-2**), and fish habitat (**Impact Geom-3**) would be the same as described for Alternative A for Trinity Lake, Lewiston Reservoir, Trinity River, Klamath River Downstream of the Trinity River, Whiskeytown Lake, Spring Creek, Shasta Lake, Keswick Reservoir, Clear Creek, Lake Oroville, Thermalito Complex, Feather River, Sutter Bypass, Yolo Bypass, Folsom Lake, Lake Natoma, American River, the Delta, Suisun Bay, San Pablo Bay, and San Francisco Bay. These operational changes under Alternative C would result in changes in geomorphologic conditions that would be **less than significant** as compared to the Existing Conditions/No Project/No Action Condition.

Under Alternative C, construction of the additional pump at the Tehama-Colusa Canal Authority Red Bluff Pumping Plant would occur within the existing pumping plant and would not result in changes in geomorphologic conditions as compared to the Existing Conditions/No Project/No Action Condition.

Operational impacts associated with implementation of Alternative C for the Sacramento River downstream of Keswick Reservoir are discussed in the following sections.

Impact Geom-1: Substantial Alteration of Natural River Geomorphic Processes

The average amount of suspended sediment that would be entrained into the existing Tehama-Colusa Canal Authority Red Bluff Pumping Plant Intake under Alternative C would be approximately 50,000 tons per year as compared to 40,000 tons under the Existing Conditions/No Project/No Action Condition (Appendix 8A Sedimentation and River Hydraulics Modeling). Therefore, the amount of suspended sediment in the in the Sacramento River downstream of the Tehama-Colusa Canal Authority Red Bluff Pumping Plant Intake under Alternative C would be reduced by approximately 2.4 percent as compared to 2.0 percent under the Existing Conditions/No Project/No Action Condition.

The amount of suspended sediment entrained at the existing GCID Main Canal Intake under Alternative C would be approximately 57,000 tons per year as compared to 47,000 tons per year under The Existing Conditions/No Project/No Action Condition. Therefore, the amount of sediment in the Sacramento River downstream of the GCID Main Canal Intake under Alternative C would be reduced by approximately 1.5 percent as compared to a 1.2 percent decrease under the Existing Conditions/No Project/No Action Condition.

Modeling results indicate that the amount of suspended sediment that would be entrained at the Delevan Pipeline Intake/Discharge Facilities intake would be approximately 56,000 tons per year (Appendix 8A Sedimentation and River Hydraulics Modeling), representing approximately 1.3 percent of the amount of suspended sediment in the Sacramento River at that location. This intake is considered part of the Primary Study Area, but the downstream effects would occur in the Secondary Study Area.

The diverted suspended sediment at the three intake locations would be 5 percent of the total suspended sediment moving in this reach of the river under Alternative C as compared to 3 percent under the Existing Conditions/No Project/No Action Condition. However, because the water and sediment would both be diverted, the concentration of the sediment in the water would remain unchanged, the geomorphic changes under Alternative A would be **less than significant** on sediment concentration, turbidity, or water clarity as compared to the Existing Conditions/No Project/No Action Condition.

Impact Geom-2: Substantial Alteration of Natural River Meandering, Bank Erosion, and Deposition, and Substantial Alteration of Riparian Vegetation and Habitat Complexity

The installation of the fish screen at the proposed Delevan Pipeline Intake/Discharge Facilities would be functionally equivalent to bank protection, and may affect meandering downstream of the diversion. However, the bank at this location includes geologic control (an erosion resistant unit). In addition, the existing Maxwell Irrigation District Pumping Plant, located immediately upstream from the proposed Delevan Pipeline Intake/Discharge Facilities location, is in a narrow section of the river and consequently acts as a local flow control point (Reclamation, 2012).

The Reclamation Meander Study (Appendix 8A Sedimentation and River Hydraulics Modeling) produced flow duration curves that indicated similar conditions under Alternative C as under the Existing Conditions/No Project/No Action Condition for flows in excess of 30,000 cfs, which is the flow that the Reclamation Meander model assumed would result in substantial geomorphologic river changes.

The Reclamation Sacramento River Bedload Analysis (Appendix 8A Sedimentation and River Hydraulics Modeling) indicated that the bedload transport capacity of the Sacramento River from immediately upstream of Red Bluff to downstream of Colusa would be similar under Alternative C and the Existing Conditions/No Project/No Action Condition.

Modeling performed using SRH-1DV (Appendix 8A Sedimentation and River Hydraulics Modeling) indicated that the riparian vegetation conditions along the Sacramento River between Red Bluff and Colusa under Alternative C would be similar to conditions under the Existing Conditions/No Project/No Action Condition.

Modeling performed using SacEFT (Appendix 8B Sacramento River Ecological Flows Tool) indicates that the risk of post-initiation scour (following establishment of seedlings) to Fremont cottonwoods, bank swallow habitat, and IWM recruitment (which effects Western Pond Turtle habitat) along the Sacramento River from Red Bluff to Colusa would be similar under Alternative C and the Existing Conditions/No Project/No Action Condition. It should be noted that the SacEFT model output considered in this analysis assumed that there would be no change to bank protection (e.g., riprap) under the action alternatives as compared to the Existing Conditions/No Project/No Action Condition.

Therefore, changes in geomorphic conditions in the Sacramento River and in surface water bodies downstream of the confluence of the Sacramento and San Joaquin rivers (including the western Delta, Suisun Bay, San Pablo Bay, and San Francisco Bay) under Alternative B as compared to the Existing Conditions/No Project/No Action Condition would be **less than significant**.

Impact Geom-3: Substantial Alteration of the Amount of Instream Woody Material, Boulders, Shaded Riverine Aquatic Habitat, or Spawning Gravel in Rivers, with Effects on Fish Habitat

Modeling performed using SacEFT indicates that the IWM recruitment to the Sacramento River would remain similar under Alternative C as compared to the Existing Conditions/No Project/No Action Condition.

It is not certain how Alternative C would affect the shaded riverine aquatic habitat that occurs along the banks of a stream (Appendix 8A Sedimentation and River Hydraulics Modeling).

The Reclamation Sacramento River Bedload Analysis (Appendix 8A Sedimentation and River Hydraulics Modeling) indicated that the bedload transport capacity of the Sacramento River from immediately upstream of Red Bluff to downstream of Colusa would be similar under Alternative C and the Existing Conditions/No Project/No Action Condition; and that no bedload sediment is projected to be entrained in the two Project intakes.

Therefore, changes in geomorphic conditions under Alternative C as compared to the Existing Conditions/No Project/No Action Condition would be **less than significant**.

8.3.5.3 Primary Study Area – Alternative C

Project activities that have the potential to affect geomorphic processes within the Primary Study Area are limited to construction, operation, and maintenance of the Delevan Pipeline Intake/Discharge Facilities, located on the west side of the Sacramento River at RM 158.5. The remaining Primary Study Area facilities do not have the potential to affect geomorphic processes or riparian habitat and are therefore not discussed further.

Construction, Operation, and Maintenance Impacts

Alternative C would include the Delevan Pipeline Intake/Discharge Facilities within the Primary Study Area in the same manner as described under Alternative A. The impacts associated with Alternative C in the Primary Study Area as they relate to natural river geomorphic processes (**Impact Geom-1**), riparian vegetation and habitat complexity (**Impact Geom-2**), and fish habitat (**Impact Geom-3**) would, therefore, be the same as described under Alternative A for the Primary Study Area.

8.3.6 Impacts Associated with Alternative D

8.3.6.1 Extended Study Area – Alternative D

As described in Section 8.2.2, there would not be any geomorphologic or riparian habitat changes in the Extended Study Area; therefore, there would be no impact as compared to the Existing Conditions/ No Project/No Action Condition.

8.3.6.2 Secondary Study Area – Alternative D

Construction, Operation, and Maintenance Impacts

Operational changes associated with Alternative D as they relate to natural river geomorphic processes (**Impact Geom-1**), riparian vegetation and habitat complexity (**Impact Geom-2**), and fish habitat (**Impact Geom-3**) would be the same as described for Alternative A for Trinity Lake, Lewiston Reservoir, Trinity River, Klamath River downstream of the Trinity River, Whiskeytown Lake, Spring Creek, Shasta Lake, Keswick Reservoir, Clear Creek, Lake Oroville, Thermalito Complex, Feather River, Sutter Bypass, Yolo Bypass, Folsom Lake, Lake Natoma, American River, the Delta, Suisun Bay, San Pablo Bay, and San Francisco Bay. These operational changes under Alternative D would result in changes in geomorphologic conditions that would be **less than significant** as compared to the Existing Conditions/No Project/No Action Condition.

Under Alternative D, construction of the additional pump at the Tehama-Colusa Canal Authority Red Bluff Pumping Plant would occur within the existing pumping plant and would not result in changes in geomorphologic conditions as compared to the Existing Conditions/No Project/No Action Condition.

Operational impacts associated with implementation of Alternative D for the Sacramento River downstream of Keswick Reservoir are discussed in the following sections. As described in Appendix 8A Sedimentation and River Hydraulics Modeling and Appendix 8B Sacramento River Ecological Flows Tool, the geomorphic modeling analyses was based upon the result of CALSIM II model outputs for flows in the Sacramento River during the winter and spring months when flows would exceed 30,000 cfs (the minimum flow that was considered in the geomorphic models that would result in geomorphic river changes including sediment transport, meander channel migration, and ecological changes. The amount of flow diverted under the Project at the different intakes also was related to the amount of sediment removed from the Sacramento River. As described in Chapter 6 Surface Water Resources and the shown in the model results presented in Appendix 6B Water Resources System Modeling, Sacramento River flows in December through May of Wet and Above Normal water years (when Sacramento River flows would exceed 30,000 cfs), the Sacramento River flows under Alternative D are similar to those under

Alternative A. In addition, flows diverted at the three intakes are similar under Alternative D and Alternative D in December through May of Wet and Above Normal water years as shown in Chapter 6 Surface Water Resources and Appendix 6B Water Resources System Modeling. Because the Sacramento River flows and diversion flows are similar under Alternative D and Alternative A; it is assumed in this EIR/EIS that the geomorphic model results are similar under Alternative D and Alternative A. The impacts associated with Alternative C in the Secondary Study Area as they relate to natural river geomorphic processes (**Impact Geom-1**), riparian vegetation and habitat complexity (**Impact Geom-2**), and fish habitat (**Impact Geom-3**) would, therefore, be the same as described under Alternative A for the Secondary Study Area.

8.3.6.3 Primary Study Area – Alternative D

Project activities that have the potential to affect geomorphic processes within the Primary Study Area are limited to construction, operation, and maintenance of the Delevan Pipeline Intake/Discharge Facilities, located on the west side of the Sacramento River at RM 158.5. The remaining Primary Study Area facilities do not have the potential to affect geomorphic processes or riparian habitat and are therefore not discussed further.

Construction, Operation, and Maintenance Impacts

Alternative D would include the Delevan Pipeline Intake/Discharge Facilities within the Primary Study Area in the same manner as described under Alternative A. The impacts associated with Alternative D as they relate to natural river geomorphic processes (**Impact Geom-1**), riparian vegetation and habitat complexity (**Impact Geom-2**), and fish habitat (**Impact Geom-3**) would, therefore, be the same as described under Alternative A for the Primary Study Area.

8.4 Mitigation Measures

Because no potentially significant impacts were identified, no mitigation is required or recommended. Environmental commitments are included in all Project alternatives and discussed in Chapter 3 Description of the Sites Reservoir Project Alternatives.