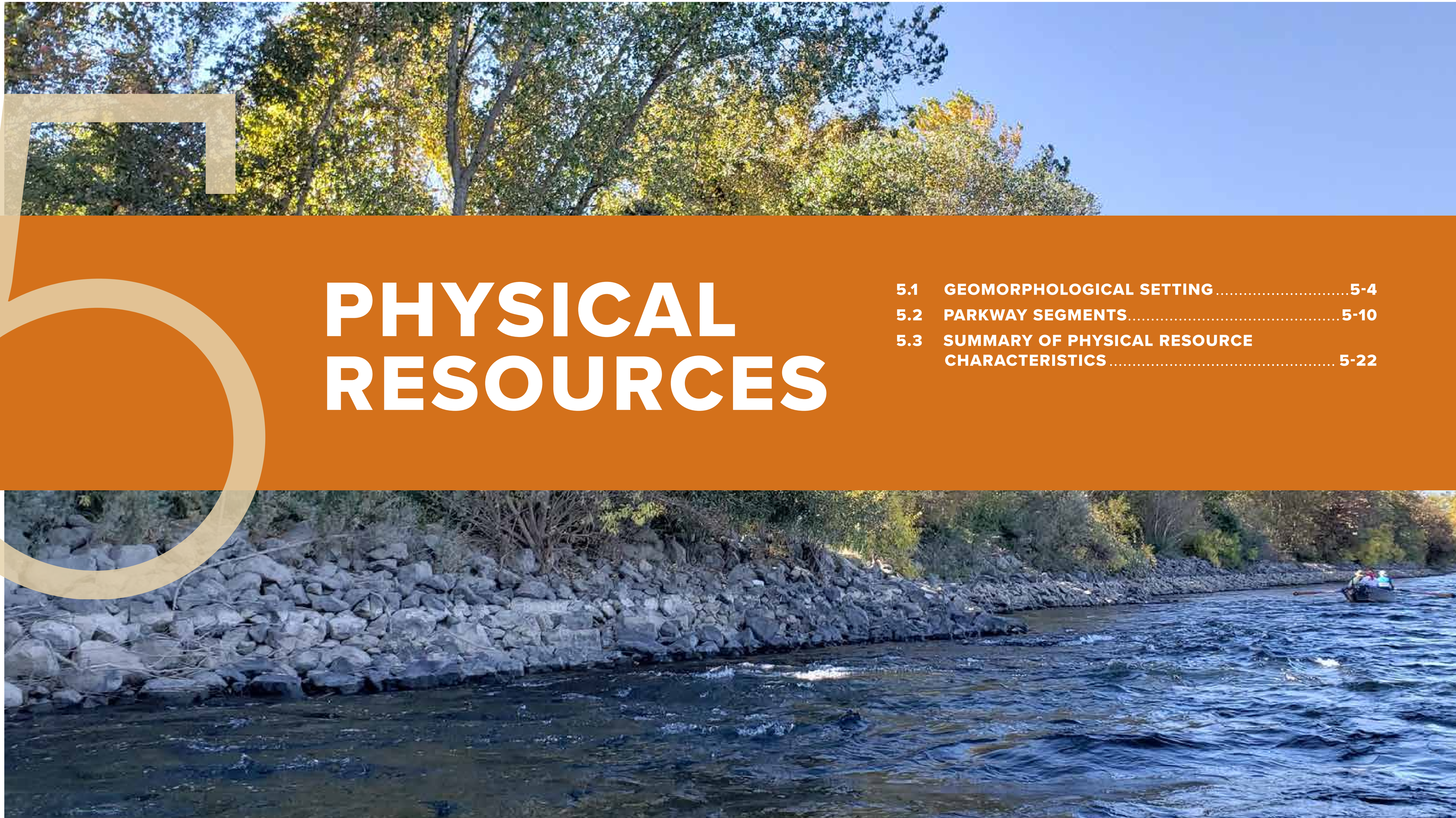


5

PHYSICAL RESOURCES

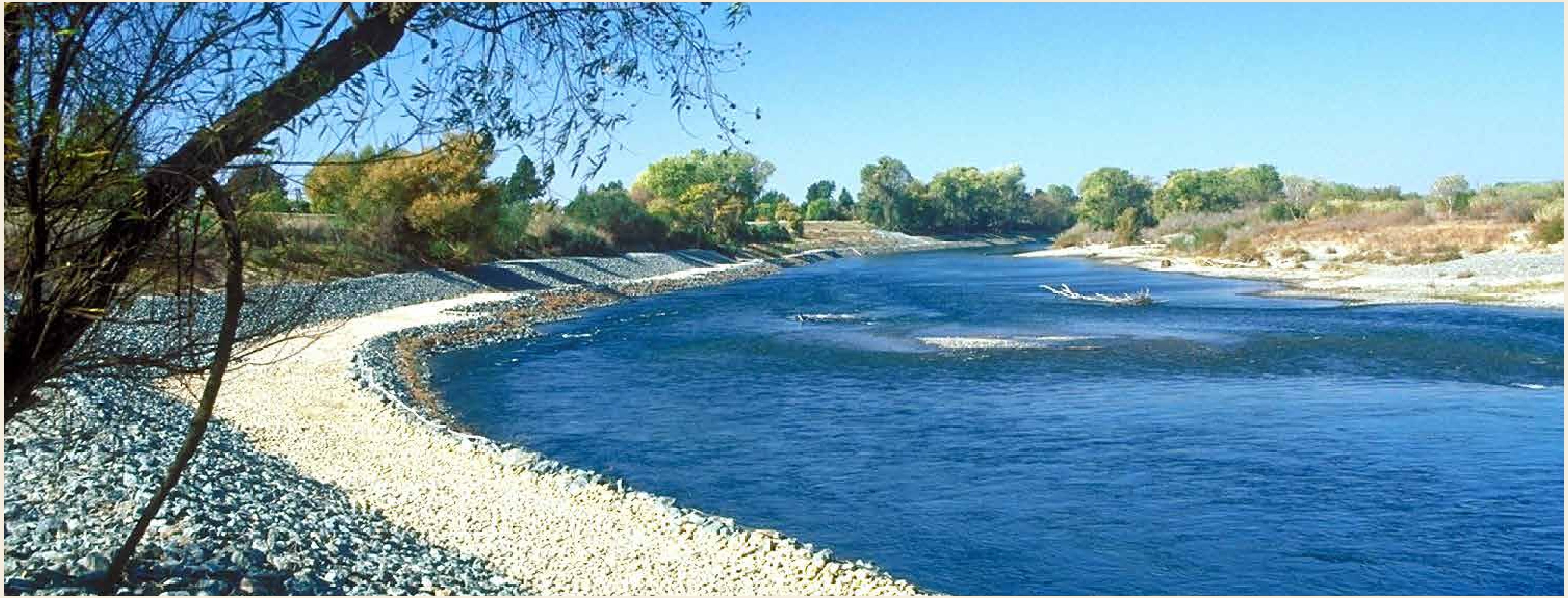
CHAPTER 5

INTRODUCTION AND OVERVIEW

The physical features and characteristics of the Parkway reflect the significant direct and indirect changes brought about by human activities reaching back several hundred years.

Past human interactions with the Lower American River (LAR) corridor, including in-channel gold and aggregate mining, sediment deposition from upstream hydraulic mining, channel realignment, the construction of the Folsom and Nimbus Dams, bank enhancements for flood protection, and installation of infrastructure, have altered natural landforms and river processes in a way that has had cascading effects on the natural resources and human use of the Parkway. Today, alterations of the Parkway for flood protection, habitat enhancement, operations, and related purposes continue to transform the Parkway's physical features. As a result, the Parkway's physical resources show the effects of both the historical and present-day human development that has resulted in an altered, but still dynamic river system.

The LAR is part of a highly regulated river system fed by the American River basin that extends from Carson Pass on the south to Donner Pass on the north, and from the crest of the Sierra on the east to its confluence with the Sacramento River on the west. In the upper watershed, there are many notable reservoirs, including French Meadows, Hell Hole, Union Valley, Ice House, and Stumpy Meadows. The North and Middle forks of the American River



Riverbank revetment site pre-planting. Photo Credit: Regional Parks

come to a confluence near the City of Auburn, CA before flowing on to Folsom Lake, the largest reservoir in the American River basin, dammed in 1955. The South Fork American River discharges into Folsom Lake after flowing along the US Highway 50 corridor from Echo Summit. Discharge from Folsom Dam is controlled to balance

the water resource needs and flood risk control of the greater Sacramento area, while maintaining the ecological integrity of the LAR. It also provides hydroelectric power generation (USBR 2016). The furthest downstream dam and reservoir, about seven miles downstream of the Folsom Dam is Nimbus Dam and Lake Natoma. Lake Natoma acts as a regulating reservoir for the Folsom Dam, generates hydroelectric power and diverts water to the Folsom South Canal. After discharge from Lake Natoma, the LAR flows through the cities of Folsom, Fair Oaks, Carmichael, Rancho Cordova, and Sacramento before joining the Sacramento River.

This chapter discusses the Parkway's physical resources; the section supplements and summarizes the data included in the Physical Resources technical appendix (Appendix B). First, the Geomorphological Setting (5.1) of the LAR is presented, followed by a discussion of the various Parkway river segments (5.2). The river segments are discussed from the confluence upstream towards Lake Natoma.

5.1 GEOMORPHOLOGICAL SETTING

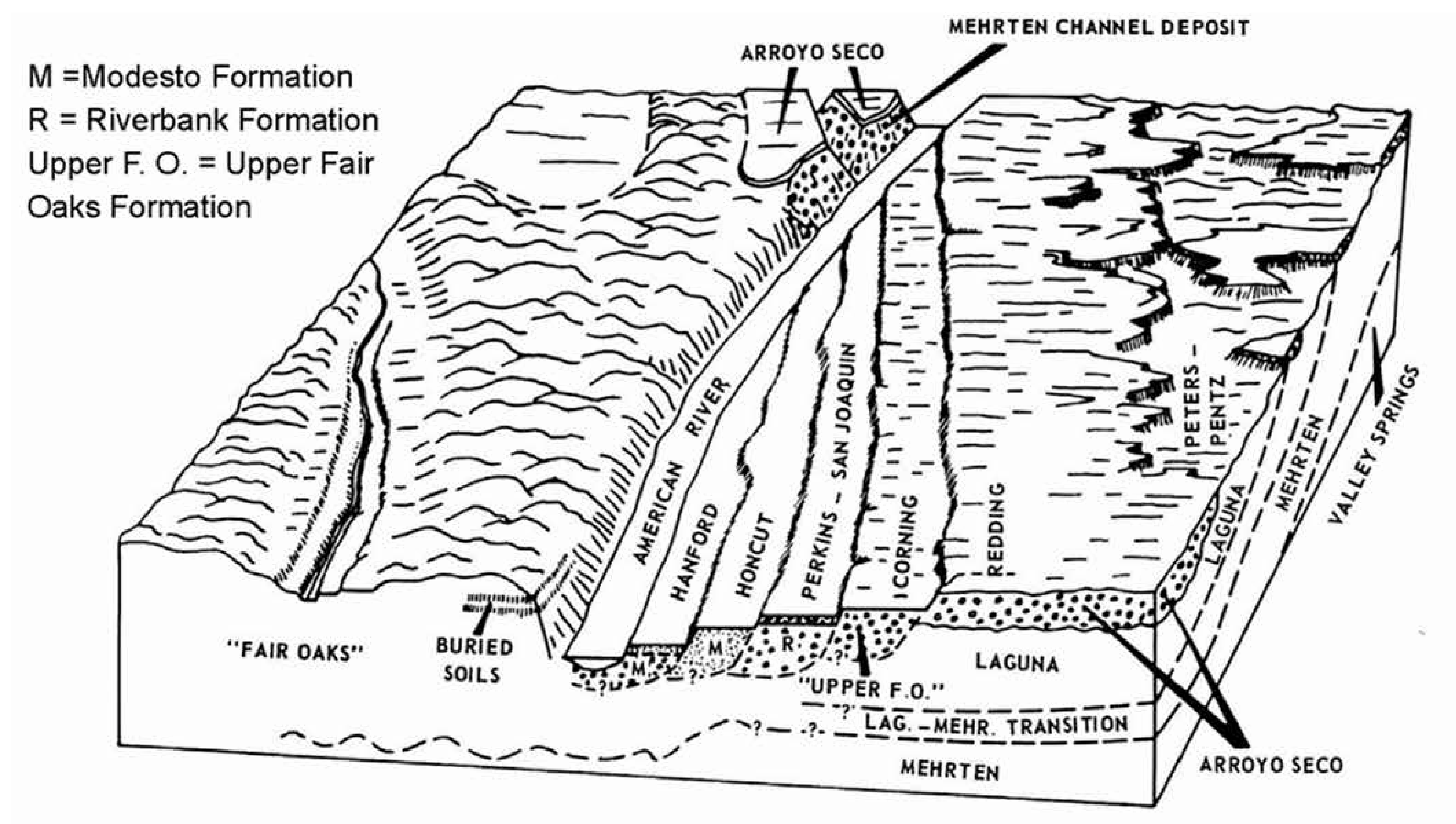
The geomorphology and present behavior of the LAR are intricately related to the area's geology, hydrology, and fluvial geomorphic history. Geomorphic development over the geologic time scale, including terrace sequences and associated fluvial deposits, plays a significant role in channel stability. The underlying geologic and geomorphic setting is key to understanding the river's current state, as well as the type and extent of restoration or mitigation that can ultimately be achieved within the confines of the physical setting. Descriptions of the LAR's underlying geologic units are given in Figure 5-1, and Figure 5-2 depicts the geologic and geomorphic setting of the LAR corridor and surrounding landforms.

The LAR and its floodplain are situated in Plio-Pleistocene-age geologic units (5.3 million years ago to 11.7 thousand years ago) and primarily composed of deposits from the ancestral river system as the ancestral channels were cut and then filled, shifting in location during repeated glaciations. Throughout the Pleistocene, periods of glaciation introduced large volumes of coarse sediments within valley channels; during periods of deglaciation, fine sediments (i.e., sands and silts) would wash down from the foothills, bury the braided channels, and coalesce into large alluvial fans (Shlemon 2000). From oldest to youngest, these formations are called Laguna, Arroyo Seco Gravel, Fair Oaks, Riverbank, and Modesto respectively (Shlemon 1976). The Fair Oaks formation is a locally-recognized geologic unit that correlates to the Laguna and Turlock Lake formations and forms the steep and relatively stable bluffs along the north side of the Lower American River (LAR). This erosion resistant layer is exposed intermittently along the channel bed and banks.

FIGURE 5-1 GEOLOGIC UNIT DESCRIPTIONS

PLEISTOCENE	Qmu	Modesto Formation; upper member; unconsolidated gravel, sand, silt, and clay.
	Qml	Modesto Formation; lower member; unconsolidated to semi-consolidated gravel, sand, silt and clay.
	Qru	Riverbank Formation; upper member, semi-consolidated to consolidated gravel, sand, silt and minor clay.
	Qrl	Riverbank Formation; lower member; consolidated gravel, sand, silt, and clay, generally associated with strong duripan horizon.
	Qtl	Turlock Lake formation; chiefly well consolidated sand with some silt and minor gravel.

FIGURE 5-2 GEOLOGIC SURFACE (ADAPTED FROM SHELMON 1967)



Understanding the formation and location of these geologic units is important for assessing the capacity for erosion-resistant layers to resist scour and to help achieve levee stability under high flood flows (Fugro 2012). Fair Oaks-aged gravel deposits can also be found on terraces aged between the later formations encountered (Shlemon 1976).

The younger Riverbank and Modesto formations comprise progressively younger, topographically lower alluvial deposits nested within the older geologic formations that were formed as the river migrated northward. Roughly twice as old as the Modesto Formation, the Riverbank Formation has undergone more physical and chemical weathering, reflected in its greater degree of soil horizon development relative to soils formed on the Modesto. The youngest Pleistocene alluvium, the Modesto Formation is mostly manifested on distinct alluvial terraces, but also formed alluvial fans and some remnant, mid-river ridges (Helley and Harwood 1985). These formations make up most of the surficial and shallow subsurface geology of the LAR.

Regional Watershed and Local Tributaries

The current LAR is part of a highly regulated river system fed by the American River basin that originates on the west side of the Sierra Nevada (Figure 5-3a and 5-3b) and encompasses portions of the Sierra high country, foothills, and central valley of California (Streamstats 2019). Several upper watershed reservoirs and tributaries collect, store, and convey water from the west slopes of the Sierra Nevada down to Folsom Lake, a reservoir created by Folsom Dam. From there the water continues down to Lake Natoma regulated by Nimbus Dam, the upstream end of the LAR Parkway. While tributaries exist along the LAR, their flow is negligible; however, their outfalls pose an erosion risk.

FIGURE 5-3A UPPER AMERICAN RIVER WATERSHED (ADAPTED FROM SRWP 2010)

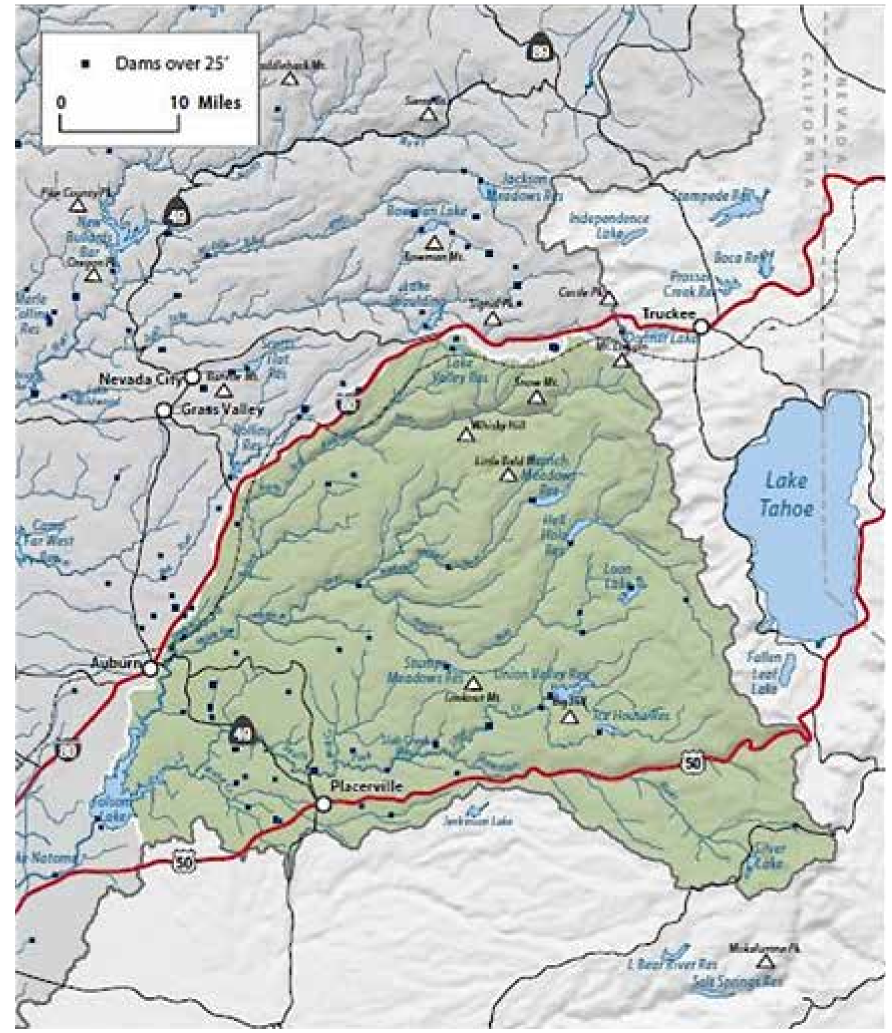


FIGURE 5-3B LAR WATERSHED (ADAPTED FROM SRWP 2010)

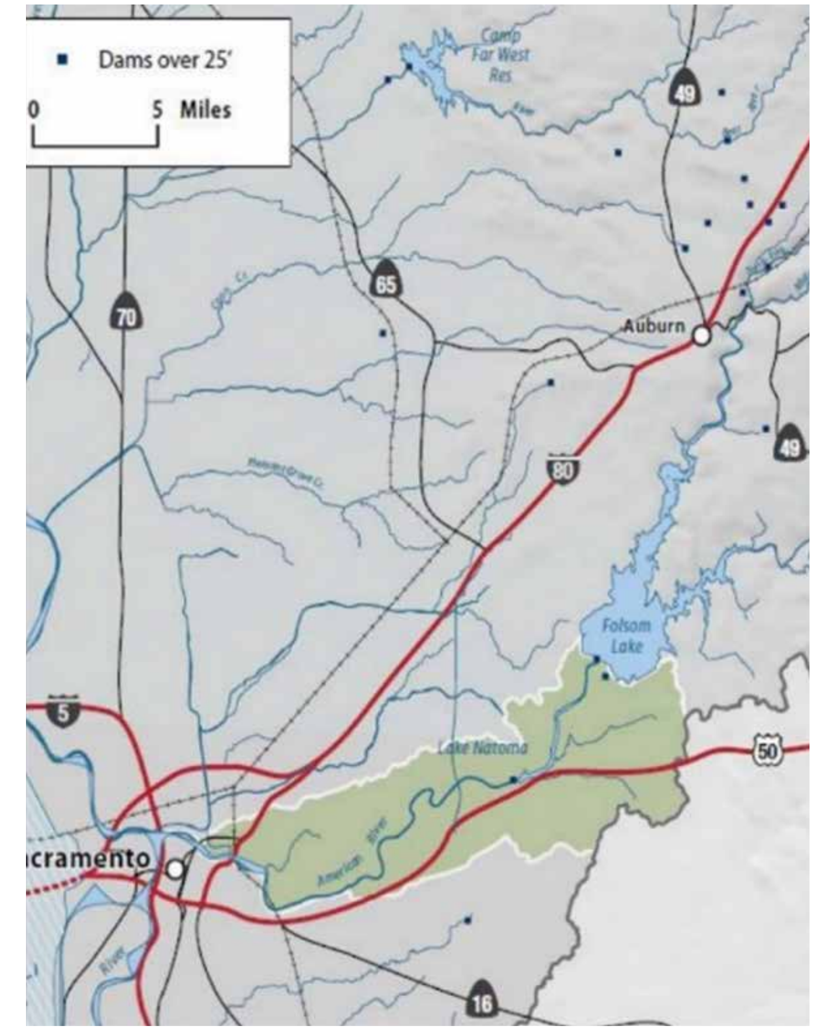


FIGURE 5-4 HISTORIC TIMELINE LAR

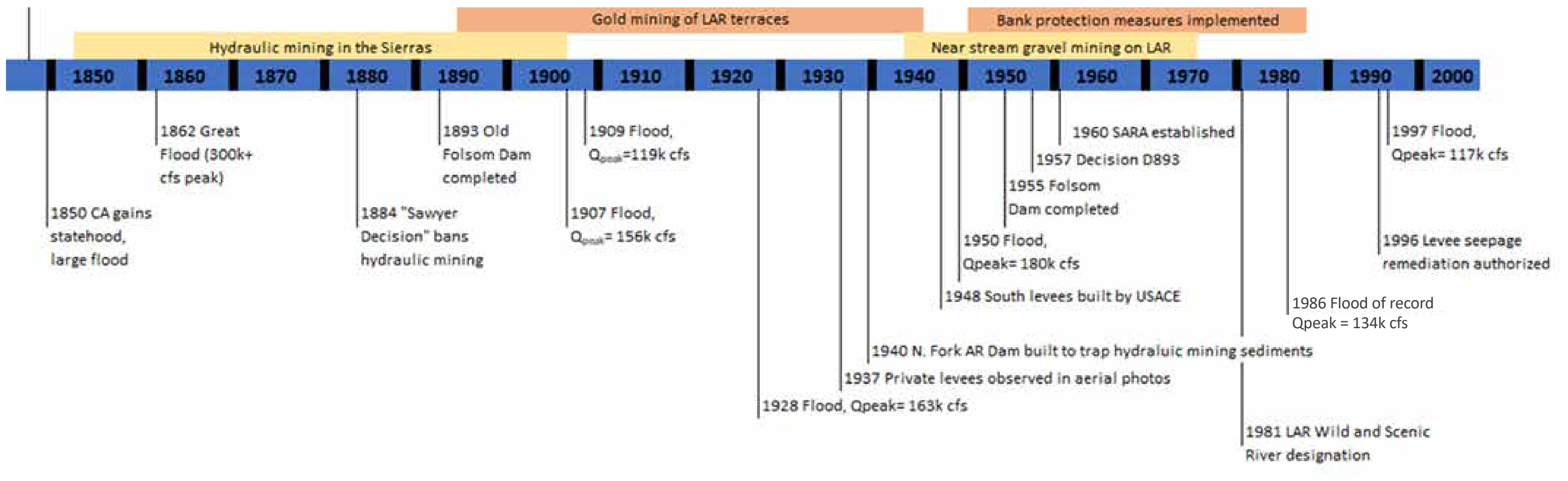
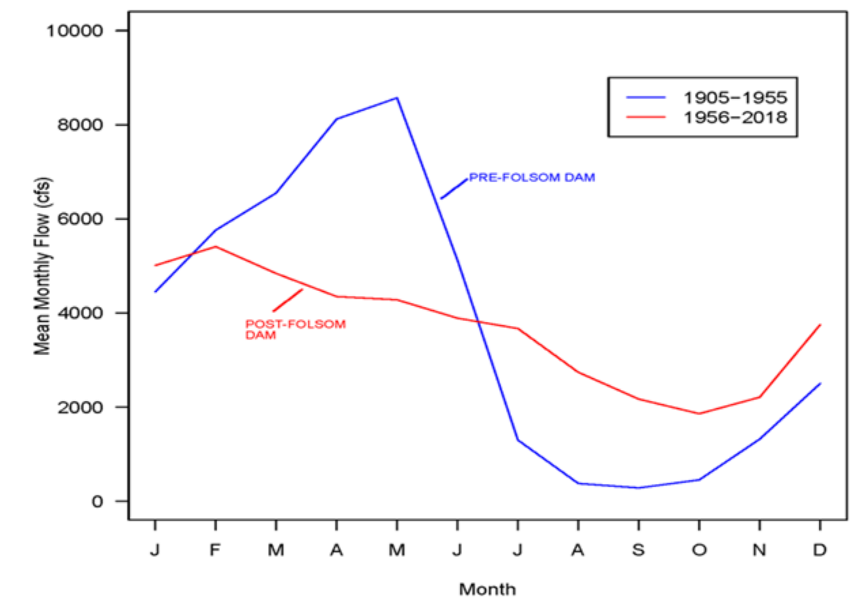


FIGURE 5-5 PRE-FOLSOM DAM VERSUS POST-FOLSOM DAM FLOW REGIME



Historic Use and Disturbance

The LAR evolved under a seasonal flood disturbance regime until recent historic human impacts caused considerable disturbance and resultant changes to channel form and condition. Gold and gravel mining in the nineteenth and twentieth centuries had major detrimental geomorphic effects. During the twentieth century and up to present, the Sacramento metropolitan area has expanded and currently occupies the historic floodplain. As a result of urban development within the floodplain, flooding of the LAR has been mitigated by the City of Sacramento. Figure 5-4 gives a historical timeline of events that resulted in significant physical changes along the LAR.

Upstream Gold Mining and Debris

In 1848 gold was discovered in the Sierra Nevada foothills, leading to the start of hydraulic mining in 1853. Hydraulic mining was incredibly destructive, turning clear mountain streams into thick yellow mud (Sierra College 2009). So much sediment was washed downstream that the lower reaches of the river aggraded, causing streams to avulse and forcing farmers to build levees to protect their farmland (James 1994). In 1884 hydraulic mining was outlawed (Vigars 2016) but this did not stop the continual transport of loosened debris from flowing toward the valley. In 1886 the lower two miles of the LAR were purposely straightened to increase flow velocities and move the accumulated sediments downstream. This effort had the dramatic result of moving the confluence with the Sacramento River about a mile northward (USBR 2006). The North Fork Dam and Lake Clementine were constructed in the upper watershed around 1940 in an effort to contain hydraulic mining debris and were reported to have held back roughly 70 percent of the material from the North Fork basin (Ayers 1997, James 1997).

Flow Regime and Dam Construction

Historically, and prior to the implementation of several dam control measures, the hydrology of the American River was similar to other large river systems that drain the western slopes of the Sierra Nevada. Annual flows typically resulted from spring snowmelt and peaked in April or May, followed by a receding hydrograph to the annual minimum base flow in September and October. Flooding often resulted from warm winter storms called "atmospheric rivers," which brought heavy precipitation to the Sierras and produced large floods from rain-on-snow events. As seen in Figure 5-5, prior to dam control there was a much greater seasonal fluctuation in flow regime, with greater changes in average flows moving from the spring to summer and fall months and from fall to the winter and spring months. Prior to dam control (and other human disturbances described in the following section), the LAR channel and associated riparian vegetation was directly tied to the more varied unimpeded flow regime and accompanying sediment inputs from the upper watershed.

Large floods throughout the recent history of the LAR spurred numerous flood control measures. More than one million dollars were spent between 1850 and 1861 to build and improve levees in and around Sacramento (Null and Hulbert 2007). Following the Flood of 1862, thousands of cubic yards of fill were hauled in by wagons, and the city streets were raised almost ten feet. The original street level can still be seen in Old Sacramento basements and under boardwalks (City of Sacramento 2018).

In 1940, the U.S. Congress approved the American River Basin Development Project. Its scope included constructing the Folsom and Nimbus Dams for flood control, hydroelectric power generation, and water storage/diversion. Construction of the Folsom and Nimbus Dams by the US Army Corps of Engineers started in 1948 and was completed in 1955 (Figure 5-6). At the end of 1955, the dams were functionally storing full capacity and producing electricity. The dams have been continuously operated and maintained by the US Bureau of Reclamation (USBR). The dams essentially cut off the spawning and rearing habitat along the American River, so as part of the Folsom-Nimbus Dam construction, USBR also constructed the Nimbus Hatchery (overseen by CDFW) to replace the salmon and steelhead runs (CDFW 2019).

The construction of these and other dams and reservoirs within the American River Basin has resulted in the delay of the annual peak discharge from snowmelt and substantially reduced the peak flood discharges from the occasional large winter floods, although they did not always prevent flooding, such as during the Flood of Record in 1986 (Figure 5-7). Conversely, under a more subdued seasonal hydrograph, the low flows that typically occur in the late summer and early fall saw a general increase compared to the pre-dam condition (Figure 5-5). The completion of Folsom Dam cut off sediment inputs to the LAR, and the channel began to incise into the mining deposits (Fairman 2007, James 2012). This lowered the channel bottom by up to 30 feet in the lower few miles of the LAR and changed channel alignment to its current location (Fairman 2007). During this period, localized bed and bank sand, gravel, and cobbles became the only erosional sources under low rates of sediment transport, creating a sediment-starved system with incision continuing into the upper reaches until the channel meets resistance from older alluvial layers.

Maximum allowable discharges from Folsom Dam are dictated by the capacity of the LAR channel and levee system (CRS 2006, USACE 2015). The maximum allowable release from Folsom Dam during this time was 115,000 cfs, acknowledging that significantly higher releases would likely cause levee damage and/or flooding in the City of Sacramento (USACE 2015, 2017). During flood events, there are also regulations dictating the rate of change of discharge through Folsom and Nimbus Dams (USACE 2017). As of 2006, studies suggested that the City of Sacramento flood protection capacity was below the 100-year precedent (1% probability of annual occurrence), the standard for considering building permits and flood insurance requirements under the National Flood Insurance Program (CRS 2006).

From 1958 to 2006, California State Water Rights Board Decision (CASWRB) D 893 regulated- low-flow releases from Nimbus Dam (CASWRB 1958). This 1958 decision marked the first time the CASWRB set a flow threshold for the benefit of fisheries (Water Forum 2015). In addition to protecting fisheries, the minimum flow policies on the LAR were instituted to ensure delivery of allocated water rights to the Delta and LAR and to promote salinity repulsion from the Sacramento-San Joaquin River Delta.

FIGURE 5-6 FOLSOM DAM CONSTRUCTION, 1953 (SOURCE: MY FOLSOM.COM 2019)

FIGURE 5-7 1986 FLOOD PHOTO (SOURCE: SAC BEE 2012)

FIGURE 5-8 RECENT LAR TIMELINE

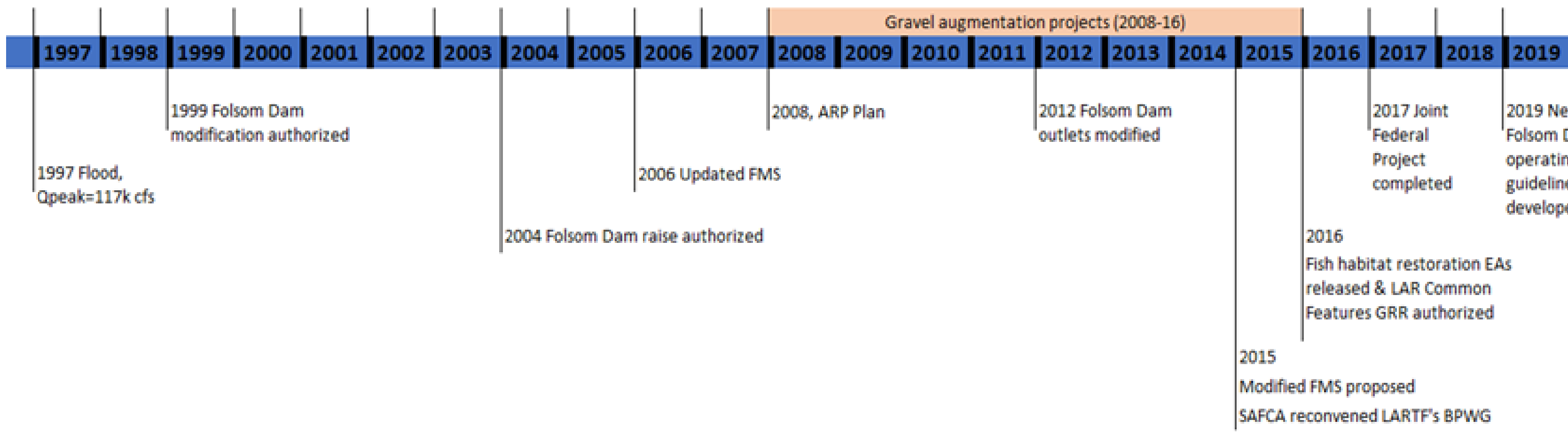
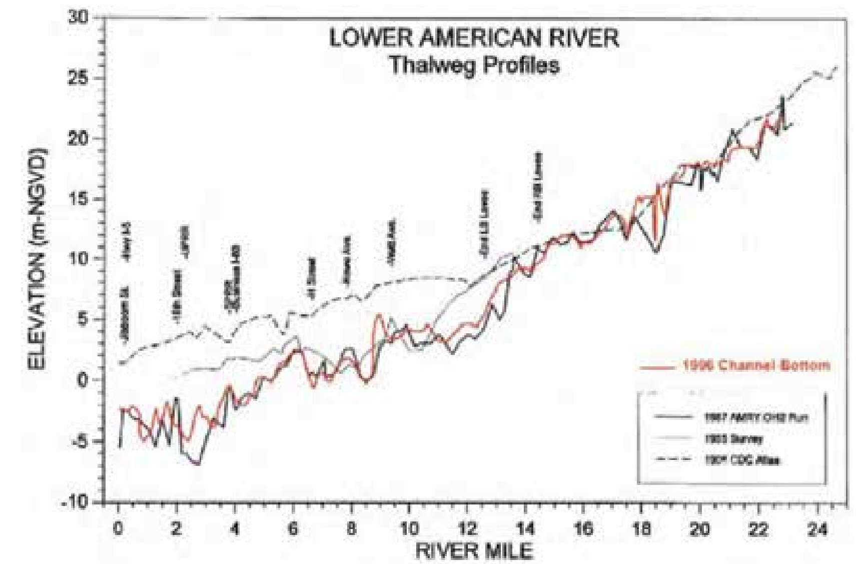


FIGURE 5-9 HISTORICAL CHANNEL THALWEG PROFILES (NHC 2016)



Since 2008, continued improvements to Folsom Dam and spillway and operational procedures have reduced flood risk in the Sacramento Metropolitan Area (USACE 2019). These procedures include facilitating the release of more water from the reservoir earlier in a storm event and operating in a manner to maintain more flood volume capacity in Folsom Lake.

Figure 5-8 gives a timeline of recent events and developments that have influenced the physical resources of the LAR.

New dam operation rules were recently developed that include the following (USACE 2019):

- Pass the Probable Maximum Flood (PMF) with at least three feet of freeboard below top of dam
- Control a 100-year flood with max release of 115,000 cfs
- Control a 200-year flood with max release of 160,000 cfs; and
- Incorporate improved forecasting capabilities

Levee System

An extensive system of federal levees protects the Sacramento Valley from flood risk. In response to the 1986 flood event (Figure 5-7), several levee assessment and upgrade efforts were put into motion in the 1990s and continue today to mitigate potential damage to the existing levee system, particularly if the allowable 200-year Folsom Dam release discharge of 160,000 cfs were to occur. (USACE 2017). The ongoing bank protection projects are implemented through USACE, Central Valley Flood Protection Board (CVFPB), and Sacramento Area Flood Control Agency (SAFCA). The primary projects driving levee improvements are the Sacramento River Bank Protection Project originally authorized under the Flood Control Act of 1960 (USACE 2020) to provide long term flood risk management, and the American River Common Features Project (ARCF) approved by Congress to provide levee and dam improvements following the 1986 flood.

Geomorphic Functional Surfaces

The geomorphic processes and channel conditions within the Parkway have been modified extensively by the historical impacts, natural system responses, and continuing operations and management introduced earlier. The relationships between geology, topography, soils, vegetation, and the active river channel vary somewhat throughout the LAR reach. Take for example the LAR plan and profile, where mineral extraction and sedimentation, dam, and levee construction; rising tides; and flooding on the Sacramento and American rivers has exacerbated large swings in sediment supply, changed the degree and type of lateral and vertical confinement, and altered downstream base water levels and backwaters. Severe aggradation from hydraulic mining debris raised the riverbed and floodplain surfaces along the American River in the late 1800s. The termination of impactful mining practices, capture of debris upstream, and closures via Folsom and Nimbus Dams led to gradual lowering of the channel over several decades, with the largest vertical fluctuations of the channel bed in the lowermost reaches (Figure 5-9). The resultant lowering of the channel bed while the adjacent banks remained generally at their post-aggradation elevations, particularly in the lower reaches has resulted in artificially high banks where overbanking of floodwaters is significantly reduced and opportunities for willow and cottonwood regeneration extremely diminished. The end result is that the height of the overbank area is artificially high compared to the channel bed. It is therefore not inundated as often and this has limited riparian regeneration (e.g. cottonwoods and willows) on these now higher floodplains. This is a major ecological issue driven by the geomorphic history.

In order to reflect the combined effects of natural and human factors on present river corridor condition and to help guide decision-making, we divided the LAR into Parkway Segments based on Geomorphic Functional Surfaces (Table 5-1). Existing topography and flood inundation zones indicated by recent hydraulic modeling are the primary basis for grouping landscape features into functional surfaces. Additionally, the relationship of current topographic and hydraulic conditions to the surficial geology and soil series informs the functional surface boundaries.

TABLE 5-1 GEOMORPHIC FUNCTIONAL SURFACE BREAKOUT

FUNCTIONAL GEOMORPHIC SURFACE	INUNDATION ZONE	PRINCIPAL GEOLOGIC UNIT(S)	TYPICAL SOIL SERIES
Active Channel	Area inundated by the 20,500 cfs (~2-year event) flow	Recent Alluvium and Basin Deposits; Holocene Alluvium; isolated outcrops Fair Oaks Formation (Upper)	Riverwash; Sailboat; Laugenour; Columbia; Xerofluvents
Floodplain	Area inundated by flows greater than 20,500 cfs and less than 115,000 cfs	Recent Aluvium, Holocene Alluvium and Modesto Formation, upper member	Xerofluvents; Riverwash; Rossmoor
High Floodplain / Low Terrace	Area between the 115,000 cfs and 160,000 cfs inundation boundaries	Modesto Formation, upper member	Rossmoor; Xerofluvents; Xerorthents, dredge tailings; Urban Land
Terrace(s)	N/A	Modesto Formation (upper and lower members); Riverbank Formation	Xerarents; Xerorthents, dredge tailings; San Joaquin; Urban Land
Bluffs and Hills	N/A	Fair Oaks Formation (Upper); Arroyo Seco Gravels; Laguna Formation; Mehrten Formation	Xerarents; Xerolls; Red Bluff; Americanos; Urban Land

5.2 PARKWAY SEGMENTS

The Parkway Segments described in the following sections are designed to provide a management tool to help decision makers understand the geomorphic processes that are dominant in each reach. The segments start at the confluence with the Sacramento River and move upstream. These segments are based on river channel and corridor-wide geomorphic conditions and processes, historic uses and disturbances, natural system responses, and trends. In addition, each segment considers Plan Area boundaries, recreation use, water supply, storm drainage infrastructure, flood protection infrastructure, and operations. The Parkway Segment pages that follow should be consulted before any decision is made pertaining to in-channel and bank improvements.

Soils and Sediment

There is a clear gradation in bed material starting at the furthest upstream Parkway Segment 5, with a coarse bed of cobbles transitioning to smaller cobbles and gravels and some new bars forming from local erosional sources or gravel augmentation in Parkway Segments 3 and 4, transitioning to smaller gravels and eventually sand and sediment in Parkway Segments 1 and 2.

5.2.1 Parkway Segment 1

CHARACTERISTICS: Channel Sinuosity 1.0, Channel Slope 0.02%, 40% Active Channel 60% Floodplain with backwater floodplain basins (Figure 5-10)

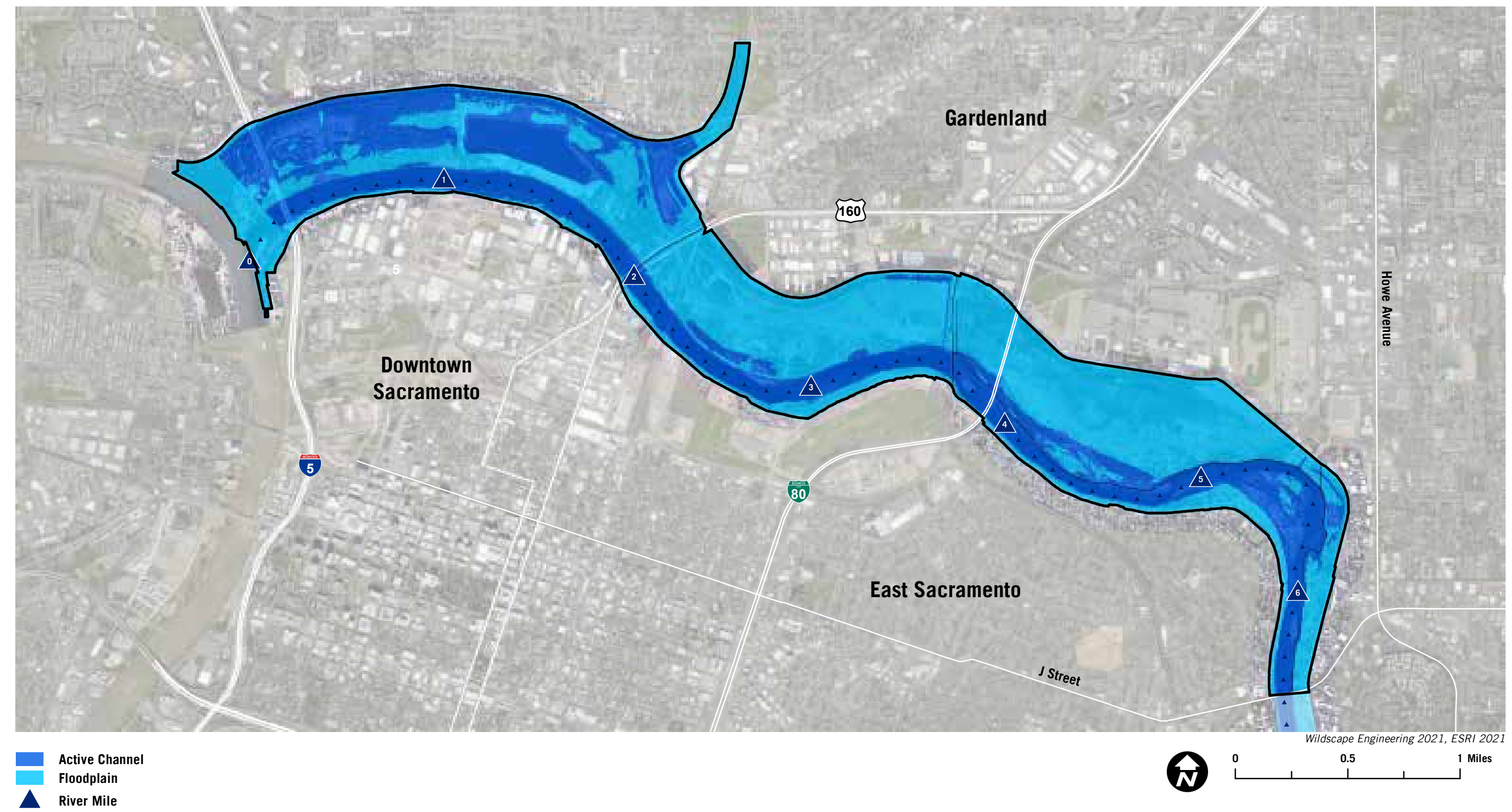


Figure 5-10
Lower American River Functional Geomorphic Surfaces Map - Segment 1

Figure 5-10 River Mile (RM) 0 to 6.5, Discovery Park, Woodlake, Cal Expo, Paradise Beach, Campus Commons

RIVER CORRIDOR AND CHANNEL TOPOGRAPHY: The River continues along the lowlands of the Central Valley until it meets the Sacramento River in Parkway Segment 1. In this area, the surrounding topography and that of the LAR is nearly level, featuring secondary and relic channel swales, backwaters, and off-channel basins. In the highly urbanized areas throughout Parkway Segments 1 and 2, the channel is laterally constrained by flood control levees. For roughly three miles upstream of the confluence, the LAR River is extremely flat and slow moving as it is largely influenced by tidal backwater from the Sacramento River. Historic LAR profiles show that this segment experienced large vertical fluctuations in riverbed elevation (Figure 5-9), most likely due to aggradation from the high sediment load produced by mining and subsequent scour during high flow events that occurred without the extensive flow control experienced by the current river system.

GEOMORPHIC FUNCTIONAL SURFACES: Consistent with geologic and topographic conditions and hydraulic context, floodplain and active channels are the only geomorphic surfaces in Parkway Segment 1. With a wider channel encompassed by a narrower levee corridor, particularly in the Discovery Park area, the proportion of active channel to floodplain in Parkway Segment 1 is greater than the Parkway as a whole, roughly 40 percent compared to 30 percent. A few channel features such as backwaters, alcoves, mid-channel bars, and disconnected low flow threads, indicated by the ecological flow modeling and the recent imagery, occur in Parkway Segment 1 and Segments 2 and 3 discussed later. Limited only by levees, the floodplain areas are increasingly inundated as flows begin to exceed the 2-year peak flood event, particularly along Discovery Park, Woodlake and Cal Expo where the floodplain is wide and expansive in Segment 1.

INUNDATION SURFACES: The modeled ecological or "Eco flow" of 2,000 cfs is largely confined to the main channel in the lower portion of the reach (Parkway Segment 1). As expected, the approximate 2-year flow of 20,500 cfs is required for wetted areas to occur beyond the main channel in Segment 1 or along the south (left bank looking downstream) side of the Paradise Beach bend. Given the levee and topographic confinement, the 115,000 cfs flow covers the entire river corridor in lower Parkway Segments 1 and 2.

MOBILIZATION AND TRANSPORT: Modeling indicates that the lower third of the river corresponds with lower shear stresses. This result was not surprising given that the decreasing slope and increasing width in the lower reach of the LAR significantly reduces velocities in Parkway Segment 1. In addition, the lower reach is the most impacted by backwatering from the confluence of the LAR with the Sacramento River. The bed material in this reach is dominated by fine grained sediments and sand.

TERRACE GRAVEL MINING: From about the turn of the twentieth century until the 1970s, aggregates and gravels were procured by mining active bars, terraces, and in-channel areas (Watson 1985). While most mining occurred upstream of River Mile (RM) 8, aerial photos from 1968 identified some sites in Segment 1: RM 1.1-1.4 LB, 2.5-3.1 RB, and 4.2-5.0 RB.

BED AND BANK TYPES: In the lower LAR reaches (Parkway Segment 1), the most common banks are earthen side slope banks with varying amounts of native and non-native vegetation. Adjacent to a sediment-laden stream with slow moving water, these banks are stable and relatively homogenous, with little to no floodplain variability (Figure 5-11). In the high use Parkway areas, banks are often heavily compacted or crisscrossed with social trails. A few scattered locations vulnerable to erosion within Parkway Segment 1 are armored with cobble/gravel toe protection, primarily for levee protection. At Paradise Beach, a well-vegetated bar along the left bank was reportedly cleared during the 1997 flood flows of 115,000 cfs. As seen in Figure 5-12, the vegetation grew back in essentially the same footprint, exhibiting a "scour and sprout" phenomenon as opposed to a meandering floodplain channel with point bars and downed woody debris (Watson 2019). Further downstream along Parkway Segment 1 there is a shift to more intermittent vertical banks.

FIGURE 5-11 MATURE OAKS LINE UPPER PORTION OF MOSTLY BARE EARTHEN LEFT BANK NEAR CONFLUENCE (~RM0.2)

FIGURE 5-12 LEFT BANK VEGETATED BAR AT PARADISE BEACH (~RM 5.6)

BANK STABILITY: As discussed, spatial distribution of geologic layers with varying degrees of resistance along the LAR define where bed and bank migration are largely impeded. For example, the younger, less-resistant Modesto formation that occurs more frequently in the lower reaches appears to be restricting river migration in some locations and is eroding elsewhere. An analysis of bank retreat using aerial imagery showed no significant degree of change from 1957 to 2010 (Ayers 2004, nhc 2012).

LEVEE PROTECTIVE REVETMENTS: While bank protection in Segment 1 has existed since 1948, it has continued to be developed over the years and most recently was upgraded to withstand the 200-yr flood (160,000 cfs) as part of the American River Common Features (ARCF) Project. As of fall of 2018 extensive work has been done to reassess geomorphology of the leveed section (RM 0 to 14) and identify erosion risks (nhc 2018). Site identification, prioritization and improvement designs for levee stability are ongoing.

OUTFALLS: Many of the outfalls along Parkway Segment 1 are associated with large stormwater drainages from the urban areas and often pose point sources for pollutants and infrastructure needs and erosion risks along the bank edge (Figure 5-13).

FIGURE 5-13 LARGE URBAN STORMWATER OUTFALL WITH BROKEN APRON (~RM 5.3)

FUTURE TRENDS: Analysis by nhc (2018) predicted future morphology of the channel over the next 50 to 100 years with a focus on the leveed reach of the LAR between RM 0 and RM 14.5 (Segments 1, 2 and 3). Sediment transport modeling of the system indicates a continuation of the post-Folsom dam trends with net deposition in the downstream reaches. Parkway Segment 1 is projected to continue to receive and generally accumulate sediment, given the supply from upstream reaches, the typically low-energy environment of Sacramento River backwater, and rising sea level. In response to net aggradation, channel adjustments are expected to result in local bank erosion and/or channel shifts. At Paradise Beach the channel could shift due to the interplay between aggradation in the main channel along the outside bend as a result of historic modifications and degradation/incision of the overflow channel that flows around the left side of the left bar. This could result in a "cut off" of the meander and head cut up the deepening overflow channel, causing the overflow channel to become the main channel and slope through the area to increase. This possible channel cut off at Paradise Beach could increase local bed slope and bed erosion. Projected channel dynamics in this segment could increase the risk of erosion to levees.

"The Lower American River Levee System comprises 26 miles of levees between Folsom Dam and downtown Sacramento. The levees play a crucial role in protecting communities in the Arden-Arcade and North Sacramento areas as well as communities to the south in downtown Sacramento."

— **SACRAMENTO AREA FLOOD CONTROL AGENCY**

5.2.2 Parkway Segment 2

CHARACTERISTICS: Channel sinuosity 1.0, Channel slope 0.07%, 51% Active Channel, 46% Floodplain, 3% High Floodplain/Low Terrace (Figure 5-14)

RIVER CORRIDOR AND CHANNEL TOPOGRAPHY: In Parkway Segment 2, rolling hills and bluffs transition to the vast lowlands of the Central Valley. Moving westward downstream, the topographic relief decreases gradually within and adjacent to Segment 2. Similar to Parkway Segment 1, modern lateral constraints are primarily the constructed and maintained levees. Streambed surface irregularities, an overall low channel slope, and exposures of erosion resistant geologic units are evident in the channel bed profile through Parkway Segment 2 (RM 6.5 to RM 11.5).

GEOMORPHIC FUNCTIONAL SURFACES: The active channel occupies roughly 30.4% of the entire Parkway, but 51% is in Parkway Segment 2 where the levee corridor is narrower. Review of the 2-year inundation pattern, 2017 imagery, and local topography supports a description of the dominant channel form as single thread throughout the LAR including Parkway Segment 2. Additional channel features such as backwaters, alcoves, mid-channel bars, and disconnected low flow threads, indicated by the ecological flow modeling and the recent imagery, occur in Segments 1, 2, and 3.

INUNDATION AREAS: In Parkway Segment 2, the 2,000 cfs low flow enters split flow channels around the Howe Avenue, Watt Avenue, and SARA Park Areas. Given the levee and topographic confinement, the 115,000 cfs flow covers the entire river corridor in Parkway Segment 2.

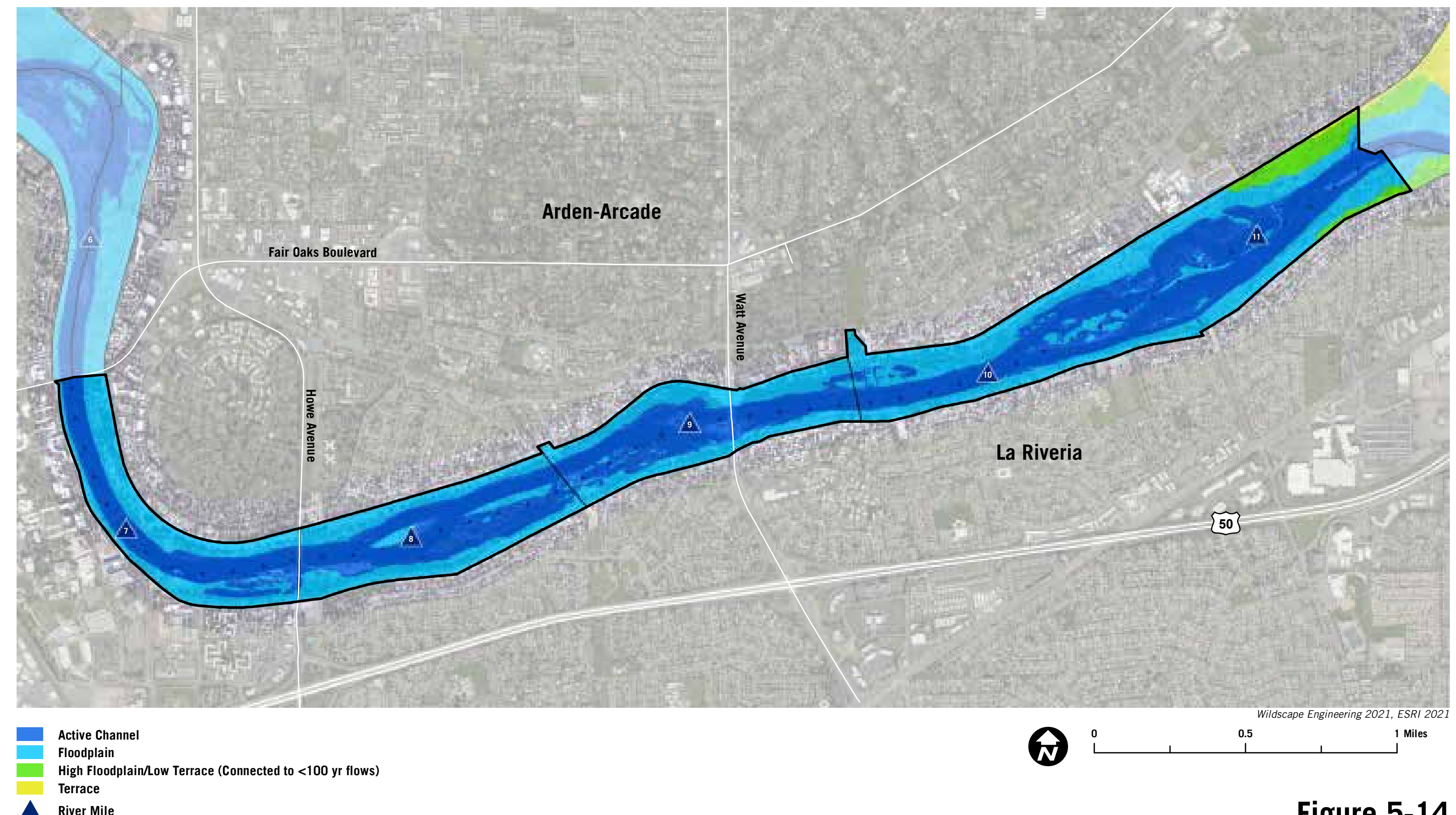


Figure 5-14
Lower American River Functional Geomorphic Surfaces Map - Segment 2

Figure 5-14 RM 6.5-11.5, Campus Commons, Howe Avenue, Watt Avenue, SARA Park

TERRACE GRAVEL MINING: Past hydraulic mining practices caused channel instability and sediment displacement on the LAR, particularly in the upper reaches. Along the upstream portion of Parkway Segment 2, hydraulic mining activities prior to 1970 widened the river from approximate RM 10 to RM 11.5 with the left bank bar first lowered to roughly the main channel bed elevation at the erosion resistant layer, followed by lowering of the right bank floodplain (nhc 2018). Channel areas that have been over-widened experience reduced velocities and sediment transport and are likely to continue to aggrade and become shallower (Figure 5-15).

BED AND BANK TYPES: Parkway Segment 2 is roughly at the terminus of gravel movement and deposition from the upstream reaches. However, in this reach there is little visible alluvial material. Most banks are earthen and vegetated with localized exceptions where the channel has been directly manipulated by human activity. On the upstream side of Howe Avenue Bridge and the downstream side of Watt Avenue Bridge, old mining excavations lowered the left banks of the river, widening the channel and forming in-channel islands with alluvium surfaces. Parkway facilities and recreational access often coincide with these artificially lowered banks due to their accessibility to the river, such as the boat ramp southwest of Watt Avenue Bridge (Figure 5-15).

BANK STABILITY: Within Parkway Segment 2 the Riverbank formation (alluvial deposit) is exposed and holding in the bed of LAR at RM 7 to 7.3, 9.4 to 10.9, and 11.6. With the Riverbank and Fair Oaks (Turlock) layers preventing continued channel incision in the upper reaches, the potential for channel widening could continue to pose an erosional risk to banks and nearby levees. In the lower reaches, there is still some bed degradation risk that could eventually impact levee integrity via toe scour. Using aerial imagery, an analysis of bank retreat showed no significant degree of change from 1957 to 2010 (Ayers 2004, nhc 2012).

LEVEE PROTECTIVE REVETMENTS: Several of the proposed and ongoing levee revetment projects are located in the upper portion of Parkway Segment 1 and into Segment 2. From RM 5 to RM 11 levees closely parallel the channel at a distance of 700 to 1500 feet. Overbank velocities and applied shear stresses at a flow of 160,000 cfs range from 2 to 5 ft/s and 0 to 0.5 psf, respectively (Ayres 2004). Between RM 9.5 and RM 15 about 5,760 linear feet (or about 9 percent of total bank length) of bank protection has been installed. As of fall 2018, extensive work has been done to reassess the geomorphology of the leveed section (RM 0-14) and identify erosion risks in

FIGURE 5-15 MINED LEFT BANK WIDENED RIVER, FORMED IN CHANNEL BAR SEEN FROM BOAT RAMP (~RM 9).

Subreach 2 (nhc 2018). Site identification, prioritization and improvement design are ongoing.

FUTURE TRENDS: Parkway Segment 2 remains within the depositional reach of the LAR according to sediment transport modeling. Parkway Segment 2 has erosion-resistant geologic materials exposed in the channel bed or at shallow depths that restrict the ability of the river to incise in the future. This Parkway Segment will continue to receive coarse sediment input from Parkway Segment 3 but would not be hydraulically capable of transporting further downstream, so coarse material would be deposited near its upstream end. The channel bed would be expected to remain stable in other portions of Segment 2, but channel widening, and local bank erosion are predicted and currently being addressed as part of the levee flood protection efforts being done by others.

5.2.3 Parkway Segment 3

CHARACTERISTICS: Channel sinuosity 1.4, Channel slope 0.15%, 29% Active Channel, 27% Floodplain, 17% High Floodplain/Low Terrace, and 27% Terrace, a few alcoves, and disconnected threads (Figure 5-16)

RIVER CORRIDOR AND CHANNEL TOPOGRAPHY: Rolling hills underlie the neighboring communities of Fair Oaks and Carmichael to the north of Parkway Segments 3 and are expressed in bluffs that border the river corridor. The gently sloping terraces south of the river in Rancho Cordova, like the terraces in Parkway Segments 3 have been directly modified by historic mining (as well as urban development). The modern lateral constraints on river dynamics and overbank flow along the LAR corridor in the upstream half (Parkway Segments 3, 4, and 5) are formed by natural geologic materials and topography that is exaggerated by post-Folsom Dam channel bed lowering. Based on several studies (Fairman 2007, Ayres 2004 and nhc 2012), modern (post-Folsom Dam) channel migration of the LAR has largely been absent and notable only in the Arden Bar and River Bend Park Areas (Parkway Segment 3). This portion of the river has a sinuous channel pattern and the highest modern bed slope. Parkway Segment 3 coincides with the section of channel between RM 12 and RM 15 that appears to have had a locally steeper channel slope since the 1860s although the bed experienced temporary burial by hydraulic mining sediment (nhc 2018).

GEOMORPHIC FUNCTIONAL SURFACES: Parkway Segments 3 and 4, particularly around the River Bend Park, Rossmoor Bar, and Sacramento Bar Areas, show more variability under the 115,000 cfs flow. There are only slight increases in inundated areas between the 115,000 and 160,000 cfs; however, it is notable that the 200-year flow goes beyond the Parkway boundary on the south side of Arden Bar in Parkway Segment 3. A variety of channel features occur in Segment 3, such as backwaters, alcoves, mid-channel bars, and disconnected low flow threads, indicated by the ecological flow modeling and recent imagery. Intermediate areas of high floodplain/low terrace surfaces are delineated and are an important component. While most of these surfaces are not subject to flood inundation for events smaller than the 100-year peak flow, the disturbed topography from past mining operations creates a complex pattern of partially connected ridges and swales that foster surface and/or groundwater-supported saturation or inundation potential.

INUNDATION AREAS: In Parkway Segment 3, the 2,000 cfs flow enters split flow channels in the Arden Bar Areas. The River Bend Park Area is inundated around the approximate 2-year, 20,500 cfs flow. At Arden Bar, the 2,000 cfs low flow surprisingly shows up within the existing pond

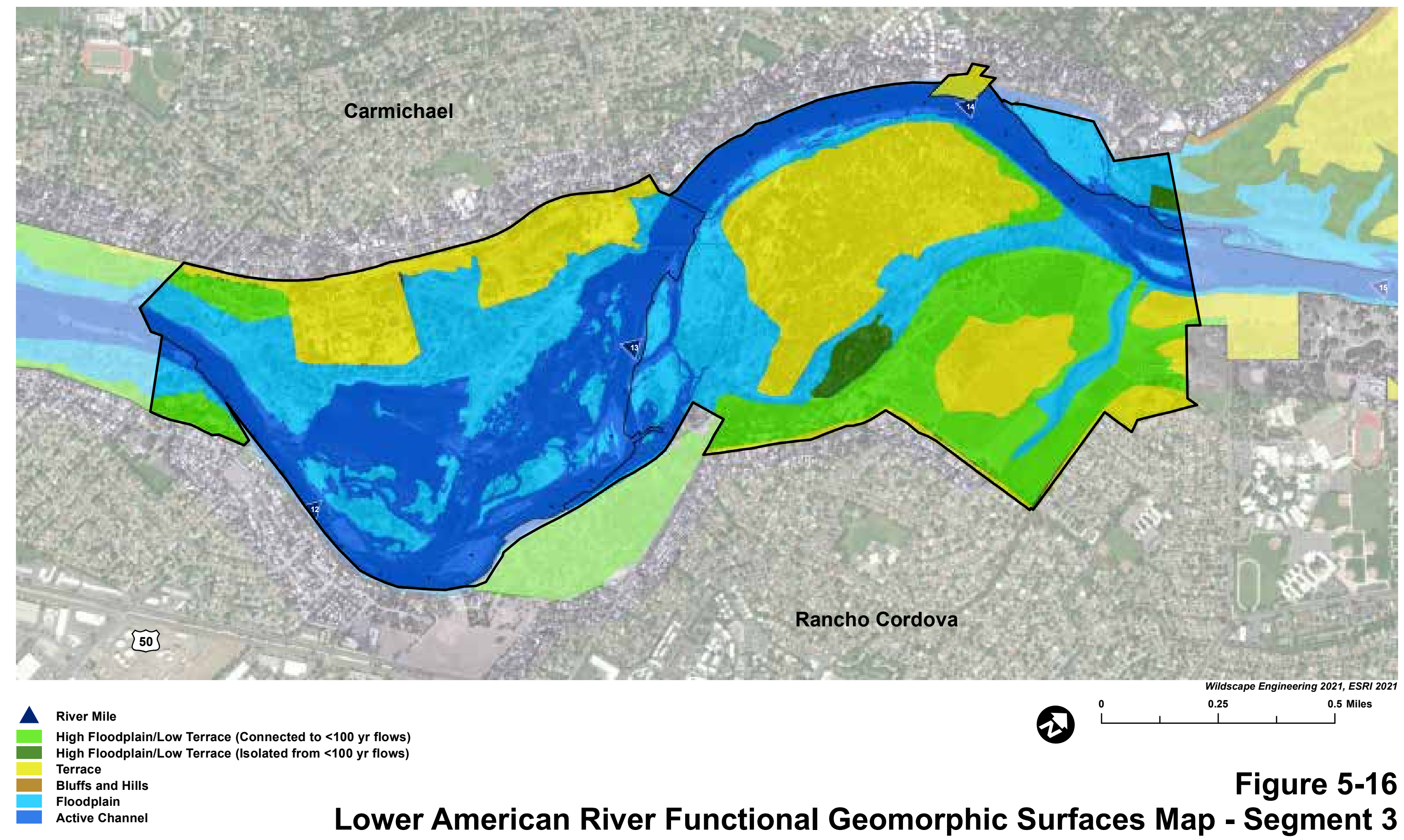


Figure 5-16 RM 11.5 to 14.6, Arden Bar, Riverbend Park, Ancil Hoffman County Park

FIGURE 5-17 COBBLE SPOILS ALONG ARDEN BAR, EVIDENCE OF PAST GRAVEL MINING

FIGURE 5-18 HEAVILY USED RIGHT BANK AT CAR TOP BOAT LAUNCH (~RM 11.6)

FIGURE 5-19 RIVER RIGHT BANK GRAVEL SIDE BAR (~ RM 12.1)

FIGURE 5-20 EXPOSED FAIR OAKS FORMATION ALONG RIVER RIGHT BANK.

and the 20,500 cfs flow goes through the pond and beyond the spillway. During the 1997 event, flows through the ponds made their way to a remnant swale and onto the Harrington Way parking lot access road before returning to the main channel, rather than through the pond's spillway (Watson 2019). Given the extent of inundation in this area at 20,500 cfs, this occurrence may become more common. The 20,500 cfs flow also enters and carries through the existing north ponds at Arden Bar in Parkway Segment 3.

MOBILIZATION AND TRANSPORT: With steeper slopes and higher velocities, smaller cobbles and gravels make up the channel bed substrate and form side bars from local erosional sources and in a few cases introduce gravels. Relatively high shear stress and scour potential was observed at sharp bends, including at Arden Bar.

TERRACE GRAVEL MINING: As introduced earlier, the majority of hydraulic mining that ended in the 1970s took place upstream of RM 8. Cobble spoil piles left behind are scattered throughout the terraces of Arden Bar from roughly RM 12 to 13 at William B. Pond Recreation Area (Figure 5-17) and could provide some local source material for future restoration efforts.

BED AND BANK TYPES: In Parkway Segment 3, the frequency of bare ground and exposed alluvial material increases in contrast to relatively undisturbed vegetated banks. Some of these areas are heavily compacted in high use areas such as boat launches (Figure 5-18). Other banks appear to be increasing in height due to overbank deposition (Figure 5-19). Locally, the more resistant Fair Oaks formation is exposed along some bank margins (Figure 5-20). Cobble spoil piles, remnants from hydraulic mining, are scattered throughout the terraces of Arden Bar from roughly RM 12 to 13 at William B. Pond Recreation Area.

BANK STABILITY: Within Parkway Segment 3 the Riverbank formation (alluvial deposit) is exposed and holding in the bed of LAR at RM 11.6 and from 13.8 to 14. With the Riverbank and Fair Oaks (Turlock) layers preventing continued channel incision in the upper reaches, the potential for channel widening could continue to pose an erosional risk to banks and nearby levees. In the lower reaches, there is still some bed degradation risk that could eventually impact levee integrity via toe scour.

FUTURE TRENDS: Sediment transport modeling of the system downstream of Nimbus Dam indicates net erosion upstream of RM 14 and net deposition in the downstream reaches, continuing recent (post-Folsom Dam) trends. Upper Parkway Segment 3 coincides with the beginning of the net erosion reaches and would potentially experience incision at its upstream end, lowering slopes and prompting continued deposition, except where the channel bed elevation is supported by erosion-resistant geologic materials at shallow depth. The discontinuous connections between active channel and overbank areas with irregular topography and over-wide and over-deep mining remnants suggest that a variety of processes and conditions may occur in this section of the LAR. Local aggradation may induce channel shifts and increase erosion of above grade fill and terrace soils. Channel shifts and increased overbank flow frequencies may deliver additional fine and/or coarse materials to existing pits and swales. Net transport of sediment to downstream reaches would also occur.

5.2.4 Parkway Segment 4

CHARACTERISTICS: Channel sinuosity 1.5, Channel slope 0.07%, 15% Active Channel, 12% Floodplain, 27% High Floodplain/Low Terrace, 43% Terrace (Figure 5-21)

RIVER CORRIDOR AND CHANNEL TOPOGRAPHY: The underlying natural geologic materials and topography in Parkway Segments 3, 4 and 5, amplified over time by post-Folsom Dam channel bed lowering, continue to constrain the river laterally in these areas. Rolling hills underlie the neighboring communities of Fair Oaks and Carmichael to the north of Parkway Segments 3, 4, and 5 and are expressed in bluffs that border the river corridor. The gently sloping terraces south of the river in Rancho Cordova, similar to the terraces in Parkway Segments 3, 4, and 5, have been directly modified by historic mining (as well as urban development). The modern lateral constraints on river dynamics and overbank flow along the LAR corridor in the upstream half (Parkway Segments 3, 4, and 5) are formed by natural geologic materials and topography that is exaggerated by post-Folsom Dam channel bed lowering.

GEOMORPHIC FUNCTION SURFACES: The channel is comparatively narrow and simple in Segments 4 and 5 while bluffs and hills are a small but important surface that only occurs in Parkway Segments 4 and 5. Terraces form the natural and modified surfaces that are generally above the 200-year inundation zone (160,000 cfs) under present conditions, although some terrace locations may have disturbed topography with isolated low spots. These broad uplands occupy approximately 40 percent of the Parkway in Segments 4 and 5. Intermediate areas of high floodplain/low terrace surfaces are delineated and are an important component of Segments 3 and 4. While most of these surfaces are not subject to flood inundation for events smaller than the 100-year peak flow, the disturbed topography creates a complex pattern of partially connected ridges and swales that foster surface and/or groundwater-supported saturation or inundation potential. The floodplain area is much more limited in Segments 4 and 5, as compared to Segments 1 and 2 where it was only limited by the levees. The areas mapped as floodplain surfaces emphasize locations that are functionally connected to the main channel or local tributaries and subject to overbanking, rather than areas of extensive topographic disturbance that complicates flow routing. Accordingly, areas of uncertain surface flow connectivity within the 115,000 cfs inundation areas are grouped in the high floodplain / low terrace surface.

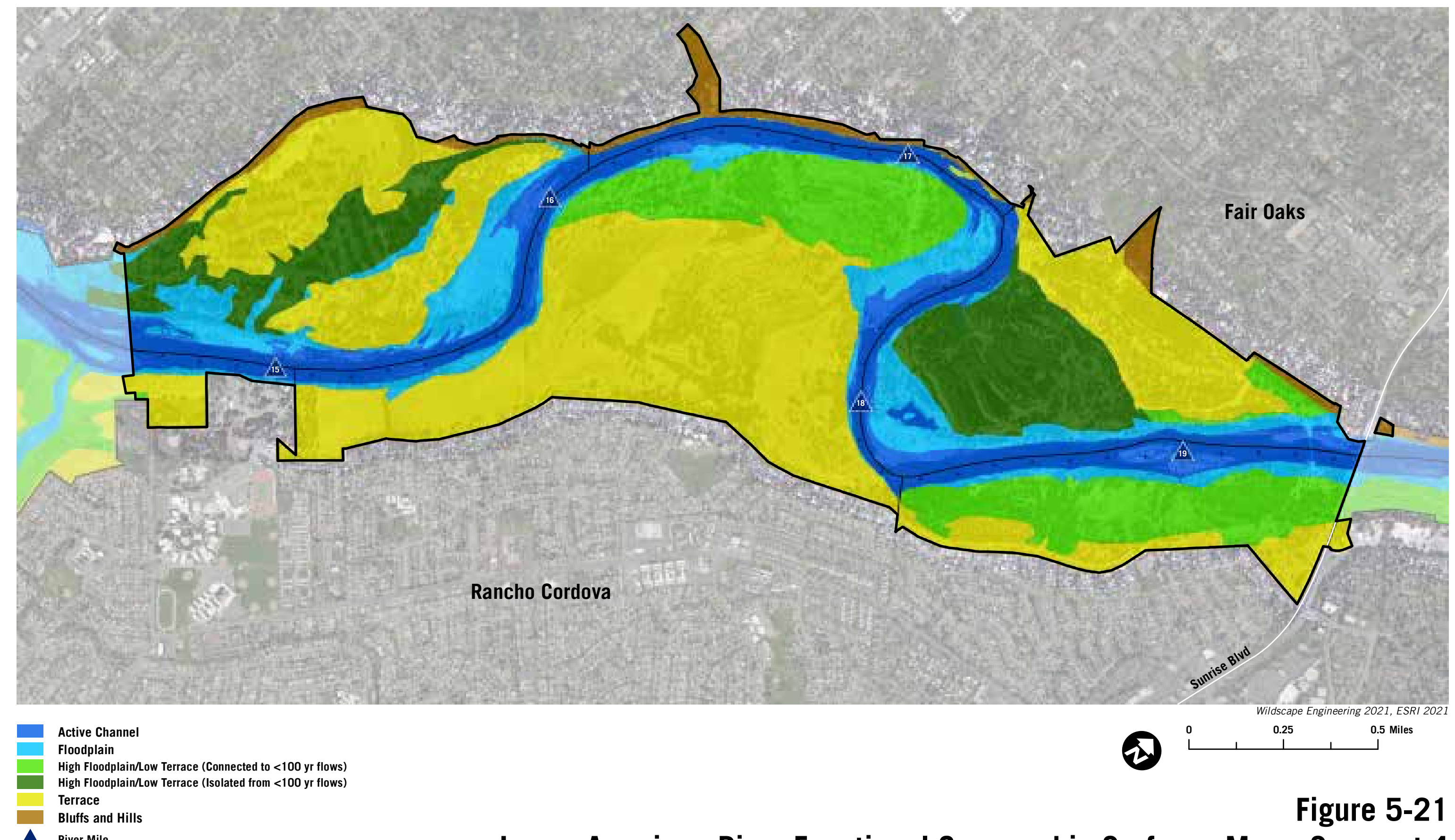


Figure 5-21
Lower American River Functional Geomorphic Surfaces Map - Segment 4

Figure 5-21 RM 14.5-19.5, Ancil Hoffman County Park, Rossmoor Bar, Sacramento Bar, Lower Sunrise

FIGURE 5-22 EXPOSED EROSION RESISTANT BANK TOE (~RM 15.3)

FIGURE 5-23 EROSION ALONG CLAY SHELF (~RM 16.7)

FIGURE 5-24 ACTIVELY ERODING BANK ALONG CLAY SHELF (~RM 17.8)

FIGURE 5-25 ROCK RIP-RAP PLACED AT CORDOVA CREEK OUTFALL (~RM 14.5)

INUNDATION AREAS: The low 2,000 cfs flow is contained within the main channel in the upper reaches through Parkway Segments 4 and 5 with more of the margins activated under the approximate 2-year, 20,500 cfs flow. Parkway Segments 3 and 4, particularly around the River Bend Park, Rossmoor Bar, and Sacramento Bar Areas, show more variability under the 115,000 cfs flow.

MOBILIZATION AND TRANSPORT: Relatively high shear stress was observed at the sharp bends between the Upper and Lower Sunrise Areas. Following the trend of net erosion in the upper reaches and moving towards deposition in the lower reaches, bedload sorting from Parkway Segment 5 through Parkway Segment 4 transitions from larger, coarser cobbles to smaller cobbles and gravels.

BED AND BANK TYPES: The channel bed in Parkway Segment 4 is holding grade due to the underlying Fair Oaks formation (Figure 5-22) and cobble size armoring, particularly in the upper portions. The hardened bed through this area applies increased pressure on the earthen banks during higher flow events, often causing accelerated erosion on sparsely vegetated or unprotected outer banks (Figure 5-23). While some well-vegetated banks with a small amount of woody material at the toe were observed in Parkway Segment 4, there is limited evidence of downed wood along the river margins, giving further evidence to a limited active floodplain and little to no natural channel migration (Figure 5-24).

BLUFFS: In the upper reach of Parkway Segment 4 and into Parkway Segment 5, the resistant Fair Oaks formation has been more fully exposed and there are a number of nearly vertical but relatively stable bluffs, often with a clay shelf forming along the toe. However, the cliff banks can be destabilized by activities from above, including loading the upper surface via irrigation or stormwater runoff, and from below via trail encroachment, road maintenance, or channel overflow events impinging on the face of the bank. These events could produce mass wasting due to slumps, slides or surface erosion that could threaten private property and cause a large sediment influx to the river, impacting water quality, fish spawning grounds, or other sensitive resources.

FUTURE TRENDS: With minimal upstream sediment and the impact of managed flow releases, Reaches 4 and 5 can expect further disconnection from surrounding surfaces, reducing the already small active floodplain, unless erosion-resistant geologic materials limit channel bed incision. A net discharge of sediment to downstream segments is forecast as the dominant trend. However, sediment delivery to the channel from streambanks and side slopes could increase locally as bed erosion occurs (increasing bank heights and instability). Whether such sediment could form sustained channel depositional features (e.g., riffles and bars) would depend on the volume, grain size distribution, and timing of sediment inputs relative to high flushing flows and vegetation establishment.

OUTFALLS: Stormwater and creek armored outfalls are interspersed throughout the Parkway segments, two of the larger tributaries between Nimbus Dam and the confluence with the Sacramento River, Cordova Creek (Figure 5-25) and Carmichael Creek outlet near the downstream end of Parkway Segment 4.

5.2.5 Parkway Segment 5

CHARACTERISTICS: Channel sinuosity 1.1, Channel slope 0.06 %, 30% Active Channel, 34% Floodplain, 12% High Floodplain/Low Terrace, 21% Terrace, 20% Bluffs and Hills (Figure 5-26)

RIVER CORRIDOR AND CHANNEL TOPOGRAPHY: As discussed earlier, the ancient geologic materials form lateral and sometimes vertical checks on these upstream non-leveed reaches. Several studies have examined the extent, elevation and location of these erosion-resistant materials including a study in 2007 that mapped the bedrock outcrops in Reaches 4 and 5 (Figure 5-27), noting more than ten along the channel bottom. Steep bluffs and high terraces continue to encompass the river through Parkway Segment 5 and impacts from hydraulic mining and urban development continue to be evident through this reach. The modern lateral constraints on river dynamics and overbank flow along the LAR corridor in the upstream half (Parkway Segments 3, 4, and 5) are formed by natural geologic materials and topography that is exaggerated by post-Folsom Dam channel bed lowering.

GEOMORPHIC FUNCTIONAL SURFACES: The channel is comparatively narrow and simple in Segments 4 and 5 while bluffs and hills compose a small, but important surface. Terrace(s) form the natural and modified surfaces that are generally above the 200-year inundation zone (160,000 cfs) under present conditions, although some terrace locations may have disturbed topography with isolated low spots. These broad uplands occupy approximately 40 percent of the Parkway in Segments 4 and 5. The floodplain area in Segments 5 is very narrow.

INUNDATION AREAS: The low 2,000 cfs flow is contained within the main channel in the upper reaches through Parkway Segments 4 and 5 with more of the margins activated under the approximate 2-year, 20,500 cfs flow.

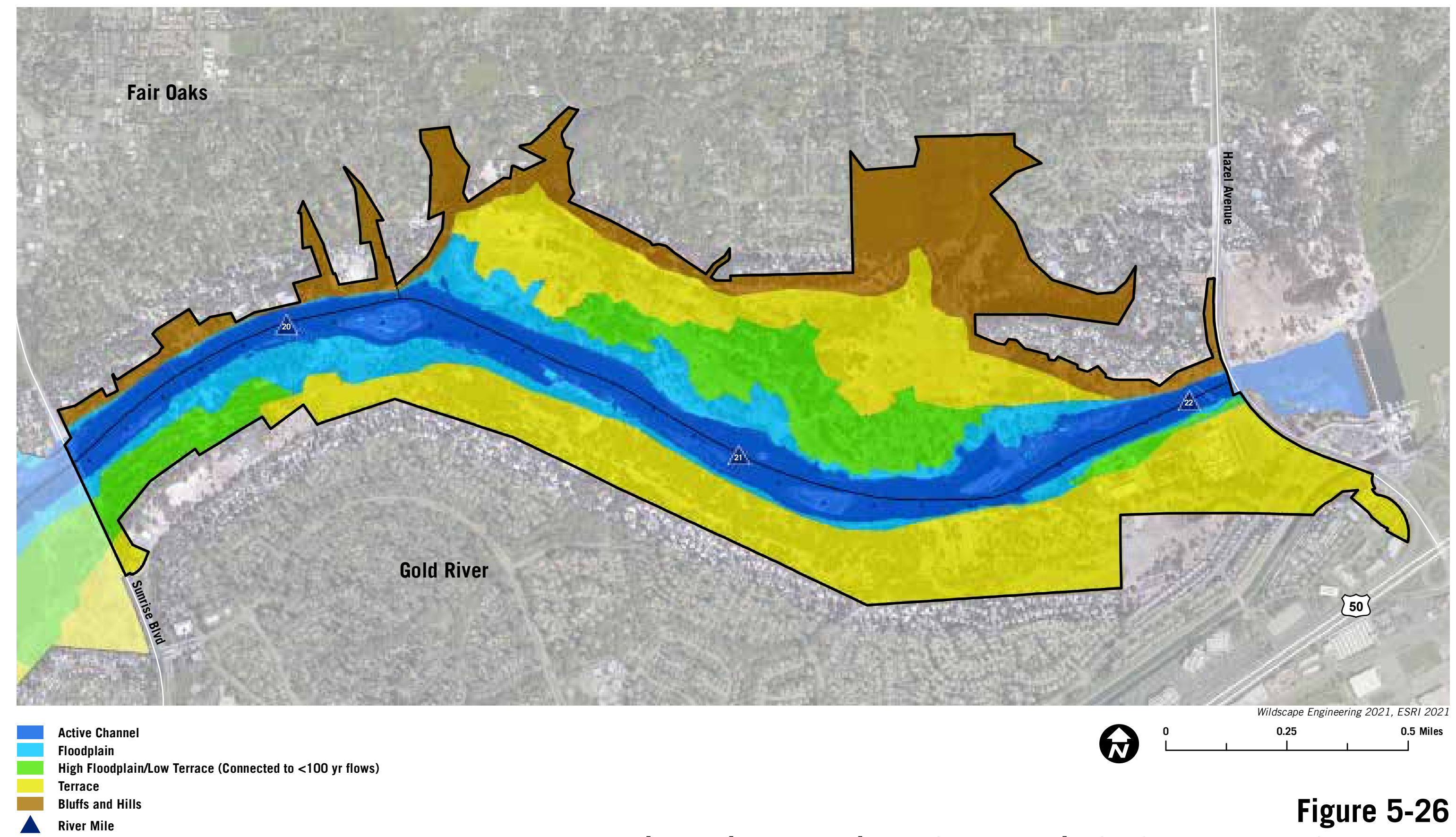


Figure 5-26
Lower American River Functional Geomorphic Surfaces Map - Segment 5

Figure 5-26 RM 19.5-22.1, Sailor Bar, Upper Sunrise

HYDRAULIC MINING: Slow-moving mid-channel bars thought to be sourced from the destabilizing hydraulic mining efforts appeared in the upper reaches between Sailor Bar and SARA Park post 1949 and likely induced short-term aggradation followed by bank scour setting up a feedback cycle of channel widening and aggradation (Watson 1985, Church and Jones 1982) in these reaches.

BLUFFS: In the upper reach of Parkway Segment 4 and into Parkway Segment 5, the resistant Fair Oaks formation has been more fully exposed and there are a number of nearly vertical, but relatively stable bluffs often with a clay shelf forming along the toe (Figure 5-28). The cliff banks can however be destabilized by activities from above, including

FIGURE 5-27 BEDROCK OUTCROPS ON UPPER LAR (FAIRMAN 2007)

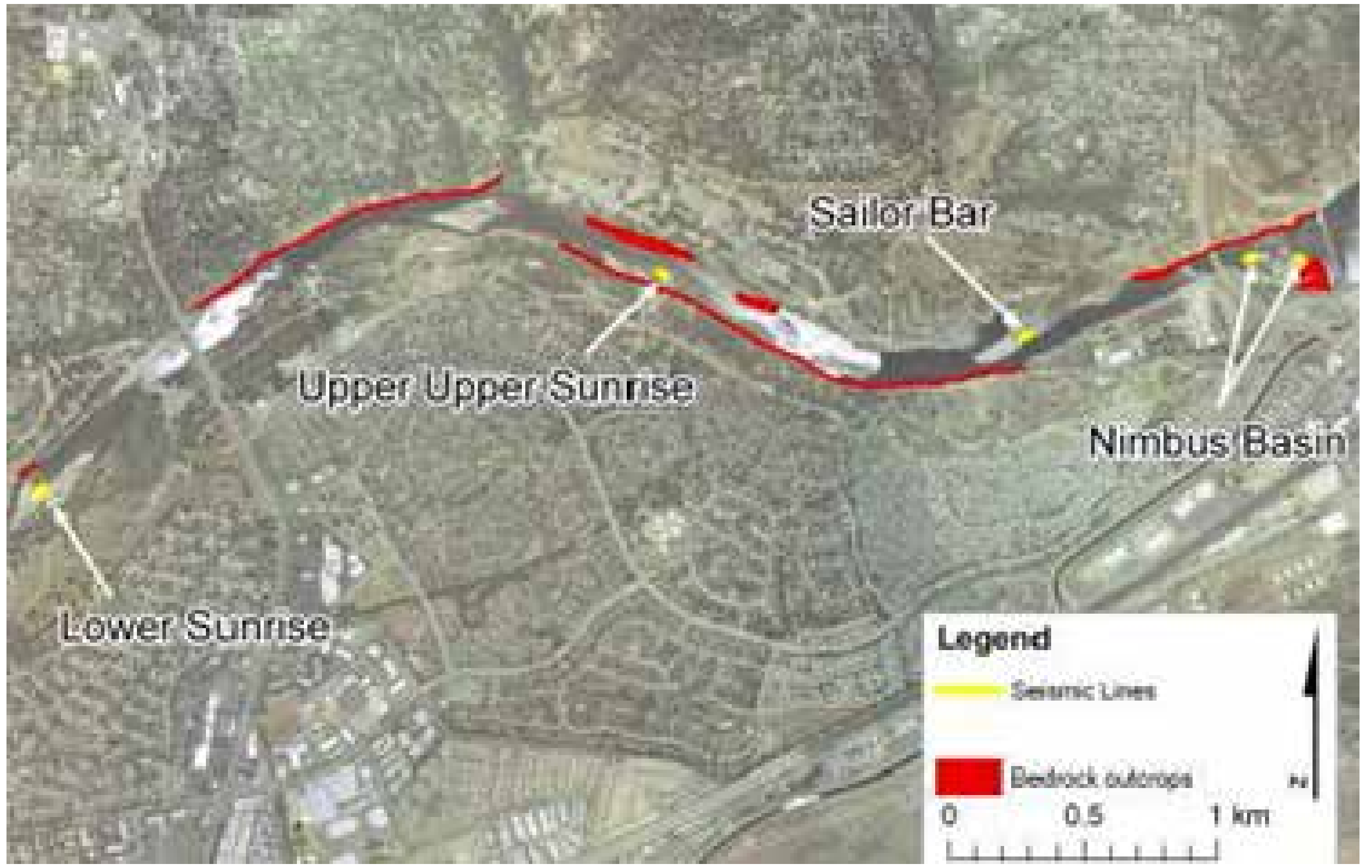


FIGURE 5-28 STEEP BLUFFS ALONG RIGHT BANK (~RM 19.4)

loading the upper surface via irrigation or stormwater runoff, and below from trail encroachment, road maintenance, or channel overflow events impinging on the face of the bank. These events could produce mass wasting via slumps, slides or surface erosion that could threaten private property and cause a large sediment influx to the river impacting water quality, fish spawning grounds or other sensitive resources.

OUTFALLS: Along with stormwater outfalls, one of the larger tributaries to LAR, Buffalo Creek outfalls in Parkway Segment 5 (Figure 5-29).

FUTURE LAR MORPHOLOGY TRENDS: Parkway Segments 4 and 5 are expected to experience channel slope decreases due to lack of sediment inputs and managed flow releases. Expected conditions will result in further disconnection from surrounding surfaces, reducing the already small active floodplain, unless erosion-resistant geologic materials limit channel bed incision. A net discharge of sediment to downstream segments is forecast as the dominant trend. However, sediment delivery to the channel from streambanks and side slopes could increase locally as bed erosion occurs (increasing bank heights and instability). Whether such sediment could form sustained channel depositional features (e.g., riffles and bars) would depend on the volume, grain size distribution, and timing of sediment inputs relative to high flushing flows and vegetation establishment.

FIGURE 5-29 BUFFALO CREEK OUTFALL (~RM 19.5)

5.3 SUMMARY OF PHYSICAL RESOURCE CHARACTERISTICS

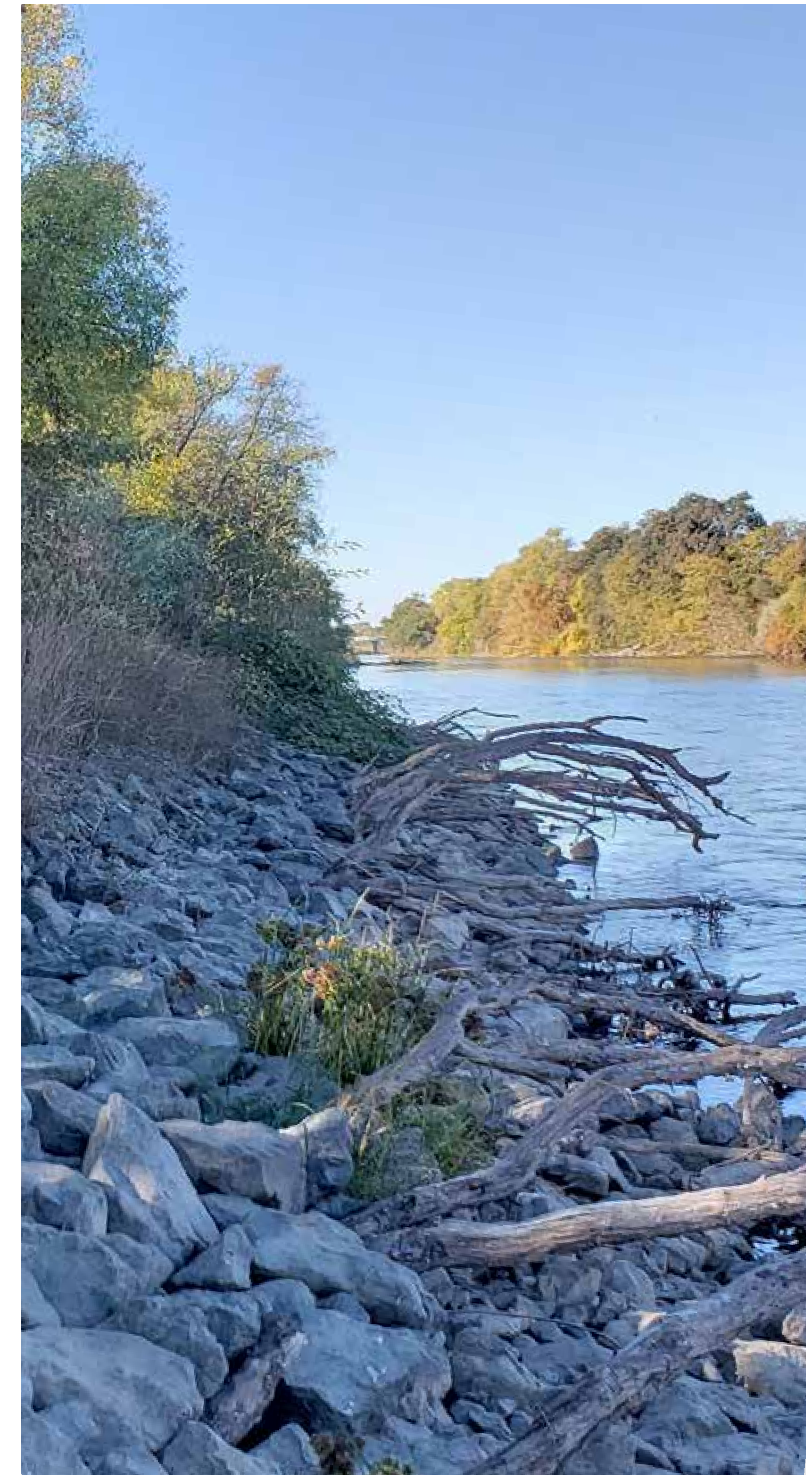
The current LAR geomorphic condition is a culmination of its pre-historic geologic formation, historic human impacts and ongoing dam and levee controls. In many ways these aspects limit the ability to achieve a balanced and more natural channel form and function. Such factors, along with changing climate and recreational access and use, need to be taken into consideration when evaluating proposed projects within the LAR riparian and floodplain margins.

The LAR condition is not consistent throughout the entire Parkway. From Parkway Segment 1 at the confluence with the Sacramento River upstream to Parkway Segment 5 just below Nimbus Dam, the river condition and behavior varies, most notably as follows from downstream to upstream:

GRADIENT: The streambed is essentially flat (0.02%) within Parkway Segment 1 near the confluence and gradually rises to its steepest gradient, 0.15% within Parkway Segment 3 then flattens some to a slope around 0.07% through Parkway Segments 4 and 5. The lowermost reaches are considered to be depositional reaches that are likely to continue to aggrade. While the upper reaches (Parkway Segments 3 through 5) are in an erosional state, however they continue to hold grade due to the underlying older and erosion resistant geologic formations resulting in more outward forces on the banks.

CHANNEL BED SUBSTRATE: Flatter gradient and slower moving waters have produced a channel bottom primarily composed of fine sediments and sands in Parkway Segment 1 and most of Parkway Segment 2. Gravel and smaller cobbles are found on the channel bed and in channel bars within Parkway Segment 3 and the materials continue to increase in size moving up through Parkway Segments 4 and 5.

CHANNEL PLANFORM: Laterally constrained by flood control levees, Parkway Segments 1 and 2 have the greatest proportion of active channel to floodplain than the Parkway as a whole and little floodplain variability. In other words, larger floods are predominantly conveyed within the main channel rather than overbanking and spreading onto floodplain areas beyond the channel. Parkway Segment 3 has the highest sinuosity, 1.4, of all the Parkway segments, the steepest gradient and consequently higher energy. In addition, it has a variety of channel and floodplain features including backwaters, alcoves, mid-channel bars, and disconnected low flow threads. In Parkway Segments 4 and 5 the channel returns to a narrower, simpler planform with high terraces and bluffs. The relative absence of channel migration and floodplain connectivity reach wide as a result of geologic and human imposed controls significantly reduces planform variability and more importantly overbanking opportunities that in turn limits riparian vegetation development and perpetuation, particularly in the overbank areas.



Revetment and riparian plantings along riverbank.
Photo Credit: KC Sorgen

BANKS: Parkway Segments 1 and 2 are characterized by earthen side slopes with varying densities of native and non-native vegetation. The younger and less resistant Modesto formation occurs more frequently in Parkway Segments 1 and 2, sometimes holding the banks and sometimes giving way to erosion. The terrace features, in addition to active channel and floodplain features, first appear in Parkway Segment 3 and a variety of bank types emerge, including exposed bare ground and alluvial deposits intermingled with undisturbed, vegetated banks. Parkway Segment 3 also includes the more resistant Fair Oaks formation exposed along some bank margins, while remnants of hydraulic mining, such as cobble spoil piles, are scattered in places. The less prominent but characteristic high Terrace/Bluff features are only present in Parkway Segments 4 and 5. Also visible in Segments 4 and 5 are the Fair Oaks formation and cobble armoring on the channel bed which redirect the flow forces outward and cause accelerated erosion and bank retreat where there are sparsely vegetated or unprotected earthen banks.

Project Opportunities and Limitations of the LAR:

LEVEES: Levee controls will continue to persist in the Parkway but limiting the extent of floodplain restoration or overbank relief that can be achieved. This does not mean that localized inset floodplain or similar opportunities cannot be considered within the corridor held by the levees.

DAM CONTROL: Flow regulation is necessary to minimize flood risk to heavily populated areas and infrastructure and maintain base flows for salmonids and other aquatic species in the LAR. Understanding the operational flows and how they translate into inundation areas, velocities, and shears by location will be key to designing restoration elements such as: increased floodplain (where achievable), enhanced riparian zones, target elevations and saturation conditions for native plant species, sizes and configurations for stable and effective bank protection measures and instream habitat enhancement structures.

ACTIVATED FLOODPLAIN CHARACTERISTICS: The LAR has little in common with a meandering channel system as it is fixed within the naturally and artificially hardened banks and its flow regime variability is drastically reduced with lesser extreme but more high flow events and consistently higher volume late season flows. This makes it difficult to introduce meanders to increase planform variability and sinuosity or promote floodplain overbank opportunities that will have persistent high-value riparian vegetation and woody debris throughout the Parkway. However, there may still be site specific, localized opportunities to integrate some of these channel features, particularly as extensions of existing features, such as those in Parkway 3.

HYDRODYNAMIC MODEL: The inundation extents, velocities and shears within the Parkway boundaries produced by the model should be taken into consideration when planning recreation, geomorphic or habitat improvements within the river corridor. These data may be key to determining location, configuration or composition of certain facilities based on where inundation areas intersect and to what degree of energy they impose. This data can also be useful to park planners highlighting where velocities are higher or lower and where sediments, gravels or cobbles may move or deposit impacting the long-term functionality of in-channel features such as boat ramps, outfall armoring, and proposed biotechnical features.

TOP *High water at the Jibboom Bridge in the Discovery Park Area in 2006. Photo Credit: Regional Parks*
BOTTOM *Boat launch in the Howe Avenue Area following June 2017 flood. Photo Credit: Regional Parks*

Revetment and riparian plantings along riverbank. Photo Credit: KC Sorgen

RECREATIONAL TRAILS: There are ample opportunities to address redundant and heavily compacted social trails, particularly in the high use Parkway areas. New or upgraded trail designs should look at the hydraulic model inundation extents and shear results by location to make sure any new or preserved trails will not be impacted or pose a safety hazard by fast moving high waters. Surface treatments could be integrated in low risk, floodplain areas to stabilize the trails in the event they are inundated.

RECREATIONAL INFRASTRUCTURE: New or improved boat ramps, piers, and similar park infrastructure should consider the current and trending channel condition in the respective Parkway Segment. Parkway facilities and recreational access often coincide with the artificially lowered banks due to their accessibility to the river, such as the boat ramp southwest of Watt Avenue Bridge. In some cases, Parkway infrastructure may become compromised as the slow-moving water in widened reaches drops material out of suspension and fills the channel. Monitoring of this location may be warranted in order to plan for when boat access may soon become infeasible or require a suite of permits to dredge and remove deposited material as the river becomes too shallow in the vicinity of the boat ramp. If and when new or updated river access infrastructure is planned for, both the inundation extents and velocities as predicted by the hydrodynamic model and sediment transport potential should be considered so as not to install infrastructure that could become inadequate or in-operational over time.

AQUATIC HABITAT IMPROVEMENTS: When considering enhancement projects in urban, high-use areas it is important to consider the cost, long-term ecological benefit, and potential recreational implications of the projects. Secondarily, when gravel augmentation projects are proposed, Regional Parks should consider if there is potential for any imported material to migrate downstream and if so, the distance and resulting potential impacts to any sensitive or restored habitat or recreational infrastructure.

OUTFALLS: An inventory of all existing outfalls within the Parkway is recommended as a first step to properly inform and prioritize improvement efforts. The inventory should include outfall type, size, and condition and include photo documentation and GPS mapped locations. Following the inventory, a set of potential projects could be developed to rectify problems, improve outfall condition, and mitigate any impacts to the tributaries and where they outlet to the LAR. Outfalls that present the greatest risk for the most widespread adverse impact on LAR natural resources should be prioritized.

ERODING BANKS: Parkway Segment 4 exhibits a continuation of bank toes hardened with gravel surfaces or exposed erosion-resistant material interspersed between the heavily vegetated banks. Some banks within this segment show signs of erosion and are retreating to areas where banks have been fortified. The channel bed in Parkway Segment 4 is holding grade due to the underlying Fair Oaks formation and cobble size armoring, particularly in the upper portions. The hardened bed through this area applies increased pressure on the banks resulting in erosional areas where the banks are most vulnerable. These banks should be flagged for monitoring and changes recorded.