American River Common Features 2016 Flood Risk Management Project, Sacramento, California

Supplemental Environmental Impact Statement/ Subsequent Environmental Impact Report XIV

Appendix G: Engineering

U.S. Army Corps of Engineers
Sacramento District

Central Valley Flood Protection Board

Sacramento Area Flood Control Agency

January 2025

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U.S. Army Corps of Engineers
Sacramento District
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LIST OF ACRONYMS

Acronym	Definition
ACE	Annual Chance Exceedance
AEP	Annual Exceedance Probability
AOP	Annual Overtopping Probability
ARCF16	American River Common Features 2016
ARMs	American River Mitigation Site
ARPP	American River Parkway Plan
BO	Biological Opinion
CVHS	Central Valley Hydrology Study
cfs	Cubic Feet Per Second
DBH	Diameter at Breast Height
DWR	Department Of Water Resources
EOE	Expert Opinion Elicitation
ER	Engineering Regulation
FDA	Flood Damage Reduction Analysis
FRM	Flood Risk Management
Grr	General Reevaluation Report
HEC	Hydrologic Engineering Center
IWM	Instream-Woody Material
JFP	Joint Federal Project
lar	Lower American River
LDB	Left Descending Bank
LiDAR	Light Detection and Ranging
LMA	Local Maintaining Agency
MCP	Magpie Creek Project
NAVD	North American Vertical Datum
NGVD	National Geodetic Vertical Datum
MNFS	National Marine Fisheries Service
NPS	National Park Service
OMRR&R	Operations, Maintenance, Repair, Replacement, And Rehabilitation
PDT	Project Delivery Team
PFM	Probable Failure Mode
RM	River Mileage
RTK-GPS	Real-Time Kinematic Global Positioning System

Acronym	Definition
Seir	Supplemental Environmental Impact Report
SEIS	Supplemental Environmental Impact Statement
SPT	Standard Penetration Test
SRFCP	Sacramento River Flood Control Project
SRMS	Sacramento River Mitigation Site
TRAC	Technical Resource Advisory Committee
TOC	Top of Conservation
UNET	Unsteady NETwork Hydraulic Model Program
USFWS	United States Fish and Wildlife Service
USGS	United States Geologic Survey
VDD	Vegetation Design Deviation
WRDA	Water Resources Development Act
WRSA	Wild And Scenic Rivers Act

1 INTRODUCTION

1.1 Overview

This engineering appendix provides a summary of engineering investigations, analyses, and design efforts completed to-date to support project components of the American River Common Features 2016 (ARCF16) Project analyzed in this Supplemental Environmental Impact Statement/Subsequent Environmental Impact Report (SEIS/SEIR). The SEIS/SEIR is a supplement to the original 2016 ARCF General Re-evaluation Report Final EIS/EIR (2016 ARCF GRR FEIS/EIR).

The ARCF16 Project was originally authorized by Section 101(a)(1)(A) of the Water Resources Development Act (WRDA) 1996, Pub. L. No. 104-303 § 101(a) (1), as amended by Section 366 of WRDA of 1999, Pub. L. No. 106-53, § 366. Additional authority was provided following the interim general reevaluation study in Section 1322(b) of WRDA 2016, Pub. L. No. 114-322 § 1322.

The SEIS/SEIR analyzes design refinements to the authorized Project, including engineering design modifications, footprint expansions, and compensatory habitat mitigation approaches. The design refinements include actions within eight major project components: American River Erosion Contracts 3B, 4A, and 4B; Sacramento River Erosion Contract 3; Magpie Creek Project (MCP), American River Mitigation Site (ARMS); Sacramento River Mitigation Site (SRMS), and installation of a Piezometer Network.

Although the SEIS/SEIR analyzes all the above project features, this appendix will focus on describing and detailing the analyses and efforts specific to the planned erosion protection along both the Lower American River (LAR)[1] and Sacramento River, and the piezometer network proposed to be installed throughout the entirety of the ARCF16 project footprint. The LAR and Sacramento River erosion contracts are described and evaluated at a project-level of detail, except for LAR Contract 4B. LAR Contract 4B and the piezometer network are described and analyzed at a programmatic level of detail because the selected sites for these actions are still early in the planning phase and substantial information is not currently available to accurately describe impacts at a project level of analysis. The engineering analyses required to support the design and construction of these projects varies by project type, project setting, and available existing information and new information acquired during design development. The following sections summarize the engineering analyses developed based on project type and location. These sections include a summary of key sources of information used in the design as well as new studies completed as part of the design process.

1.2 Report Organization

Section 1 of this report provides a summary of information that is consistent between the erosion protection efforts on the Sacramento River and LAR. Section 2 provides a summary of erosion protection efforts on the LAR including additional design criteria to comply with the Wild and Scenic Rivers Act

[1] The Lower American River is the reach of the American River located downstream of Nimbus Dam (River Miles 0-23).

(WSRA), a summary of data used in the site selection and design process, and a review of current designs. Section 3 provides a similar summary of erosion protection efforts on the Sacramento River. Section 4 provides a description of the Piezometer network, while Section 5 includes all references referred to in this appendix.

1.3 ARCF16 Project Background

The Sacramento metropolitan area is one of the most at risk areas for flooding in the United States. There is a high probability that flows in either the American or Sacramento Rivers will stress the network of federal levees protecting the study area to the point that levees could fail. The consequences of such a levee failure would be catastrophic because the inundated area is highly urbanized, and the flooding could be up to 20 feet deep. This section describes the problems addressed by the GRR to reduce flood risk in the Sacramento metropolitan area. The following sections include a description of the flood risk in terms of the probability of flooding and the resulting consequences.

The Sacramento metropolitan area has a high probability of flooding because of its location within the floodplain at the confluence of two major rivers: the Sacramento and Lower American Rivers. Both rivers have large watersheds with very high potential runoff that has overwhelmed the existing flood management system in the past. The existing federal levee system was designed and built many years ago, before modern construction methods were employed. These levees were constructed close to the river to increase velocities in order to flush out hydraulic mining debris. This mining debris has mostly been flushed out of the main river channel by floods over the past several decades, but it remains present in much of the overbank areas of LAR. The high velocities experienced during flood flows easily erode into this mining debris and can quickly put the levee at risk of failure.

1.4 Flood Risk Management System History

Evaluations of storms and floods of record indicate that critical flood-producing conditions in the project area will likely occur during the winter season when there is a wet snowpack and a prolonged series of general storms occurring over the entire basin. Usually, storm precipitation amounts are distributed in the same general pattern as normal annual precipitation amounts. However, major departures from this pattern do occur. Generally, a storm series will last from 2 to 5 days; however, some series have been longer (the 1986 storm lasted 10 days). During such periods, groundwater levels rise, infiltration capacities decline, and the natural and artificial storage within the basin is progressively filled.

Flood flows in the American River basin are rather frequent and of two general types: winter rain-on-snow floods and spring snowmelt floods. Historically, only flood flows resulting from intense winter rainfall over the foothills and mountains have caused serious flooding. Outside the winter season, storms are less severe, cover smaller portions of the basin at a time, and are so widely separated in time that existing basin flood control facilities are usually easily capable of controlling the runoff.

Prior to the construction of levees, the Sacramento River annually would overflow its banks flooding the primarily riparian and wetland habitats of the valley. After levee construction began under the Sacramento Flood Control Project (SRFCP), flows were confined to the river in most areas. Before the bypass system was constructed, levee failures occurred frequently, flooding the previously “reclaimed” areas. After completion of the SRFCP system, which included the bypasses, levee failures still occurred, but only on the more severe flood events.

The SRFCP was designed to pass the known flood of record, which at the time of Congressional authorization, was the 1909 flood. During construction of the system, a new flood of record for a portion of the system occurred in 1927, which was incorporated into the overall system design. After completion of the Federal system in the 1950s, a new flood of record occurred in 1986, followed by the slightly smaller flood of January 1997. The flood of 1986 delivered more water to the leveed reaches than they were designed to carry. On the American River, the four biggest floods occurred after completion of Folsom Dam and the SRFCP. In general, throughout the Sacramento Valley, climatology following the completion of the Federal system has been much wetter with more precipitation than the period that the original design of the system was based upon, and more flow is being delivered to the levee system than it was intended to safely carry.

1.4.1 Past Flood Events

Newspaper accounts and anecdotal evidence mention at least nine major floods prior to 1900, which prompted the construction of spoil bank levees, or non-engineered levees constructed by whatever material was readily available in the immediate vicinity of the construction, across the floodplain. The modern flood control system originated with the Sacramento River Flood Control Project (SRFCP) levees authorized in 1917, the Central Valley Project (including Shasta Dam), the completion of Folsom Dam in 1956, and the completion of Oroville Dam in 1967. In the time since Folsom Dam began operations, large floods on LAR have occurred in 1955, 1964, 1969, 1970, 1982, 1986, 1997, 2006 and 2017. The 1986 flood is the flood of record since the LAR federal levees were completed to their current extents in 1957. Prior to the completion of the LAR federal levees and Folsom Dam, larger floods did pass through the system (e.g., 1951 flood saw 180,000 cfs pass through LAR) since there was no dam on the American River[2] regulating the volume of flood waters on LAR. In these large flood events prior to Folsom Dam construction and the LAR federal levees being fully completed, the flood waters were able to expand further onto the historic floodplains, which reduced flood volumes, river stages, and velocities in the main river channel, and thus there was a lower erosion risk to the communities near the American River than under current conditions. However, the Sacramento area communities were frequently subjected to flooding, prior to the completion of the federal levee system. The federal levee system and dam construction reduced the frequency of flooding, but considering the current levee alignments, which have significantly constrained the rivers and eliminated the ability for flood volumes to spread out over a larger floodplain, has concentrated erosive forces on the river banks and levees, putting the levees at a higher risk of erosion induced failure.

1.4.1.1 February 1986 Flood

In February 1986, a series of storms led to severe flooding in central and northern California. In many areas, precipitation from this 10-day storm delivered more than half of the normal annual precipitation

[2] Use of the term "American River" in this report without the term "Lower" preceding it refers to the American River as whole, both upstream and downstream of Nimbus Dam.

for the area. The Sacramento River flood control system was overloaded and one reservoir in the system (Folsom Dam) was filled beyond its design capacity. Record flow releases from the reservoirs combined with flow from numerous unregulated tributaries to the Sacramento Valley produced river flows that exceeded the design capacity of downstream levees: water encroached into the design freeboard risking overtopping levees throughout the system including those protecting Sacramento. The timely cessation of the storm event prevented overtopping of the American River levees. At the runoff peak, approximately 134,000 cfs was released from Folsom Dam with a combined estimated flow greater than 600,000 cfs passing the Sacramento metropolitan area through the Sacramento River and Yolo Bypass out toward the Sacramento Delta.

Emergency levee work and flood fighting prevented catastrophic flooding. The extended high water caused boils, slips, sloughing, seepage, flood flow erosion, and wave erosion that required emergency work to minimize or prevent further damage during the flood. Several levees upstream from Sacramento failed during this flood. At the conclusion of the storm, the Governor declared emergencies in 39 counties, with damages totaling more than $500 million. Sacramento County had damages estimated at $49 million (1986 dollars): ~$140 million in 2024 dollars.

1.4.1.2 January 1997 Flood

In mid- to late-December 1996, heavy snow fell in the Sierra Nevada Mountains. This was followed by heavy precipitation on the western slope of the mountains. The rain began to fall on December 26, and from December 31 to January 3, an atmospheric river (locally known as a “Pineapple Express”) brought approximately 30 inches of rain on the western slopes of the Sierra Nevada, in the process dumping more than half a year’s worth of rain on Northern California in 10 days. In addition to the local rainfall, 50°F temperatures and rain in the Sierra Nevada melted the snowpack below 6,000 feet. The combination of record snowfall and record rain resulted in high stream flows around Sacramento. The Sacramento River peaked within half a foot of the 1986 record level. During the 1997 flood event, LAR experienced a peak flow of 117,000 cfs and the Sacramento River experienced a peak flow of 115,000 cfs. Upstream from Sacramento, outside of the study area, levees on the Feather River at Olivehurst and on the Sutter Bypass breached.

1.5 Definitions and Nomenclature

The levees and banks are referred to as *left* and *right* based on an observer looking downstream along the river. On LAR, the *right* bank or levee is also commonly referred to as the *north* levee, while the *left* bank or levee is commonly referred to as the *south* levee. On the Sacramento River, the *left* levee is commonly referred to as the *East* levee. Figure 1-1 shows the terms used to describe the various components of the levee, overbank bench (also referred as just ‘overbank’ or bench’), and riverbank (or just ‘bank’) along a typical cross section of the river. *Scour* refers to the lowering of the bed surface by erosive forces, while *erosion* refers to the detachment, entrainment, and transport of bank and levee material.

Overbank bench widths are quantified; however, are referred to qualitatively as “*narrow”* and “*wide”* throughout the document. *Narrow* overbank benches are typically those where the levee template is less than 100 feet from bank toe. *Wide* overbank benches generally refer to locations where the levee template is more than 100 feet from the bank toe.

Levee Template refers to the downward projected levee embankment slopes. When erosion encroaches upon the levee template, there is a higher risk of slope instabilities, which can lead to mass slope failure of the overbank and levee embankment.

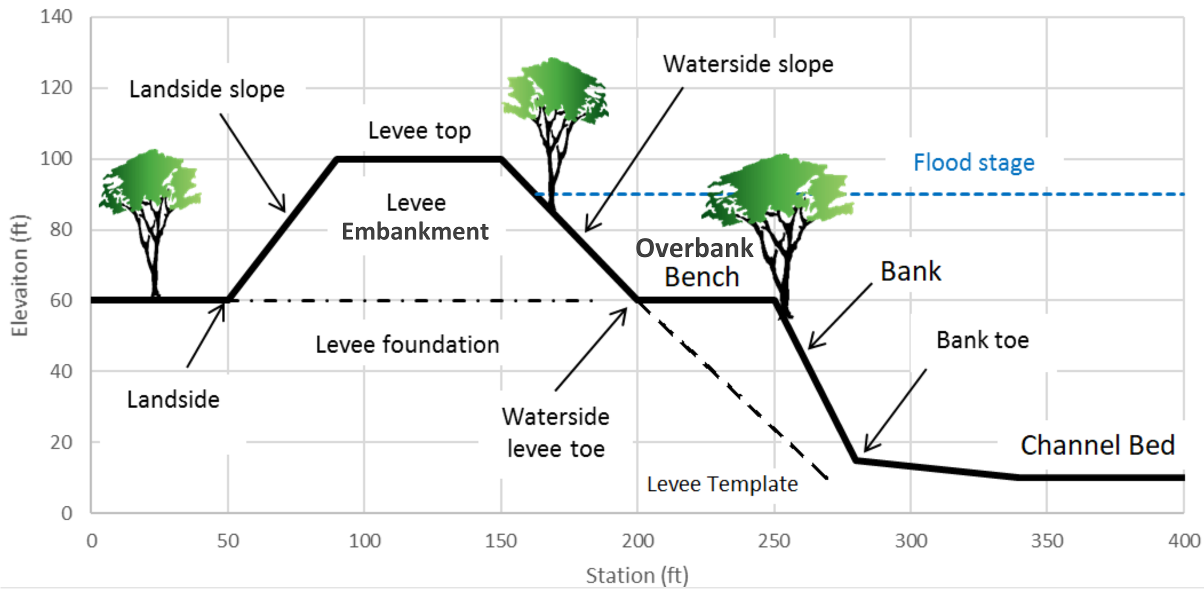


Figure 1-1. Nomenclature for banks and levees.

The analyses used to identify the proposed sites discussed in this document delineated the right and left backlines into river segments. *River Segments* (also referred as just Segments) refer to continuous sections of left or right riverbanks and overbank benches with similar hydraulic conditions, revetment designs, vegetation, as well as riverbank, overbank bench, and levee geometry. Each segment was evaluated for the need for erosion protection and conceptual designs. Adjacent segments that were recommended for erosion protection design that will require common haul routes, staging areas, and design transitions were combined to form design *Sites. Sites* are design or project locations that represent one or more continuous segments that are intended to be designed under a single set of design documents (plans and specifications) and construction contracts. While segments were used to evaluate potential for erosion during the erosion analyses and risk assessment, *Sites* refer to locations where erosion protection is required to address. Sites can include all or parts of individual segments and include adjustments in length for transitioning designs to existing Bankline and/or adjacent revetment designs. The layout of Sites is therefore not always consistent with the extents of segments used in the analysis. Design Sites were further combined into *Contracts,* which were assigned to specific Project Delivery Teams (PDT) within USACE to advance designs to construction.

All elevations referenced in the text are relative to the North American Vertical Datum of 1988 (NAVD88). Data referenced from older reports using the National Geodetic Vertical Datum (NGVD29) were converted to NAVD88 by adding 2.3 feet (NHC, 2013).

1.5.1 Risk and Risk Reduction

Risk is determined by evaluating the probability of a given event occurring in comparison to the consequences caused by that event. Consequences are determined by evaluating economic impacts, life loss, and other factors. High probability storm events that are high consequences are often classified as high risk, and low probability storm events that cause low consequences are generally classified as low risk. Risk Assessments are a process by which these risks are identified and quantified. For the ARCF16 Project, the risks identified pertain specifically to probability of a levee failure occurring and the consequences of a levee failure on the surrounding structures and inhabitants protected by the levee. Along LAR and the Sacramento River, within the ARCF16 Project extents, the consequences of a levee breach would be catastrophic. The flooding would rapidly inundate a highly urbanized area with minimal warning or evacuation time, and these flood waters would be cold, which decreases survivability. The population at risk is upwards of 500,000 people and over 140,000 structures.

The objective of risk reduction efforts is to reduce the likelihood of an identified risk being realized, in a manner which is commensurate with the consequences and is economically and socially acceptable. For the ARCF16 Project, the risk reduction objective is to reduce the likelihood of a levee failure due to overtopping, seepage, stability, and erosion risks. For the content covered in this Engineering Appendix, the specific risks evaluated pertain to erosion induced levee failures. Please refer to Section 1.6 for more information on these identified erosion risks.

1.5.2 Erosion Protection Features

The four key erosion protection features proposed for placement along LAR and the Sacramento River, all forms of rock revetment, are bank protection, launchable trench, launchable (rock) toe, and tiebacks. The definitions and typical applications for each of those four features are provided Table 1-1.

Table 1-1. Types of Erosion Protection Features

Name	Definition	Types seen
Bank Protection	Revetment placed on riverbank or levee embankment/slope.	Soil-filled revetment: Includes soil between and above revetment to establish vegetation on the surface. Soil-filled levee embankment revetment: soil filled revetment placed on the levee embankment. Soil filled riverbank revetment: placed on or near the riverbank. Bank protection without soil fill is typically seen in areas where construction of soil filled revetment would not be feasible, such as in the water.
Launchable Trench	Revetment buried underground that launches to provide flood protection during flood condition where erosion occurs.	Buried, near the levee embankment toe. Buried, on the river overbank typically above the typical wetted channel.

Name	Definition	Types seen
Launchable (Rock) Toe	Revetment placed at waterward face of planting bench or along riverbank that launches when riverbank erodes away during flood conditions.	Launchable toe with planting bench- Placed at the waterward face of a planting bench. Launchable toe- Placed along the riverbank near the riverbank toe. When at riverbank toe, can be included with or without a planting bench.
Tiebacks	Revetment placed perpendicular to the river that impedes erosion from progressing.	Tie-back features are typically incorporated element with erosion features listed above as necessary to meet flood risk measures. Buried Rock Tieback- Placed on its own and installed under the ground. Planting Bench Rock Tie Backs- Placed within planting benches and spaced intermittently.

1.5.3 Design Service Life

The design service life for the improvements implemented as a part of the ARCF16 Project and described in this Engineering Appendix is 50-years. Design service life is the length of time a project will remain in use to provide its intended function. After the design service life expires it is expected the features will require repair or rehabilitation. The 50-year design service life is based on the life cycle established within the 2016 GRR feasibility report.

1.6 Levee Erosion Failure Processes

Levees can fail due to overtopping, erosion, seepage, and under-seepage. The mechanisms by which failure can occur are identified as probable failure modes (PFM's) and developed as part of USACE's risk assessment process. The ARCF16 Project's proposed erosion protection improvement addresses the risk to levee failure due to erosion. On LAR, seepage PFMs were addressed via previous authorizations over the past 25-years; on the Sacramento River, seepage PFMs are being addressed under the ARCF16 Project authorization but are not subject to the scope and content of the SEIS/SEIR and this appendix. "Erosion" in this document refers to the interactive processes causing lateral bank retreat. These processes can include fluvial erosion and soil destabilization. Fluvial erosion refers to dislodgement and removal of soil material by the hydraulic forces exerted by flowing water and/or waves. Soil destabilization has many names, including slope instability, slope stability failure, or mass slope failure. Fluvial erosion can lead to steepening of the riverbank, leading to soil destabilization. Therefore, both fluvial erosion and soil destabilization contribute to the overall erosion process.

Table 1-2 provides a description of several types of fluvial bank erosion mechanisms adapted from the USACE channel rehabilitation manual (U.S. Army Corps of Engineers, 1999).

Table 1-2. Description of fluvial bank erosion processes

Fluvial Process	Typical Conditions or Evidence of Erosion
Parallel flow	Observation of high flow velocities close to the bank; near bank scouring of the bed; under-cutting of the toe/lower bank relative to the bank top; a fresh ragged appearance to the bank face; absence of bank vegetation.
Impinging flow	Observation of high flow velocities approaching the bank at an acute angle; bars directing flow toward the bank; tight meander bends; strong eddying adjacent to the bank; near-bank scouring of the bed; under-cutting of the lower bank; ragged appearance to the face; absence of vegetation.
Scour	Local riverbed lowering near the bank and/or levee toe due to local scour processes or channel incision. Scour may cause translational sliding of the upper bank, particularly when revetment has been placed, leaving scars on the bank. Local bed scour occurs around obstructions and scour holes are often visible where flow dives over or around spurs, intakes, or other bank features.
Wind-generated waves	Large channel width or long, straight channel with an acute angle between eroding bank and long stream direction; a wave-cut notch just above normal lower water plane; a wave-cut platform or run-up beach around normal low-water plane.
Vessel-generated waves	Use of river for navigation; large vessels moving close to the bank; high speeds and observation of significant vessel-induced waves and surges; a wave-cut notch just above the normal low-water plane; a wave-cut platform or “spending” beach around normal low-water plane.

Table 1-3 provides descriptions of soil destabilization adapted from the USACE channel rehabilitation manual (U.S. Army Corps of Engineers, 1999).

Table 1-3. Description of soil destabilization

Failure Process	Typical Conditions or Evidence of Failure
Rotational Slips	Banks formed in cohesive soils; high, but not especially steep banks; deep seated, curved failure scars; back-tilting of the top of failure blocks toward intact banks; arcuate shape to intact bank line behind failure mass; tension cracks or openings in soil behind mass.
Planar Slips	Weakly cohesive bank materials; thin slide layers relative to their area; planar failure surface; no rotation or toppling of failure mass; ragged edge at detachment point.
Cantilever failure	Composite or layered bank stratigraphy; cohesive layer underlain by less resistant layer; under-mining; overhanging bank blocks; failed blocks on the lower bank and at the toe.
Slab type block failures	Cohesive bank materials; steep bank angles; deep seated failure surface with a planar lower slope and nearly vertical upper slope; deep tension cracks behind the bank-line; forward tilting failure mass into channel; planar shape to intact bank-line behind failure mass.
Piping failures	Pronounced seep lines, especially along sand layers or lenses in the bank as indicated by vegetation; pipe shaped cavities in the bank; notches in the bank associated with seepage zones; run-out deposits of eroded material on the lower bank.

For the purposes of this report, levee overtopping is identified as PFM 1. When evaluating the risk posed by other PFMs (such as erosion and seepage), they are all evaluated in comparison to PFM 1. The rationale behind this is that there should be a high degree of certainty that the levees will not fail prior to them being overtopped (i.e., levee breach prior to overtopping). Essentially, the risk reduction objective when addressing PFMs for a levee breach prior to overtopping is to ensure that the probability of a levee breach occurring prior to the levee being overtopped is significantly lower than the probability of the levee being overtopped. Also, the measures implemented to address PFMs for breach prior to overtopping must not increase the probability of the levee being overtopped.

Fluvial erosion risks are captured by PFM 2 and PFM 3, which are defined below:

> **PFM 2:** Erosion of the levee leading to a levee breach. If the velocity and duration of flows are higher than the predicted resistance of the soils and vegetation, then erosion of the levee is expected. Erosion can narrow the width of the levee until a breach occurs. The total width of levee lost can be predicted based on soil type, applied hydraulic force, and flood duration.
>
> **PFM 3:** Erosion of the levee foundation (typically from bank erosion at the bank or bank toe) resulting in soil destabilization affecting the levee. If the velocity and duration of flows are higher than the predicted resistance of the soils and vegetation, then erosion of the levee foundation is expected. Erosion of the levee foundation generally occurs at the riverbank toe where fluvial forces are highest. During long duration floods, this riverbank toe erosion can progress closer to, and eventually into/below, the levee embankment, which can ultimately lead to failure of the levee. PFM 3 erosion doesn't need erode into/below the levee embankment to induce a failure, either; in instances where the erosion progresses into the levee template (also referred as the levee prism) (see Figure 1-1), it can lead to instability of the bank. This bank instability can result in a slope failure that eliminates a significant portion of the levee embankment that ultimately leads to a levee breach.

Scour (the process of water removing soil to create a vertical depression) may occur in the channel and/or along bank toes, steepening banks and increasing bank heights. Plant roots typically do not extend more than a few inches to a few feet into the soil column and are highly affected by river water levels. If soils beneath the vegetation are lost, the vegetation above can be destabilized. For example, grass on a steep slope of sand will easily be lost if the sand beneath it is washed away. The design team assessed the potential for slope instability by collecting topographic and soil data to create slope stability computer models. These models were peer reviewed and checked by multiple engineers and geologists as part of USACE's technical review process.

1.7 Design Criteria and Standards

For both LAR and the Sacramento River, there are common design criteria and standards applicable to both river systems. These common criteria and standards are described below. However, LAR has a unique subset of criteria and standards the proposed designs must adhere to. These unique LAR criteria and standards are described Section 2.2.

1.7.1 Public Safety Objectives

USACE is responsible for managing a portfolio of dams and levees across the nation. USACE uses risk assessments and risk-informed design to ensure risk to public safety is minimized, (commonly referred to as risk reduction). Risk assessments identify risk drivers, which are events and processes that result in life loss and/or economic loss. The primary (and approximately equal) risk drivers for flooding from the American and Sacramento Rivers into areas protected by the federal levee system are levee breach prior to levee overtopping due to erosion (i.e., PFM 2 and 3) and overtopping of the levees (i.e., PFM 1). The overarching objective of the ARCF 2016 erosion protection improvements is to reduce the probability of PFM 2 and 3 induced levee failures for flows up to the discharge of 160,000 cubic feet per second (cfs) on the LAR and up to 117,000 cfs on the Sacramento River without increasing the risk of PFM 1, which could occur if the river is overly constricted by additions of engineered structures within the channel. The design team consistently balances these objectives by ensuring that engineered structures within the channel will not overly constrict the channel but still adequately address the erosion risks and meet habitat mitigation requirements. Engineered structures include erosion protection features such as elements defined in Section 1.5.1 above and on-site habitat mitigation features such as planting benches, in-stream woody material and a replanting plan.

1.7.2 Design Standards

Analyses and designs were completed in accordance with USACE-prescribed standards and guidelines. Table 1-4 summarizes some of the pertinent USACE Engineering Manuals and Reports that were referenced during the design process.

Table 1-4. USACE engineering manuals and reports referenced for design development.

Manual	Date	Title
EM 1110-2-1601	June 30, 1994	Hydraulic Design of Flood Control Channels
EM 1110-2-1418	October 31, 1994	Channel Stability Assessment for Flood Control Projects
EM 1110-2-1913	April 30, 2000	Design and Construction of Levees
EM 1110-2-1614	June 30, 1995	Design of Coastal Revetments, Seawalls and Bulkheads
EM 1110-2-2302	October 24, 1990	Construction with Large Stone
ER 1110-2-1405	September 30, 1982	Hydraulic Design for Local Flood Protection Projects
EP 1110-2-18	May 1, 2019	Guidelines for Landscape Planting and Vegetation Management at Levees, Floodwalls, Embankment Dams, and Appurtenant Structures
ECB 2022-7	October 20, 2022	Interim Approach for Risk-Informed Designs for Dam and Levee Projects.

Table 1-5 summarizes other manuals and documents that were considered during the design process. These documents, plus other technical documents referred to in the text, such as State and Local requirements, were used to supplement USACE criteria. Several documents listed were considered to aid avoiding and minimizing impacts to sensitive environmental conditions to the greatest extent possible. General operations, maintenance, repair, replacement, and rehabilitation (OMRR&R) criteria for the project are set forth in the Standard Operations and Maintenance Manual for the Sacramento River Flood Control Project (U.S. Army Corps of Engineers, 1955); and each levee unit's respective Supplement to the Standard Manual.

Table 1-5. Other manuals and documents referenced for design development.

Source	Year	Title
California Central Valley Flood Protection Board	2017	Central Valley Flood Protection Plan's Conservation Strategy
California Department of Water Resources	2012	Urban Levee Design Criteria
California Legislature	1972	State WSRA (PRC Section 5093.50-5093.70)
Federal Highway Administration National Highway Institute Countermeasures	2009	Hydraulic Engineering Circular No. 23: Bridge Scour and Stream Instability Countermeasures: Experience, Selection, and Design Guidance-Third Edition
Federal Highway Administration National Highway Institute Countermeasures	2012	Hydraulic Engineering Circular No. 18: Evaluating Scour at Bridges-Fifth Edition
NOAA National Marine Fisheries Service	2021 (Amended the 2015)	Endangered Species Act Section 7(a)(2) Biological Opinion, and Magnuson-Stevens Fishery Conservation and management Act Essential Fish Habitat Response, for the American River Common Features General Re-evaluation Report
Public Law 90-542; 16 U.S.C. 1271	1968	Federal WSRA
Sacramento Area Flood Control Agency	2010	Instream Woody Material Installation and Monitoring Guidance Manual
Sacramento County	2008	American River Parkway Plan
US Fish and Wildlife Service	2021 (Amended the 2015)	American River Common Features Project Biological Opinion
USACE, Sacramento District	2015	American River Common Features General Revaluation Report
USACE, Sacramento District	2007	American River Common Features American River Levee Raising Sacramento County, California Top of Levee Profile and Design Documentation Report
USACE, Sacramento District	2008	Geotechnical Levee Practice REFP10L0
USACE, Sacramento District	2007	Geotechnical Levee Practice SOP-EDG03

1.7.3 Biological Opinions

In the biological assessment for consultation under Section 7 of the Endangered Species Act, USACE proposed minimization measures, including mitigation, to minimize and offset effects of the Proposed Action on federally listed fish species The United States Fish and Wildlife Service (USFWS) issued a 2021 Biological Opinion (BO) for the American River Common Features Project including Incidental Take for Delta Smelt (*Hypomesus transpacificus*) (on the Sacramento River), the Valley Elderberry Longhorn Beetle (*Desmocerus californicus dimorphus*) and the Western Yellow-billed Cuckoo (*Coccyzus americanus*). The National Marine Fisheries Service (NMFS) issued a 2021 BO for Sacramento River winter-run and Central Valley spring-run Chinook Salmon (*Oncorhynchus tshawytscha*), Green Sturgeon (*Acipenser medirostris*) (on the Sacramento River), and Steelhead (*O. mykiss*). The USFWS BO established Conservation Measures and Terms and Conditions for the Project, while the NMFS BO established numerous Conservation and Avoidance Actions, Reasonable and Prudent Measures, Terms and Conditions, and Conservation Recommendations. Key to selection of sites and designs, one of the Terms and Conditions of the NMFS BO required USACE to work with an interagency working group to coordinate stakeholder input to deliberate proposed bank protection designs including intent, purpose, and proposed designs with emphasis on fish friendly designs.

Consultation under Section 7 of the Endangered Species Act for new impacts to special status species, since the Amended 2021 BO's, is ongoing between USACE and the resource agencies at the time of drafting this appendix. New BO's will be issued to USACE from USFWS and NMFS for incorporation into the Final SEIS/SEIR and are expected in early 2025.

1.7.4 Erosion Protection Design Alternatives

During the feasibility study documented in the GRR (U.S. Army Corps of Engineers, 2015 (Revised 2016)), a number of design alternatives for addressing the erosion risks, such as waterside armoring of the levees, launchable rock trenches, bioengineering solutions, grade control structures (i.e., a structure that reduces flow velocities), along both LAR and the Sacramento River were considered. Setback levees, (realignment of levees further from the river channel) were not considered during feasibility due to the heavy residential and commercial development, which exists immediately adjacent to the levees along both rivers. The impacts to the surrounding communities by setback levees would be too great for setback levees to be considered a viable alternative.

The GRR determined waterside armoring of the levees (bank protection), launchable rock trenches, and bioengineering solutions could all be effective methods of reducing erosion potential on the levees. However, bioengineering solutions were only considered viable in areas where a wide natural bank exists on the river, but it could not be used on levee slopes. Grade control structures were determined not to be a viable alternative because analyses of the erosion potential of the riverbeds determined this erosion potential was not a significant risk during the 50-year design life period of analysis. The GRR's final alternatives array for erosion protection measures included bank protection, launchable rock trenches, and bioengineering solutions. These three alternatives were the alternative measures carried forward into the design development phase following authorization of the ARCF16 Project in 2016.

1.7.4.1 Application of Bioengineering Alternatives

Bioengineering erosion protection measures provide an alternative erosion protection solution to traditional bank protection measures, the latter of which typically use substantial amounts of rock revetment. Per USACE's Engineering Research and Development Center (ERDC):

> "*Bioengineering is the combination of biological, mechanical, and ecological concepts to control erosion and stabilize soil through the use of vegetation or a combination of it and construction materials. Both living and nonliving plants can be used. Nonliving plants are used as construction materials, similar to engineered materials.*" (U.S. Army Corps of Engineers, 1997).

For LAR, during the conceptual erosion protection design development phase, bioengineering solutions were considered for use in appropriate locations where the overbank is wide enough to support and justify use of such measures. For example, in LAR Contract 2, which was constructed in 2022 and 2023, bioengineering solutions were considered at a site immediately downstream of Howe Avenue; however, during consultation with resources agencies on the use of these bioengineering solutions there were significant concerns about the longevity of the bioengineering solutions and the impacts repair and replacement of these solutions would have on the on-site mitigation plants and habitat. For these reasons, bioengineering erosion protection solutions were not used on any of the constructed sites to-date, nor are they being proposed in any of the erosion protection measures subject to the contents of this Engineering Appendix (see Section 2.5).

For the Sacramento River, bioengineering erosion protection measures have been incorporated into Sacramento River Erosion Contract 4 (constructed in 2024). However, because of the lack of sufficient overbank width for most of the Sacramento River in the ARCF16 Project area and because of the nature of the erosion being addressed, bioengineering solutions were determined not to be viable for use in the proposed Sacramento River Erosion Contract 3 subject to the contents of this Engineering Appendix (see Section 3.4).

1.7.5 General Design Approach

USACE's general design approach is focused on balancing multiple project objectives (e.g., achieving public safety requirements and minimizing environmental impacts). Design concepts (i.e. 10% designs) developed since late 2019 have been further refined and reviewed incrementally with formal review from multiple disciplines, project partners, and stakeholders occurring at the 35%, 65%, 95% design phases to date for LAR and the Sacramento River (as further described in Sections 2 and 3, respectively).

A sequential overview of the design process to meet design objectives is laid out below.

a) Incorporating a panel of local, regional, and national experts to identify erosion hazards and drivers for sections of the river that share common site characteristics.
b) Incorporating a panel of local, regional, and national experts to identify habitat, cultural and recreational resources, mitigation requirements and compliance needs both on a program and project level.

c) Through a consortium of ecologists, biologists, landscape architects, geomorphologists, hydraulic and geotechnical engineers across local, state, and federal agencies, developed, weighed, and selected a preferred concept alternative on a local river segment level for the design team to advance.
d) Developed comprehensive design criteria to guide and control design outcomes.
e) Developed a suite of analysis tools across design disciplines to support design layout, assess associated impacts and provide design justification.
f) Collected data to support analysis tools needed.
g) Collaborated and engaged with project partners on a local, state, and national level and included subject matter experts across all design phases.
h) Included a robust review charge for the design team to follow. Reviews included local, regional, and national experts internal and external to USACE to identify fatal flaws or recommendations for design refinement.
i) Design review included risk informed design process to arrive at the minimal design footprint to meet flood risk objectives.
j) Each design phase included a detailed assessment of habitat impacts.
k) CAD layout of proposed features included direct use of collected habitat, recreational and cultural datasets to minimize impacts.
l) During design phases, proposed erosion footprints were assessed in the field and modified where plausible to avoid sensitive habitat, recreational and cultural amenities.
m) Each design phase included documentation of supporting design analysis, proposed design layout and impact assessment.
n) Addressed review comments in subsequent design phase.

1.7.6 Summary of Design Criteria

Erosion protection is targeted to locations where there is an unacceptably high risk of erosion induced levee failure during the life of the project. Below list provides critical criteria each design must adhere to.

- Erosion protection designs cannot increase water surface levels during high flow events such that they may increase the potential for levee overtopping (i.e., PFM 1).
- Erosion protection designs must limit the footprint and impact to only what is necessary to meet public safety objectives.
- Erosion protection projects must be developed in consultation with inter-agency working groups.
- Erosion protection projects must incorporate as much on-site habitat and recreational mitigation as feasible to offset impacts caused by construction and installation of the erosion protection.

1.8 Site Evaluations and Selection

The 2016 ARCF GRR deferred erosion protection site selection to the design development phase, as additional analysis was needed to identify and prioritize sites needing erosion countermeasures. To meet the project needs, a two-phase site selection process was adopted to ensure that critical erosion countermeasures were identified, designed, and constructed quickly to provide additional protection to Sacramento while ensuring that areas needing erosion countermeasures are not overlooked or that unnecessary erosion countermeasure construction is avoided.

The Phase I analysis included an expert opinion elicitation (EOE) based on existing data and preliminary analysis to develop initial recommendations for sites to include erosion countermeasures. This analysis looked at a range of high flow events up to the design flow and provided recommendations for additional erosion protection on the expected performance of the site. The Phase I evaluation identified key sites where erosion protection was immediately required to convey the design flow, locations where erosion protection may be required in the future to convey the design flow, and locations where erosion protection was unlikely to be required either now or in the future.

The Phase II analysis included additional studies to expand on the preliminary studies used in the Phase I analysis. These studies included detailed assessments of existing revetment on both rivers and ongoing improvements to the hydraulic models on both rivers. On the LAR, the Phase II analysis also included field investigations to gather additional geologic information, and detailed model studies to improve estimates of potential lateral bank retreat. The Phase II analysis culminated with a baseline risk assessment to identify a probability of failure at each segment following USACE criteria. The results of the Phase I and Phase II evaluations were used in the final decision by USACE Sacramento District to determine where erosion protection was needed to meet overall project objectives. The evaluations and ultimate final selection of where erosion improvements were determined necessary resulted in a total of 6 miles erosion improvements along LAR, reduced from 11 miles estimated in the GRR, and a total of 6.5 miles of erosion improvements along the Sacramento River, reduced from 10 miles estimated in the GRR.

1.8.1 Phase I Site Evaluations –Identification of Initial Sites

A consultant contracted by the Project Partners, facilitated an EOE to estimate probability of levee failure because of erosion. The EOE panel consisted of local experts with experience working on the LAR and Sacramento River systems, representatives from the California Department of Water Resources (DWR), as well as national experts from USACE. The panel included hydraulic engineers, geotechnical engineers, geo-scientists, and ecologists. The panel evaluated individual segments that were identified in previous erosion assessments. The erosion assessments included a summary of existing data for each segment. After discussion of segment conditions and assignment of a probability of failure, the expert panel then designated each segment as Tier 1, Tier 2, or Tier 3, which were defined as:

- Tier 1—Segments that have the highest risk of erosion and are subject to an immediate threat to the levees during high flows.
- Tier 2—Segments that are not subject to an immediate threat to the levee but are anticipated to reach that condition after one or more high flow events (during the 50-year design life of the project).
- Tier 3—Remaining segments that are not considered subject to an erosion threat that could lead to levee breach (during the 50-year design life of the project).

Results of the EOE and resulting segment rankings can be found in Section 2.4.1 for LAR and Section 3.3.1 for the Sacramento River.

1.8.2 Phase II Site Evaluations - Identification of Remaining Sites

The Phase II site evaluations built upon the Phase I evaluations by incorporating new data and analysis, which reduced uncertainty in the evaluation process. New data and analysis included:

1) A new 2D hydraulic model using the USACE HEC-RAS software (see Sections 2.3.3 and 3.2.3).
2) New project-specific soil sampling and testing (see Sections 2.3.4 and 3.2.4).
3) An existing revetment condition assessment (see Sections 2.3.7and 3.2.5).
4) New probabilistic bank retreat estimates using the new project-specific soil properties at segments deemed as moderate to high overall erosion potential was completed on the LAR (see Section 2.3.10).
5) Evaluating erosion induced levee breach risk for each levee segment by a risk assessment team.

Consistent with USACE Engineering Regulation (ER) 1105-2-101, risk assessment teams, composed of a USACE Risk Cadre, Sacramento District PDT members, and SAFCA and DWR representatives (experts who also participated in the Phase I evaluations), re-evaluated the risk of erosion failure at each segment under baseline (pre-project) conditions using the new data and analysis. Risk Cadre teams are multi-disciplinary teams within USACE with special training in risk assessments that assess USACE infrastructure across the nation. The Risk Cadre team completing the baseline risk assessment had previously completed a risk assessment of the LAR and Sacramento River systems to support the GRR and had foundational knowledge of both river systems.

The team used event trees[3] for PFM 2 and 3, previously defined during the baseline risk assessment, that would lead to levee failure. This included an assumption that if a flaw exists it would result in exposure of erodible soils (This could result from either failure of vegetal cover due to excessive hydraulic force, mass slope failure based on instability of the riverbank or levee embankment toe, tree-fall, or other site specific conditions), erosion of bank soils (erosion initiation), erosion extending into the levee template (erosion progression), the potential for intervention such as flood fighting to arrest the erosion, and finally a levee breach occurring in an eroded condition. The risk assessment teams evaluated PFM 2 fluvial erosion of the levee and PFM 3 fluvial erosion of the levee foundation event trees (see section 1.6) at each segment defined in the erosion assessments to determine the likelihood of levee failure during a single large storm event. Segments with unacceptably high risk for failure due to erosion were recommended for repair. Key risk driving attributes at individual segments that led to high-risk ratings were identified to be addressed during design.

[3] An event tree is an analytical technique for modeling a system or sequence of events. It is a sequence of nodes and branches that describe the possible outcomes of an initiating event. Each unique pathway through the tree describes a unique sequence of events that could result from the initiating event.

1.9 Long-Term Levee System Monitoring

Long-term Operation, Maintenance, Repair, Replacement and Rehabilitation (OMRR&R) of the levee systems and their flood risk management features (i.e., within the ARCF16 Project) is the responsibility of the project partners (CVFPB, DWR, & SAFCA). This responsibility is delegated by the project partners to Local Maintaining Agencies (LMA). Within the ARCF16 Project footprint, these LMAs include the American River Flood Control District, the City of Sacramento, and DWR Maintenance Area 9. The LMAs are charged with regularly inspecting the flood risk management (FRM) features throughout a given year, patrolling and monitoring the levees within their area of responsibility during high water events, and implementing repairs to the levee system as determined necessary based on the LMAs regular inspections and periodic inspections performed by USACE Sacramento District.

Patrolling and monitoring of the levees during high water events is triggered based on river elevations, or stages, as read at key stream gages throughout the levee system. These stream gages are a critical piece of infrastructure owned and operated by the DWR, which provides real-time data on current river stage and flow conditions of rivers and streams throughout the State. When a given river stream gage reaches a predesignated "Monitoring" elevation, the LMA for that levee system is required to begin regular, daily patrols of the levees along that river. The information these gages provide is critical not only for annual monitoring performed by the LMAs, but it also provides a record of river conditions, which hydraulic engineers can utilize to calibrate their analytical models and ensure their model's outputs provide reasonable and accurate results.

1.9.1 Piezometer Network

Similar to the stream gage network described above, the planned ARCF16 piezometer network would provide critical, real-time information on groundwater conditions in and around a given levee. The information from these piezometers can be used by LMAs to monitor current performance of the levees during high water conditions and can be used by engineers in future analysis efforts to calibrate additional analytical models, such as seepage analysis models. The data gathered by the piezometers would be a vital tool in evaluating future risks to the levee system and allow engineers to better refine and minimize future projects that may become necessary if, based on future needs, performance of the current levees is determined to be inadequate. For more information on the planned piezometer network, please refer to Section 4 of this document.

2 LOWER AMERICAN RIVER EROSION PROTECTION

2.1 Background

The LAR federal levees were originally intended to convey a release from Folsom Dam of 115,000 cubic feet per second (cfs). During several events since the construction of Folsom Dam, flows have equaled or exceeded the design capacity and caused significant erosion distress. All four significant flood events since the completion of the Federal flood control system in the mid 1950s (1955, 1966, 1986, and 1997) caused considerable damage to the LAR levee system due to erosion. The 1986 event had an imminent threat of levee failure. In addition, all four events required extensive repair after the event so the LAR levee system could perform for the next major event. Based on past performance and recent investigations, erosion is a serious threat to the LAR levees that must be addressed considering the consequences of a levee failure along LAR.

Section 2 of this section provides a summary of past performance of the levees along LAR and a detailed summary the proposed erosion protection design efforts on LAR under the ARCF16 Project. LAR is designated as a Wild and Scenic River under the federal and state of California WSRAs. Section 2.2 summarizes the LAR specific design criteria used to identify the sites for repair and develop designs. Section 2.3 includes a summary of key data sources relied on in the site identification and design, as well as a summary of tools developed for analysis. Section 2.4 provides a summary of how sites requiring improvements were identified. Section 2.5 summarizes the design process and designs at each location in LAR Contracts 3B, 4A, and 4B. Section 2.6 summarizes the implementation process for the proposed projects.

2.1.1 Historical Performance

The history of the American River has been significantly impacted by human activity. During the California Gold Rush of 1849 to 1864, the foothills upstream of the river were mined hydraulically, resulting in millions of cubic yards of mining debris being sent down LAR. The hydraulic mining caused approximately 15 to 20 ft of aggradation in the project reach. Dredge mining for gold caused alignment changes to the floodplain and in-channel bars and significantly altered the topography. Subsequent sand and gravel mining in the river and floodplain resulted in the development of split flow reaches. In 1864, a rechanneling project moved the downstream end of LAR to its present location from an alignment, which ran roughly through the Union Pacific rail yard. In the 1950's, the construction of Folsom Dam (RM 30) and Nimbus Dam (RM 23) essentially eliminated the sediment supply from the upper watershed, causing the lower reaches of LAR to become sediment starved and a lowering, or down cutting, of the river channel invert.

Construction of the south levee of LAR started around 1850 and was completed in the 1910's. Construction of the north levee of LAR, located between the Sacramento River and about RM 5 (near Cal Expo), occurred in the 1910's. Construction of the remainder of the north levee, upstream of Cal Expo extending to RM 14, occurred between 1955 and 1957.

In 1955, the American River experienced the flood of record. This is an important flood event in that of the 1 million acre-feet reservoir at Folsom Dam (only 400,000 acre-feet of reservoir capacity is allocated to flood control) was filled in a single event. The peak release from this flood event was 115,000 cfs. Soon after this flood event, the flood magnitude was factored into the hydrology for Folsom Dam operations, which led to the level of protection provided by Folsom Dam being considerably lowered.

Sacramento experienced significant flood events again in 1964, 1986, 1997 and 2017. The 1964 flood event was the first time the complete LAR levee system was tested with a flow of 115,000 cfs. The 1964 flood event showed considerable stress on the levee system for a flow of 115,000 cfs. An emergency flood-fight along the left bank of LAR near H Street was required to pass the flood event.

The 1986 flood event is significant in that it required a peak release from Folsom Dam of 134,000 cfs in order to avoid a dam failure. The peak flow was passed without a levee failure, but two locations were in the process of failing as flows were receding. Figure 2-1 shows one of these erosion sites located just upstream of the Capital City Freeway. Had the discharge sustained longer, the levee would have likely failed from erosion.

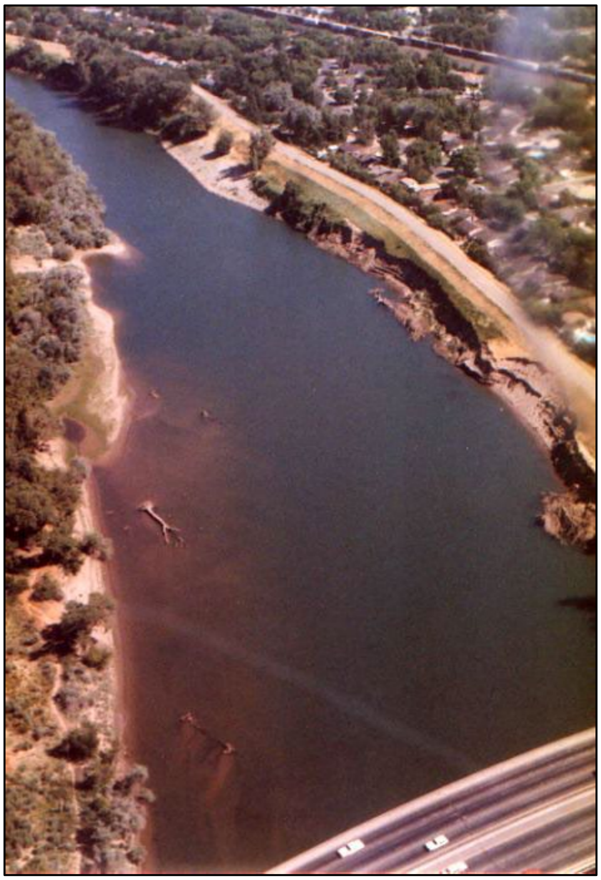


Figure 2-1. Left bank levee and riverbank erosion from 1986 flood event (134,000 cfs) upstream of Capital City Freeway

In 1997, the Sacramento and San Joaquin River systems experienced record flooding and a number of levee breaks. However, in the American River watershed, Folsom Lake experienced a peak inflow of 255,000 cfs and was able to control it to slightly above the 115,000 cfs objective release at a flow of 117,000 cfs down LAR, with 28 percent of the flood management storage available at the peak of the storm. Nonetheless, significant erosion occurred at five sites along LAR, which required immediate repair following the flood event. These repairs were accomplished under the SRBPP.

All four significant flood events since completion of the federal flood control system in the mid 1950's (1955, 1964, 1986, and 1997) caused considerable damage to the levee system because of erosion. After each of these four flood events extensive erosion repairs were necessary so the system was ready for the next major flood event. In addition, erosion also occurred during a flood event in 2006 with a peak flow of just 37,000 cfs. For example, on the left (south) bank upstream of Watt Avenue erosion sites developed at RM 10.0 and 10.6 that were repaired under the SRBPP in 2011. The extensive number of erosion repairs constructed prior to the ARCF16 project's authorization are depicted in Figure 2-4.

2.1.2 Folsom Dam Historical Performance

Folsom Dam is located along the American River, approximately 26 miles upstream from the confluence with the Sacramento River. Folsom Lake is the largest reservoir in the American River watershed with a gross pool capacity of 967,000 acre-feet. In conjunction with levees on LAR and the Sacramento River and other system improvements, Folsom Dam and Lake provides FRM for the greater Sacramento area. Construction of the Folsom Dam and Lake project was completed by the Corps in 1956. The project was transferred to the Bureau of Reclamation (Reclamation) for operation and maintenance as part of the Central Valley Project. Reclamation operates Folsom Dam for FRM with criteria established by USACE, along with other authorized purposes such as hydropower, recreation, and water supply.

A flood of record on the American River watershed in 1986 seriously taxed both the control of Folsom Dam and the downstream LAR levee system and showed that there was a much greater flood risk to the Sacramento area than previously estimated based on observed inflows during the 1986 flood event. Because of that flood, USACE conducted several studies under the authority of the Flood Control Act of 1962 (Pub. L. 87-874). These hydrologic studies demonstrated that relative to the size of the American River watershed and the watershed's flood potential, Folsom Dam was too small to adequately accommodate potential flood inflows and protect the downstream communities. Based on that understanding, it was determined improvements to the Folsom Reservoir's storage capacity and Folsom Dam's outlet works were required.

2.1.3 Folsom Dam Operation Improvements

The existing configuration of Folsom Dam is such that the lower-level outlets are at elevation 280 feet; the spillway sill is at elevation 418 feet, and the bottom of the 400,000 acre-feet permanent flood control pool is at elevation 427 feet. Because of this configuration, only 30,000 cfs can be released until the stage in the reservoir reaches the spillway. The objective release for Folsom Dam is 115,000 cfs. However, prior to construction of the auxiliary spillway, this amount of flow could not be released until the stage was sufficiently high enough above the spillway to force it through the spillway. With this configuration and with the levees downstream of Folsom Dam only able to reliably convey 115,000 cfs, the level of flood protection was relatively low as compared to other similar sized cities throughout the country.

The Folsom Dam flood pool is the portion of reservoir space to be reserved (kept empty) for the purpose of maintaining a target level of downstream flood protection. It is bounded on the bottom by the top of the conservation (TOC) pool, which can vary by date or as a function of watershed state. When water is stored above TOC, the reservoir is said to be encroached. When encroached, water is released as rapidly as possible subject to operational and physical constraints. Under "normal" flood operations, releases are made for the purpose of providing downstream flood protection by safely conveying releases in the downstream leveed channel. The maximum release that can be made under routine flood operations is the normal objective release of 115,000 cfs, and the maximum allowable pool elevation for normal flood operations is the top of flood pool (bottom of surcharge pool) at 468.34 feet NAVD88. Once the objective release is being made, if the combination of current inflow and pool elevation are sufficiently great, the Emergency Spillway Release can require releases greater than 115,000 cfs. When under an emergency spillway release condition, "emergency" flood operations are in effect and releases are made to prevent the dam from overtopping. The greatest release that can be made without overtopping downstream levees is the emergency objective release of 160,000 cfs; however, emergency spillway releases can greatly exceed the emergency objective release if necessary to prevent a dam failure.

Because of the downstream constraint imposed by the inability of the LAR levees to safely convey the 160,000 cfs flow release, benefits provided by the Folsom Dam improvements cannot be fully realized. Furthermore, until the LAR levees are able to safely convey 160,000 cfs, Folsom Dam will remain at a greater risk of overtopping and overtopping induced failure, as evidenced by the 1986 flood event and subsequent hydrological studies, which determined the 115,000 cfs release capacity to be inadequate to manage the flood potential within the American River watershed. For this reason, the design flow along LAR is the emergency objective release from Folsom Dam of 160,000 cfs.

To help illustrate the critical benefits provided by releasing 160,000 cfs from Folsom Dam we can compare the storage capacity maintained by releasing the additional 45,000 cfs above 115,000 cfs to the benefits provided by the Folsom Dam Raise project. The Dam Raise improvements currently under design and construction will decrease downstream flood risk by adding approximately 45,000 acre-feet of surcharge storage. Over a one-day period the ability to release the emergency objective release of 160,000 cfs, rather than the normal objective release of 115,000 cfs, evacuates approximately 90,000 acre-feet of water from Folsom reservoir, double the additional storage provided by the Dam Raise improvements. In other words, every single 24-hour period that the Dam releases 160,000 cfs releases an equivalent of two Dam Raise storage capacities more than the 115,000 cfs release. Together, the Dam Raise improvements and ability to release 160,000 cfs will combine to significantly reduces downstream flood risk and increase the reliability of the overall American River flood control system.

2.1.4 LAR River Mileage

River mileage (RM) is measured from the mouth of LAR along its centerline, with mile zero located at the junction with the Sacramento River. The reference mile markers used in this study are from the USACE Comprehensive Study Unsteady NETwork (UNET) model. They have also been used in other studies recently prepared for USACE and are considered the most consistent set of markers. River mileage is used to bound subreaches and sites, but the references are not intended to be precise.

Mileage markers shown on United State Geologic Survey (USGS) quadrangle maps (1:24,000) differ from those prepared by USACE. The USGS markers match the USACE markers near the mouth but fall short of the USACE markers further upstream. This shift results in USGS RM 16 marker being about 2,000 feet (0.4 miles) downstream of USACE RM 16. Mileage references in older reports do not always refer to the current USACE or USGS mile markers. Care is required when using mileage references in older documents to locate sites relative to the current USACE markers.

2.1.5 LAR Definition and Nomenclature

LAR was divided into four planning subreaches as shown in Figure 2-2. Design or Project sites (e.g., Site 3-1) are referred to by the Subreach they are predominately located in (e.g., Site 3-1 is in Subreach 3). Subreaches were initially evaluated individually, and segments were numbered sequentially in each subreach (e.g., each subreach has a Segment 1). As the study progressed, design sites were evaluated comprehensively requiring discussion of segments in different subreaches to be discussed. Segments are now often referred to with similar nomenclature as design sites by referring to the subreach and then the segment number (Segment 3-9 refers to Segment 9 in Subreach 3).

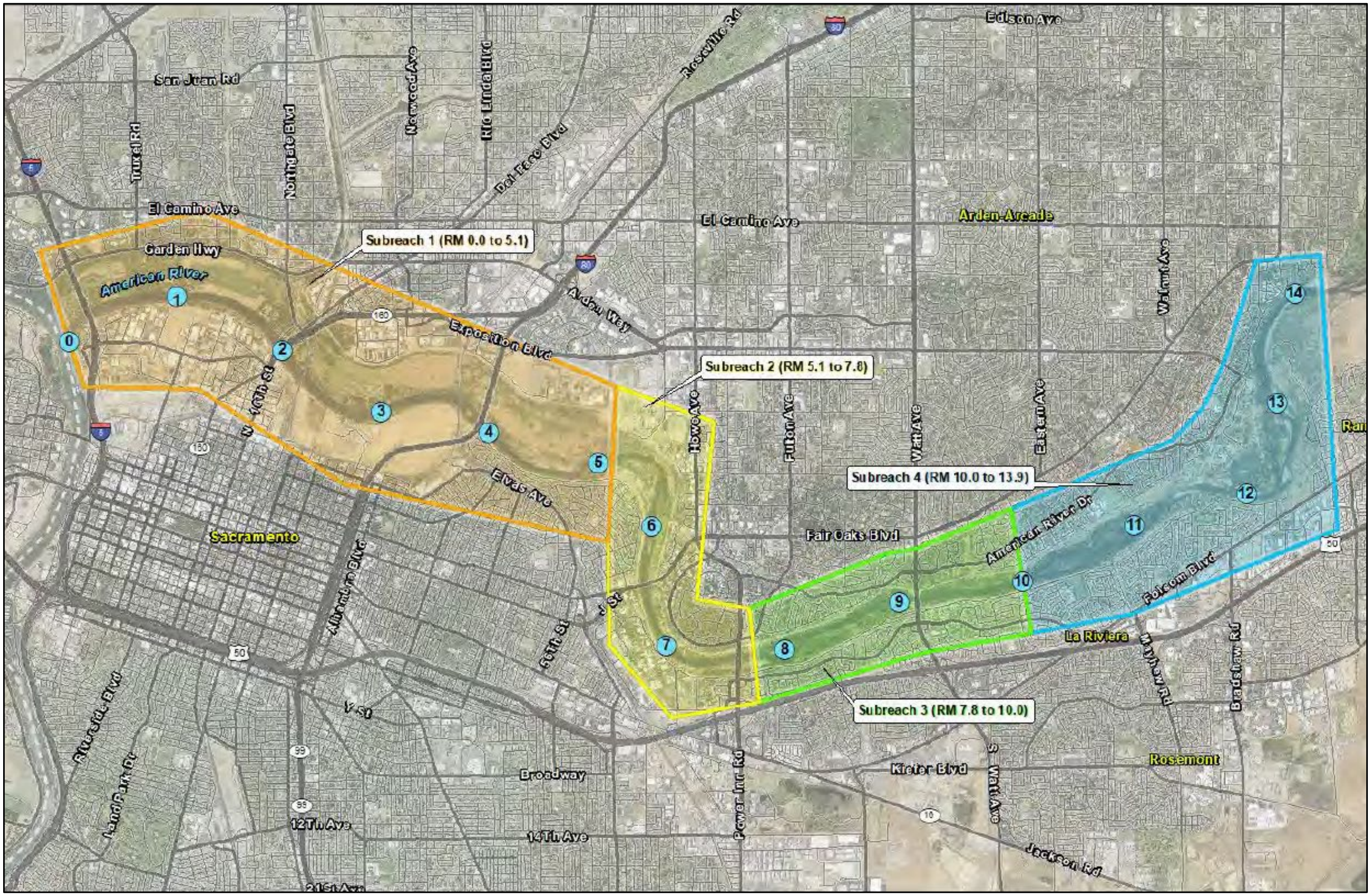


Figure 2-2. LAR Subreach locations

2.1.6 LAR Contracts 1 and 2

The designs developed for LAR Contracts 1 and 2 (see location map shown in Figure 2-3) were unique and necessary to address the high erosion risk specific to that location along LAR. Site evaluations of LAR determined the left bank along this reach (Subreach 2) of the river between Paradise Beach and Guy West Bridge had the highest erosion risk along the entirety of the leveed portion of LAR. Conditions that contributed to this determination included highest flow velocities along the entire leveed portion of LAR, narrowest section along LAR between the two levees (approximately only 750-feet wide), proximity of the main river channel to the levee (i.e., little to no overbank on the left side of the channel), and poor soil composition of the levee and overbank. For more information on the site evaluation and selection process, please refer to Section 2.4.

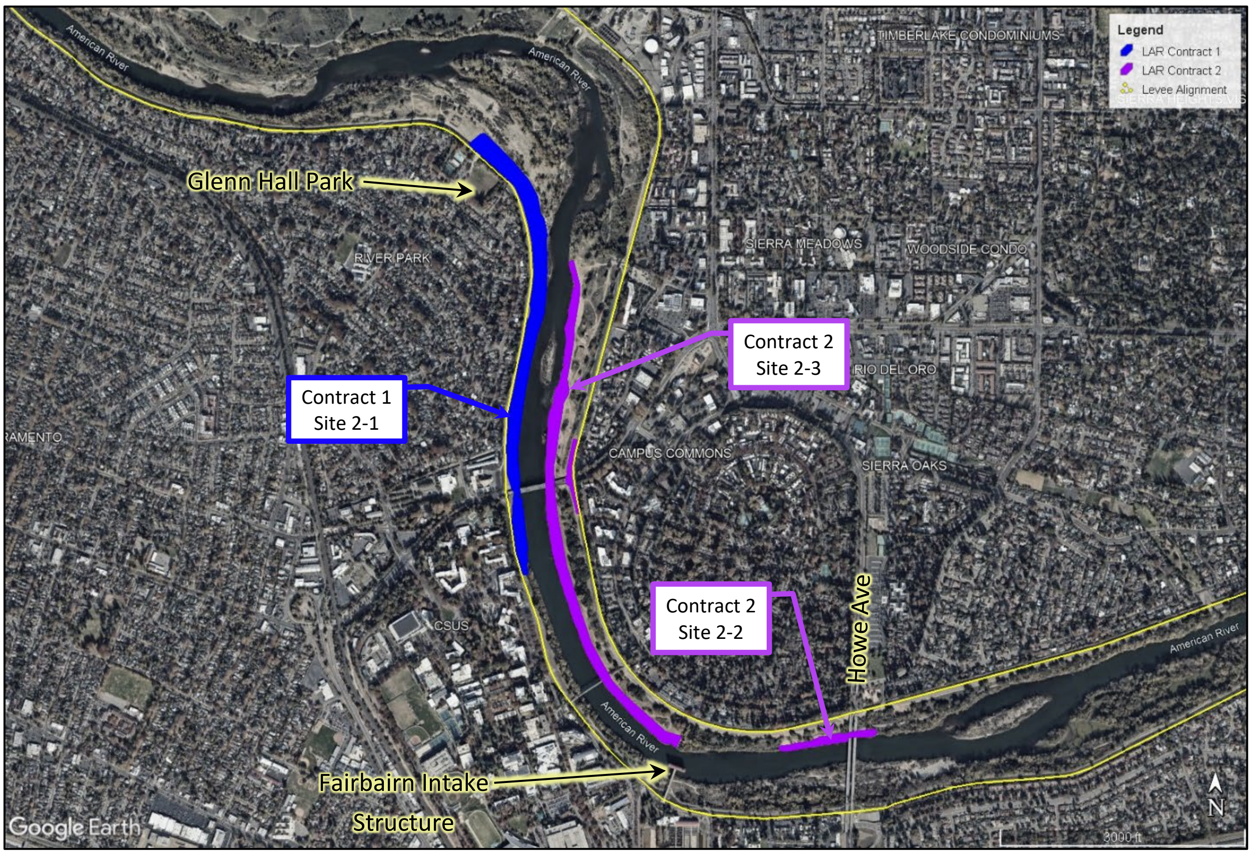


Figure 2-3. LAR Contracts 1 and 2 Location Map

At both Site 2-1 and 2-3, the high velocities resulting from the already constrained (narrow) floodplain at this location created a rise in water surface elevation for fill placed within the channel. The Technical Resource Advisory Committee (TRAC) considered various design alternatives for Subreach 2. Although the Site 2-3 design had significant short-term impacts (due to the removal of all trees from the footprint), the long-term benefits of the site were expected to offset the short-term impacts. The increased conveyance form Site 2-3 also offset the hydraulic impacts of the planting bench at Site 2-1 and allowed for vegetation to be re-established on the Site 2-1 bank line. The hydraulic improvements of Site 2-3 also extended upstream, allowing less impactful designs to be incorporated in the Contract 3B footprint. ***The expansiveness of the impacts within these two sites is unique to these two sites as no other site has the height (bank toe to edge of water) and length of Site 2-1 requiring repair, and no***

other site is proposing cutting banks back similar to Site 2-3. Please refer to Sections 2.1.6.1 and 2.1.6.2 for details on the designs included in Contracts 1 and 2.

Site 2-2 within Contract 2 serves as a better example of what most of proposed bank protection included in Contract 3B will look like, and how much less impactful the Contract 3B improvements will be to the parkway's resources when compared to Sites 2-1 and 2-3. For more information on Site 2-2's design, please refer to Section 2.1.6.2. For more information on the proposed designs for Contract 3B, please refer to Section 2.5.2.

2.1.6.1 LAR Contract 1

LAR Contract 1 was constructed in 2022 and early into 2023. To adequately address the identified erosion risks within Subreach 2 (see Figure 2-2 above), a significant bank protection footprint was required along the left bank starting approximately 1,000 feet upstream of H-Street bridge and continuing downstream into Paradise Beach and terminating near Glenn Hall Park. In this segment, referred to as Site 2-1, river velocities are high from down in the bottom of the river channel all the way up on to near the levee crown, so stone bank protection was required from near the levee crown down to the riverbank toe. Because stone bank protection was necessary for the entire height of the bank, all existing vegetation within Site 2-1 had to be removed to permit construction of the bank protection. Preserving trees in place by placing rock around existing trees rather than fully removing all trees was considered earlier in the design development phase. Evaluations of older erosion repairs along the LAR where existing trees were preserved in that manner showed those trees did not fare well or eventually died post construction. Based on those observations and to reduce the need for potential future impacts and costs were a preserved tree to die as a result of the constructed features, the Technical Resource Advisory Committee (TRAC) recommended all the trees within the footprint be removed and the design include features, which would allow for better establishment of planned on-site mitigation plantings following construction of the erosion protection features.

To offset as much of the habitat impacts as possible within Site 2-1 itself, this design included construction of planting benches at summer mean/low water level elevations to increase habitat for vegetation, recreation, and wildlife (see Figure 2-4). To accommodate these mitigation features, the planting bench had to extend well into the river channel, which, along with the vertical extents of rock installed, significantly constricted the already narrowest section of the river to a degree which, if not offset or mitigated, would cause unacceptable hydraulic impacts. To address this design induced impact, Contract 2, Site 2-3 was developed alongside Contract 1 to excavate the right-side bank opposite of Site 2-1 and offset the hydraulic impacts caused by Site 2-1, the river channel. See Section 2.1.6.2.2 for more details on the design of Contract 2, Site 2-3. Figure 2-5 below shows the changes in channel cross section pre- (red linework) and post construction (green linework) of LAR Contracts 1 and 2 (note: the scale of this cross section is vertically exaggerated).

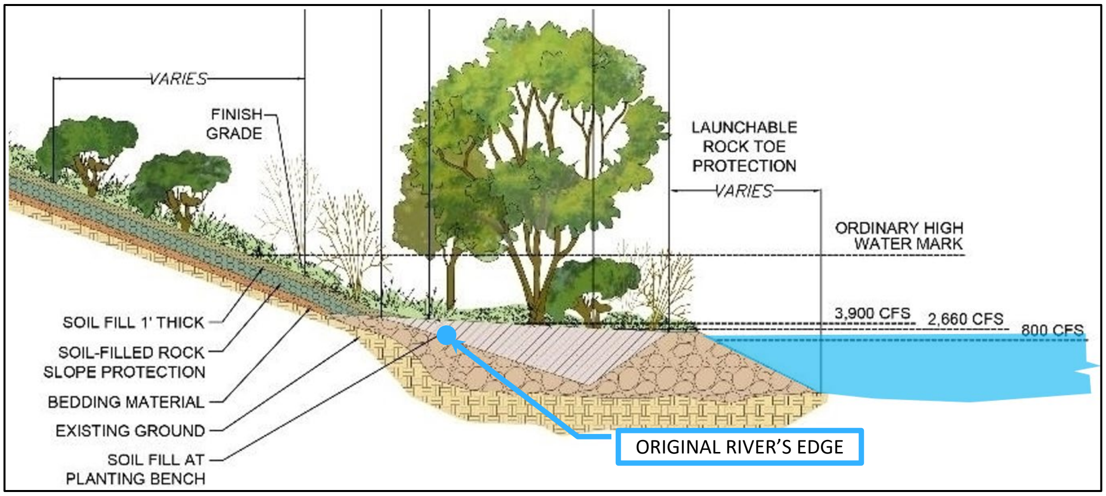


Figure 2-4. Contract 1 Site 2-1 planting bench conceptual cross section

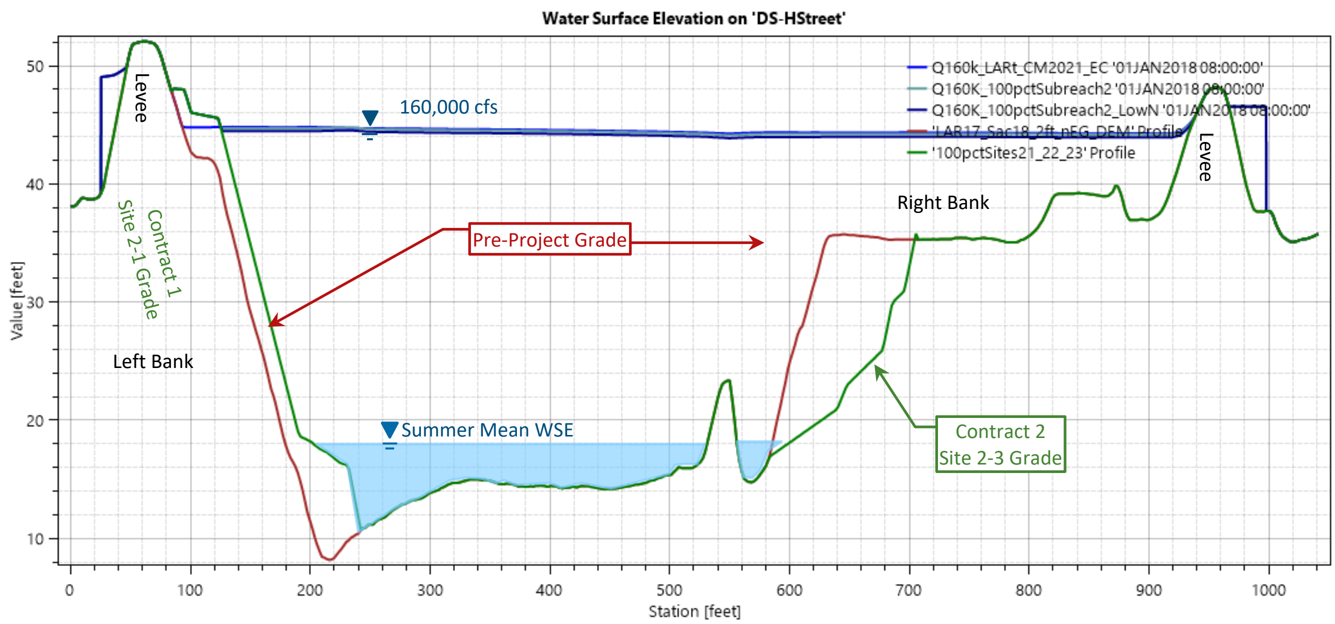


Figure 2-5. Cross Section showing Contract 1 and 2 modifications to LAR channel

2.1.6.2 LAR Contract 2

LAR Contract 2 was constructed over a two-year period between 2022 and 2023. Contract 2 encompassed construction of two separate sites, Sites 2-2 and 2-3, on the right (north) bank of LAR starting just upstream of Howe and extending downstream to Cadillac Drive approximately 2,700 feet downstream of the H Street Bridge. As mentioned above, Site 2-3 was intended to offset the hydraulic impacts caused by construction of Contract 1, Site 2-1 across the river, while site 2-2 was focused on addressing erosion that threatened to undermine the levee embankment near Howe Avenue. Please refer back to Figure 2-3 above to see the location and extents of Sites 2-2 and 2-3.

Both Sites 2-2 and 2-3 are good examples of erosion protection efforts, which provided an opportunity to not only reduce flood risk to the community but also improve habitat within the American River Parkway. Through rigorous coordination with environmental resource agencies, the National Park

Service, and Sacramento County Parks, the designs were optimized to maximize on-site habitat improvements to the Parkway while simultaneously minimizing the impacts caused by construction of the erosion protection measures. More details on the designs for Sites 2-2 and 2-3 are provided below.

2.1.6.2.1 Site 2-2

Contract 2, Site 2-2 is located on the right bank starting just upstream of Howe Avenue and continuing approximately 1,100 feet downstream of Howe Avenue. This site was much less impactful to parkway resources compared to Site's 2-1 and 2-3. Like Site 2-3, prior to construction the riverbank within Site 2-2 had very steep slopes, which were gradually being undermined and were retreating landward. Fortunately, because this site is located in a wider section of the river, there was opportunity to extend the bankline waterward, and similar to Site 2-3, expand habitat areas by providing a gentler slope from the top of overbank down to the river's edge. To construct this site, impacts to existing habitat were limited only to vegetation on the riverbank and some of the existing trees further up on the riverbank were able to be preserved in place (see area shown in Figure 2-6).

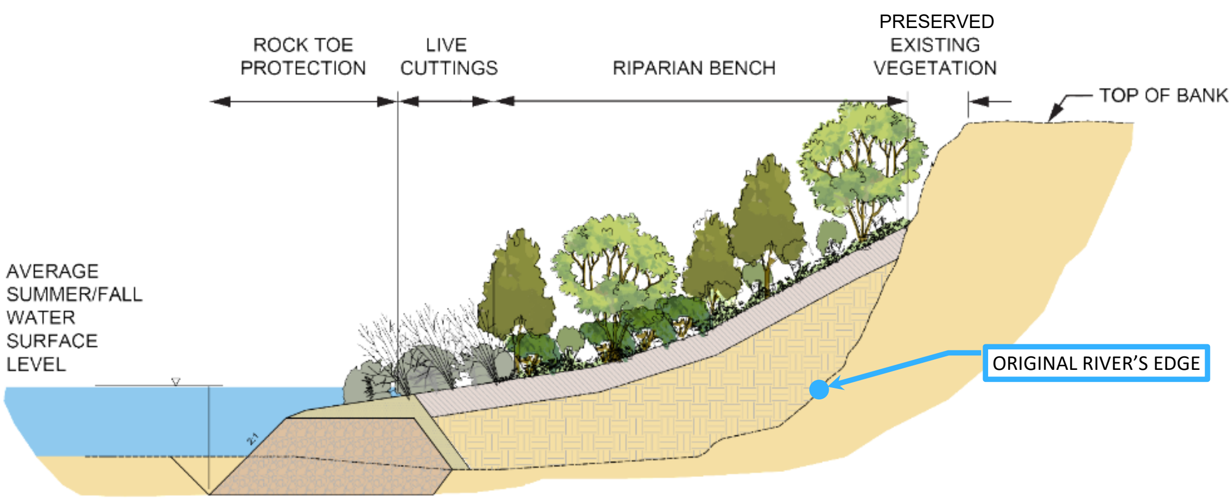


Figure 2-6. Site 2-2 Conceptual Cross Section

2.1.6.2.2 Site 2-3

Site 2-3 extends from the Fairbairn water intake structure at the upstream end downstream to Cadillac Drive (see Figure 2-5) The overbank in segment of the river is mostly composed of hydraulic mining debris that is highly erodible. Prior to construction of Contract 2 the riverbank was very steep, if not vertical, which prevented easy recreational access to the shoreline. Also, due to the steepness of the riverbank and erodibility of the overbank material, the river was gradually undermining the riverbank leading to collapse of sections of the bank and bankline retreat over time. The existing vegetation on the riverbank was gradually being lost to this bank retreat.

The design for Site 2-3 included excavation of the overbank approximately 120-feet landward (see Figure 2-3 above) and gently transitioning the grade from the river's edge upward to the landward extent of the excavation to remove the steep unstable slopes susceptible to ongoing bank toe erosion followed by mass failure, and provide planting benches at elevation near the bank toe where native species of riparian species would establish and naturally armor the bank toe. The planting benches provide elevations of floodplain closer to natural (pre hydraulic mining debris deposition) elevations, which are more frequently inundated to provide habitat, as well as a more pedestrian friendly grade for access to the river's edge. This excavation provided an opportunity to not only stabilize bank retreat and offset the hydraulic impacts caused by Contract 1, but also improve habitat values in Subreach 2 and increase recreation access to the river's edge. Additionally, the conveyance improvements provided by Site 2-3 have far reaching benefits upstream by reducing river stage as far as upstream of Watt Avenue. This improved conveyance has afforded more flexibility for the design of LAR Contract 3B upstream of Howe Avenue, has been a significant factor in minimizing the overall Contract 3B design footprint, and has minimized the impacts to parkway resources caused by Contract 3B. For more information on Contract 3B, please refer to Section 2.5.2.

2.1.6.3 Revegetation of Contracts 1 and 2

Revegetation of Contracts 1 and 2 began with plantings installed along all of Contract 1 in 2023 and the portion of Contract 2 downstream of the H Street Bridge. The remainder of Contract 2 was revegetated in 2024. Although the impacts to the parkway's resources was significant due to required vegetation removal to support construction of these two contracts these impacts are temporary, and once the revegetation plantings have had a few years to establish the Parkway will benefit from overall improved habitat and recreation opportunities. There is strong evidence to support this will be the case based on observation of previous bank protection projects constructed in the late 1990's. A great example of what can be expected for the plantings installed in Contracts 1 and 2 can be seen immediately upstream of Contract 1 on the left bank, adjacent to Sacramento State University. Old Site 4 was constructed just upstream of H Street Bridge and supports a significant strand of riparian habitat on top of the bank protection and planting bench installed at this site. A timeline between 2000 and 2015 showing the establishment and progress of the plantings installed on Old Site 4 is provided in Section 2.6.4, Figure 2-43. Likewise, the bankline immediately downstream from Site 2-2 is a rock bank protection project that was vegetated in the early 2000s and provides an example of potential for vegetation establishment on Site 2-2. Immediately upstream from Site 2-3 provides an example of the expected condition of Site 2-3. The low bench elevation that exists near the water level was uncovered by erosion in 1986, with vegetation re-establishing on similar elevations as those excavated on Site 2-3.

2.2 LAR Design Criteria and Standards

2.2.1 Wild and Scenic River Considerations

The Lower American River Parkway (23 miles) from below Nimbus Dam to the confluence with the Sacramento River is recognized as a Wild and Scenic River under both the California WSRA and the Federal WSRA. LAR was designated as a "Recreational River" in 1972 when the California WSRA was signed into law (Public Resources Code Section 5093.50-5093.70, Chapter 1.4, California WSRA). In 1980, California Governor Edmund G. (Jerry) Brown Jr. petitioned the Secretary of Interior, Cecil Andrus, to include LAR in the National Wild and Scenic River System under Section 2(a)(ii) (16 U.S.C. 1273(a)(ii)); FR August 7, 1980, p 52549). LAR was, added to the National Wild and Scenic Rivers System in 1981 (FR Vol 46. No. 14, Friday, Jan. 23, 1981, p 7484) based upon its recreational and anadromous fisheries Outstandingly Remarkable Values. The State wild and scenic river management plan was completed in 1977 and incorporated the American River Parkway Plan (ARPP) (County of Sacramento, 2008). The current ARPP was completed in 2008 and adopted by the State Legislature in 2009 (AB-889, Jones). The

ARPP establishes boundaries for the Parkway, including for the purposes of WSRA. Its recreational resources were recognized as "extraordinary values" by the State of California.

Under its obligations to manage the LAR as a 2(a)(ii) Federal WSR, the State, through the ARPP, has a non-degradation obligation. This includes limiting resource management actions that degrade the resource values for which the river was originally designated, as well as those conditions that support those resource values, and developing strategies for returning degraded resource conditions to their status at the time of federal designation (1981) where practical. The WSRA values addressed include free-flowing characteristics (i.e., as existing or flowing in natural conditions without impoundments, diversion, straightening and other modification of the waterway), water quality, cultural resources, and recreation and anadromous fisheries (along with those resource attributes that support those values, such as visual, aquatic habitat needs, and bankline structure and riparian vegetation as may be needed for fish habitat, wildlife habitat, and recreational uses and access.)

The ARPP includes specific flood control policies for implementing flood control measures on the LAR. Specifically, Flood Control Policy 4.16 states:

> "*Bank scour and erosion shall be proactively managed to protect public levees and infrastructure, such as bridges, piers, powerlines, habitat, and recreational resources. These erosion control projects, which may include efforts to anchor berms and banks with rock revetment, shall be designed to minimize damage to riparian vegetation and wildlife habitat, and should include a revegetation program that screens the project from public view, provides for a naturalistic appearance to the site, and restores affected habitat areas.*"

To be compliant with the ARPP, designs must minimize damage to riparian vegetation and wildlife habitat and include a revegetation program that screens the project from public view, provides for a naturalistic appearance to the site, and restores affected habitat values.

NPS as the Administrator for the Federal WSRA, will make Consistency Determinations only once 95% level of design is available. Once each design reaches its 95% design milestone, USACE completes a Consistency Analyses per the format specified by NPS for the ARCF16 Project and transmits it to the NPS with a request for their review and consistency Determination. Typically, a draft Consistency Analysis is provided to NPS for comment prior to completing and formally transmitting the document. Consistency Determinations have been received for LAR Contracts 1, 2, and 3A. Consistency Analyses are in development for LAR Contracts 3B, 4A, and 4B.

2.3 Background Data and Ancillary Studies

From the onset of the project, the site selection and design teams used existing data to identify data gaps, and the analyses needed to evaluate the risk and uncertainties within the LAR system. This section summarizes the various data, investigations, tools, and analyses USACE and its partners utilized throughout the site selection and design development process.

The information used to evaluate sites and develop designs was continuously updated throughout the project. Information developed for Phase II risk assessments were informed by discussions and analyses performed in the Phase I evaluations to address uncertainty and improve estimates. Likewise, the design phase (i.e., 10% through 100%) of the project worked to collect additional data and refine analyses tools to ensure design performance while minimizing design footprints. Design work and data development happened simultaneously through an iterative process. This involved defining data requirements while actively gathering and analyzing additional data. As data was developed to better inform site selection or enable a reduction in project footprint, this information was incorporated into the designs. Subsequently, the risk assessment team revisited the designs at each design review step to ensure the design footprints remained minimal while still meeting life-safety objectives.

The following sections include a summary of the best available information collected and applied to-date. Reference reports include dates of the most recent report, which may not necessarily align with the dates when the information was applied (e.g., the final erosion assessment reports included some revisions to address comments generated during the EOE assessments and have final report dates after the EOE assessments).

2.3.1 Bathymetric and Topographic Surveys

Topography and bathymetry were collected for the entire LAR study area in October 2017 using a combination of topo-bathymetric Light Detection and Ranging (LiDAR) data, single beam sonar, and Real-Time Kinematic Global Positioning Systems (RTK-GPS). At Contract 3B (Sites 3-1, 4-1, and 4-2) additional detailed topographic and bathymetric data was collected in 2019 and 2020 using a combination of conventional, GPS, LiDAR, and bathymetric survey methods. At the Contract 4A site, detailed topographic information was collected in 2021 and 2023 with RTK-GPS and total stations.

2.3.2 Hydrology

The hydrology of the LAR system is defined in the Central Valley Hydrology Study (CVHS) and includes the boundary conditions used to assess the hydraulic impacts of Contract 3B (C3B) design features. The CVHS was a multi-year study conducted by USACE and DWR that produced annual exceedance probabilities (AEP) hydrographs centered at Fair Oaks (AMR-14) (U.S. Army Corps of Engineers, 2019a), as well as a 73-year period of record of hourly flow data. The study evaluated historic hydrologic events as if they occurred with the existing reservoirs and operations requirements in place. The AEP events were used in the hydraulic model to assess impacts to water levels, calculate scour depths, and complete lateral bank erosion assessments related to the LAR project areas and design features.

Habitat and erosion control features were designed considering a wide range of flows and recurrence intervals. Habitat features are generally designed for inundation characteristics associated with lower flow stages (e.g., 2,660-cfs), while erosion control features designed to meet public safety criteria are generally focused on the larger, less frequent flow events. Revetment used for erosion protection is designed to remain stable (i.e., not transported downstream) for the 160,000 cfs flow event. The 160,000 cfs flow is the design flow from Folsom Dam based on the latest update to the water control manual completed in 2019 that accounts for the new auxiliary spillway completed under the Joint Federal Project (JFP). This design flow was used to evaluate the stability of erosion protection features associated with the flood risk management project criteria. However, lower discharges were also modeled to ensure that they do not present a more erosive condition than the 160,000 cfs discharge. While rare, the lower flows may have higher velocities at some locations because flow patterns change as the discharge increases, resulting in some locations experiencing higher velocities for lower discharges then 160,000 cfs (U.S. Army Corps of Engineers, 2019b).

Flows associated with the design of on-site resource/habitat features represent a wider range (800 to 115,000 cfs) of flows. The appropriate design flow for the resource features is a function of inundation and flow characteristics for the specific targeted species and habitats (e.g., salmonids, riparian vegetation). However, the higher design flows (i.e., 115,000 cfs) are evaluated to understand operation and maintenance needs associated with the potential erosion of habitat features.

2.3.3 Hydraulic Model Analysis

2.3.3.1 Model Selection

The project required a tool that could predict the hydraulic conditions through a full range of flow events up to the design flow event of 160,000 cfs to inform site selection and design. The spatial mapping of hydraulic forces (e.g., shear stress) during these events and designs resulting in changes to water surface elevation and velocities were fundamental elements that needed to be understood and addressed. Numerical models have been widely applied to address these concerns since the 1980s with advances in computing allowing for increased understanding and computing capabilities. Numerical models rely on the conservation of mass and momentum to provide numerical approximations to physical processes. Relative to physical models, which develop scaled models where hydraulic conditions can be directly measured, numerical models take less physical space and allow many different hydraulic and proposed physical conditions to be evaluated more efficiently.

With few exceptions, all numerical models of hydraulic processes solve the Navier-Stokes equation for the conservation of mass and momentum. The Navier-Stokes equations are a non-linear set of partial differential equations - meaning there are multiple solutions that can satisfy the results and there is no true solution to the results. Numerical models can vary in their assumptions and numerical approaches (e.g., finite element vs finite volume) used in developing solutions. All numerical models are based on some inherent assumptions and are calibrated to measured data to ensure results are within an acceptable margin of error.

Numerical models are generally defined as one-dimensional, two-dimensional, and three-dimensional models. One-dimensional models assume all flow is in streamwise direction and solve for average velocity and water surface elevation at cross-sections located along the channel. Two-dimensional models solve for a depth-averaged velocity flowing both streamwise and transverse directions as well as water depth at points on a computational grid. Three-dimensional models solve for flow velocity in all three directions- streamwise, transverse, and vertical at points within a three-dimensional computational grid. Not all three-dimensional models solve for depth as some models require a “fixed lid” condition where the top layer of the computational grid follows the water surface. The selection of the appropriate numerical model depends on the dominant processes needed to be understood in the design. One-dimensional models are ideal tools for estimating impacts to water surface elevation but are limited to spatially averaged output through a cross-section rather than mapping hydraulic forces over an existing surface. Two dimensional models provide spatially varied information over a computational grid. Three-dimensional models can add further detail where vertical velocity components are dominant processes, where significant stratification occurs in the flow between the channel bed and surface, or otherwise. High fidelity three-dimensional models such as Large Eddy Simulations, can further resolve temporal fluctuations in shear stresses induced by turbulence within the flow.

A two-dimensional model was selected for this project based on: (1) most empirical data used in the assessment of soil erodibility, erosion rates, and threshold values for vegetation to resist erosion are based on time-averaged and depth-averaged flows consistent with those provided in two-dimensional models, and (2) the two-dimensional models can accurately estimate the effects of vegetation on flow and provide spatially varied hydraulic output that can be validated by field-measured data. Hydraulic outputs from the model, including water surface elevations, velocity, and shear stress, were spatially mapped onto the existing channel banks, benches, and levees to inform erosion assessments of the bank and levee materials, as well as understand impacts of project components on the water surface elevation. The model used a typical mesh spacing of 20 feet across the 300-foot to 400-foot-wide channel and overbanks, with more refined meshes used along banklines of interest. Sensitivity analyses showed additional refinement of the mesh did not significantly change hydraulic model results, and the mesh resolution resolved impacts to hydraulics from changes in topography and vegetation.

2.3.3.2 Model Development

USACE staff with support from Project Partner consultants developed the project hydraulic models using the two-dimensional HEC-RAS model platform (cbec, 2021a). Models were incrementally and frequently peer reviewed and involved subject matter experts' direct input on model development and design application from the USACE Hydrologic Engineering Center (HEC). The model domain was developed using topo-bathymetric data collected in October of 2017 (see Section2.3.1). The height of vegetation was measured from the LiDAR data used to develop the topo-bathymetric data and was coupled with information from CDFW (2013) to assign increased roughness to locations where vegetation was present. Roughness values were determined based on vegetation height and type. The roughness values were adjusted to calibrate the model to match the high-water mark elevations observed during the 1997 event. The calibrated model was then validated at four additional flow events: 20,500 cfs (2017), 60,300 cfs (2017), 82,200 cfs (2017), and 134,000 cfs (1986). These validation runs demonstrated the model matched hydraulic conditions observed and measured during these events within a reasonable level of accuracy. Model sensitivity was tested for size separate variables including mesh sizing and orientation, computational timestep, eddy viscosity, and roughness parameters with findings consulted with HEC for further refinement. The final model is run on a computational grid with a 20-foot spacing between grid points with 10 foot-spacing along banklines and near project features and the typical channel width, not including overbank, is approximately 300-ft to 400-ft.

Specific for LAR C3B, the final suite of model runs was completed using a 30-ft curvilinear mesh (e.g. mesh orientation curves to match the meandering of the river) in areas outside of the 50,000 cfs floodplain and project footprint; a 20-ft curvilinear mesh was used for the entirety of the LAR main channel; and a 10-ft curvilinear mesh was used within the C3B project footprint and C3B overbank. The model sensitivity tests showed that the model was not sensitive (i.e., results did not significantly change) to further refinement of these user inputted assumptions.

2.3.3.3 Model Application

Design teams used the calibrated model to simulate existing and design conditions to understand relative impacts of the designs. Proposed designs were evaluated for: (1) post-construction conditions to ensure high flows would not lead to design failure before any vegetation would establish, and (2) long-term fully revegetated conditions to ensure hydraulic capacity would not be impacted. Model simulations included other ARCF16 project improvements and planned work within LAR (e.g., Sacramento Weir, LAR C1 100% design) to ensure the various erosion protection design sites will function collectively and not increase risk at off-site locations. Incorporation of the Sacramento Weir improvements and the recently constructed Site 2-3 within Contract 2 on the LAR into the hydraulic model resulted in lower water surface elevations upstream of Howe Avenue relative to the pre-ARCF16 Project existing conditions. These water surface elevation reductions allowed the Contract 3B design elements to have the minor negative impacts to channel conveyance be offset by the improvements provided by these downstream sites. A direct result of the flexibility provided by the conveyance improvements was the ability to further reduce the Contract 3B design footprint and significant reduction in impacts to vegetation and recreation features upstream of Howe Avenue. For more details on Contract 3B design refinements, please refer to Section 2.5.2.

2.3.3.4 Cumulative Impact Analysis

Overall cumulative impacts to the river system were analyzed in addition to the hydraulic modeling done for each individual site. This analysis was evaluated from two different aspects: (1) understanding the cumulative impact of building multiple projects to the entire river system, and (2) to understand if the project was maintaining or reducing the potential risk of levee overtopping. The cumulative impact analysis reports are provided in Attachment A.

2.3.3.4.1 Cumulative Impacts Hydraulic Modeling

A two-dimensional HEC-RAS model covering the entire area of the LAR, and 15 miles of the Sacramento River was developed containing all of the repair sites and habitat restoration sites, including changes to the Sacramento Weir. These models were run for multiple large flows and compared to modeling efforts of the current system (without repair sites or weir widening) to ensure that the addition of the repairs and habitat restoration did not cause significant (increase greater than 0.1 ft[4]) increases to water surface elevations throughout the entire modeled river system. If results demonstrated an increase in water surface elevations greater than 0.1 ft, a risk assessment would be required to determine the impacts to the system; however, as noted below the model results showed there was a reduction in water surface elevations, so a risk assessment was never required to address that issue.

This modeling effort demonstrated that the implementation of the Sacramento Weir Widening reduced the peak water surface elevations by approximately 1.2 to 1.8 ft within the Sacramento and LAR confluence. This reduction extends to approximately the Watt Avenue bridge on LAR, where reductions of 0.1 ft were seen. These reductions in water surface elevations allowed for installation of critical erosion protection design and habitat restoration in sections of the system that were identified as the highest erosion risk. With the combination of the weir widening, proposed erosion protection, and habitat restoration, the cumulative impacts hydraulic modeling showed that there was an overall reduction in water surface elevations ranging from 0.01 to 0.7-feet.

[4] 0.1 ft is considered significant because it is a measurable increase; changes less than 0.1 ft are considered within the margin of error of the hydraulic models.

2.3.3.4.2 Cumulative Impacts Probability Information

While the hydraulic modeling showed that the overall project would not result in an increase in water surface elevation for the large flood events, the project also checked that the project would be either maintaining the existing overtopping probability or reducing the overtopping probability (AOP – Annual Overtopping Probability – not accounting for geotechnical failures) and levee performance (AEP – Annual Exceedance Probability – accounting for geotechnical failures). Probability for failure was analyzed using the USACE Hydrologic Engineering Center's Flood Damage Reduction Analysis (HEC-FDA) model.

HEC-FDA was used to compute the expected AOP at six critical index locations assuming the levee does not fail prior to overtopping. This data represents the probability of levee failure outcome solely dependent on the effects of changes in conveyance capacity for a given scenario against the current levee height. The AOP results show a slight reduction in the probability of overtopping, meaning the ARCF16 Project was maintaining or reducing the probability of flooding potential to the area behind the levees.

HEC-FDA was also used to compute the expected AEP at four index locations to demonstrate how the assumed levee fragility affects levee system performance. In addition to failure due to overtopping, the AEP incorporates information on the levee's susceptibility to failure prior to overtopping due to erosion, seepage, and slope instability probabilities at a given index location based on levee specific characteristic (such as soil type, hydraulic loading, river velocities, etc.). This data provides a more realistic representation of the overall levee system performance as it can account for both changes in conveyance capacity and the levee improvements proposed under the ARCF16 Project. The AEP results show that the project improvements provide significantly reduce the probability of a levee failure to LAR system.

2.3.4 Geology

The current project geologic model was created using Leapfrog three-dimensional modeling software. The current model utilized the URS-GEI (2013) three-dimensional stratigraphic model of LAR that was developed as part of the 2016 GRR as a base point. The three-dimensional stratigraphic model was developed using geotechnical boring logs, laboratory testing of soil samples, direct current soil resistivity data collected by the USGS (2008) and geologic field mapping data. The objective of the stratigraphic model was to provide the three-dimensional visualization and coordinates of different geologic layers that were then used to inform design and risk assessments related to the potential for erosion on the site. The model focused on identifying locations of highly erodible post-1850 alluvium (e.g., loose deposits of silty sand material generated from historic hydraulic mining in the watershed) as well as the erosion resistant material (ERM), also referred to as the Pleistocene Fair Oaks Formation at LAR C3B. The current geologic model included additional geologic data from LAR borings completed by USACE after the GRR and by DWR as part of the Urban Levee Evaluation program in 2019 in addition to the original stratigraphic modeling from the GRR. Figure 2-7 shows an example of the stratigraphic model.

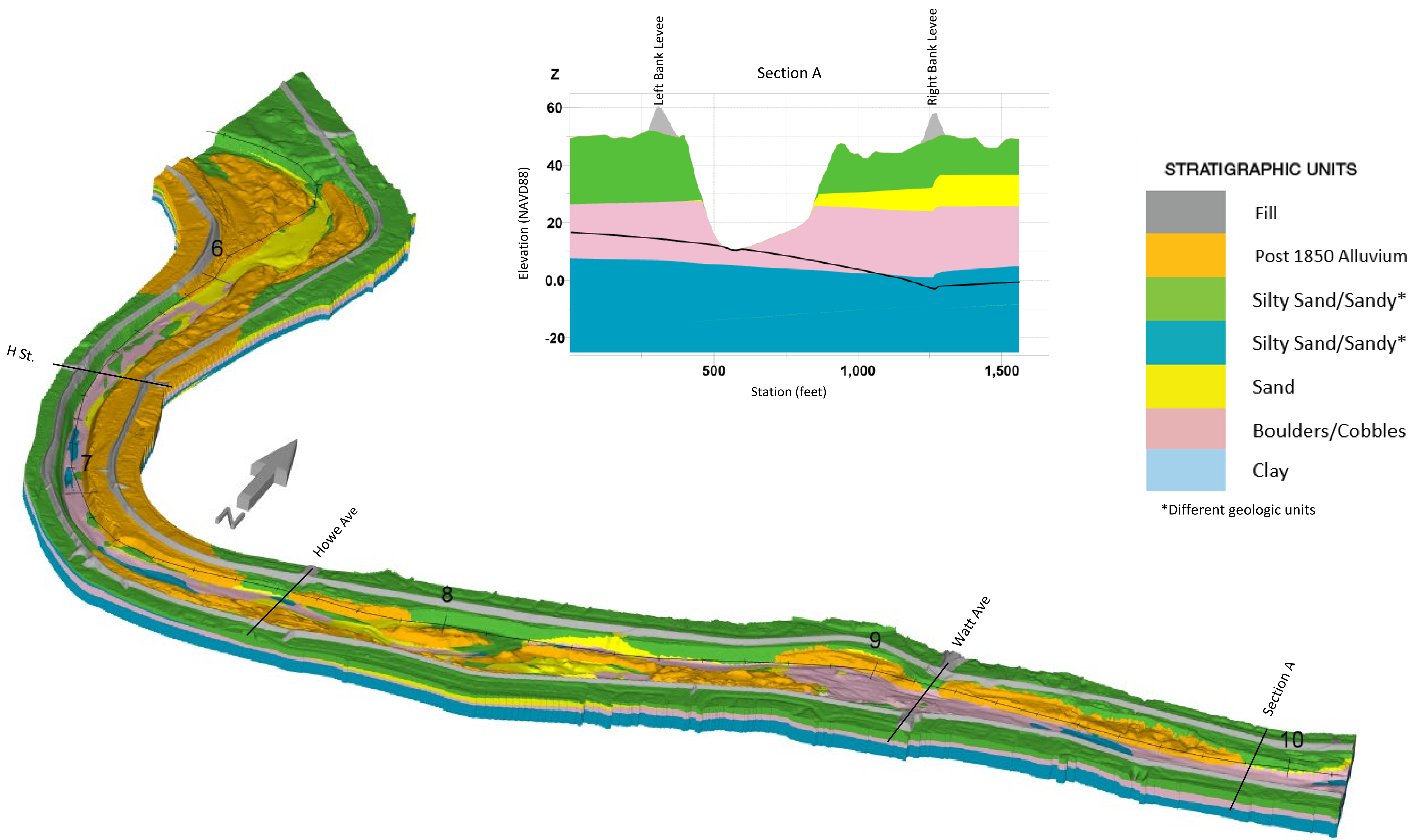


Figure 2-7. Output from URS-GEI (2013) 3D stratigraphic model of LAR extending from Paradise Beach downstream of RM6 and terminating upstream of Watt Avenue at RM 10.1

A supplemental exploration and testing program was completed for the LAR C3B project area in May and June of 2021. Twenty-one pilot borings and 6 companion undisturbed borings were completed in the foundation of the LAR C-3B project to further characterize the sub-surface in Site 3-1 and 4-1 for geotechnical analysis. Borings were collected approximately every 500 to 800-ft within the C3B study area. These borings were terminated after five feet of ERM was observed in each boring. The borings included collection of Standard Penetration Test (SPT) data, disturbed soil samples for classification testing, and undisturbed samples for strength testing and sedimentology logging. The main point of this exploration was to classify the ERM surface, which led to updated stratigraphic modeling by subject matter experts. The ERM surface was updated in 2022 as a result of additional borings collected and refined using ERM outcrop mapping completed during the low water levels in fall 2021. In Fall 2023, a geophysical data collection effort for a portion of Site 4-1 was conducted. The 2023 study used multiple forms of geophysics to map the ERM surface along the river margins and overbank for an isolated section, Segment 3-8.

Additional field sampling of geologic conditions was completed in 2018 and 2019 as part of lateral bank retreat analysis (See Section 2.3.9). This effort focused on classifying soils and measuring the erodibility for the soil material. A variety of collection and testing efforts were pursued to reduce epistemic uncertainty (i.e., uncertainty from limited data and knowledge) inherent in data collection efforts, test methodologies, and lateral bank retreat estimate methods. Additional data for the lateral bank retreat analysis was collected by a variety of agencies. The United States Department of Agriculture (USDA) Agricultural Research Service (ARS) collected information in the fall of 2018 on soil stratigraphy, site topography, unit weight, soil gradation, and bank erosion resistance parameters using the mini-Jet Erosion Test (JET). The USDA effort focused on observed soil near the surface along the main channel riverbank. Conventional drilling was completed on the American and Sacramento rivers near the riverbanks to help categorize soil stratigraphy and obtain bank erosion resistance parameters from project specific samples. The drilling effort was conducted by the U.S. Geological Survey (USGS) in the spring/summer of 2019. The U.S. Army Corps of Engineers assisted in the drilling effort to help categorize soil stratigraphy, collect soil samples, and distribute the collected soil samples. Testing of soil samples from the drilling effort was completed by a U.S. Army Corps soil laboratory at Prado Dam and a soil laboratory at Texas A&M University (TAMU). These efforts are documented in USGS (2020), TAMU (2020), and USDA (2020a).

2.3.5 Documentation of Past Performance

DWR's Urban Levee Evaluation (ULE) was cited for past performance along the levees. URS-GEI (2010) completed a geotechnical evaluation report of the LAR study area, which included approximate locations and year of boils, slides/slumps, cracking, erosion, and seepage. The information compiled in this report included interviews with local levee maintainers and review maintenance records to identify areas, which may have experienced distress between 1986 and 2006. This data was considered in both the Phase I (Section 2.4.1) and Phase II (Section 2.4.2) site evaluations. The DWR Urban Levee Evaluation was completed separately from the ARCF16 Project but provides valuable summary for considering past performance of levees when identifying sites that need erosion countermeasures.

2.3.6 Geomorphic Assessment

A geomorphic assessment was completed in 2018 of LAR to provide an initial broad, long-term perspective on fluvial geomorphic processes in the LAR and identify future channel adjustments over the next 50 to 100 years (Northwest Hydraulic Consultants, 2018). The assessment relied on previous reports prepared for USACE since 1991, academic theses, topographic and bathymetric surveys collected in 1997 and 2008, geologic maps, annual bank erosion assessments, as well as historic and current aerial imagery. The assessment discussed the existing geology, human impacts to the geomorphic process, historical response to those human impacts, as well as direct human impacts on the LAR including instream mining, levee construction, and bank protection. The geomorphic assessment considered both qualitative assessments following the approach of Schumm (1977) and quantitative assessments based on regime-type assessments using approaches provided in U.S. Army Corps of Engineers (1994) as well as additional analysis of sediment transport conditions within the channel to evaluate potential changes to the morphology of LAR over the next 50-100 years.

The contents of this report were utilized in the Phase I Site Evaluations. This geomorphic assessment is provided in Attachment B.

2.3.7 Existing Bank Revetment Condition Assessment

A revetment condition assessment was completed of all existing revetment sites on the LAR (cbec, 2021b). Figure 2-8 shows the locations of all revetments which existed prior to implementation the ARCF16 Project improvements. Historic revetment refers to revetment installed prior to the 1990s and was typically just bare rock and often used rounded cobble stone as revetment. Cobble revetment is more susceptible to failure, or unraveling, and is more easily mobilized during flood events. Modern revetment refers to erosion repair sites that utilized angular quarry stone and included more nature-friendly features such as planting benches, soil-filled quarry stone, soil cover, and ultimately plantings of native vegetation.

The study was broken out into three phases and included reviews of as-built drawings, field investigations, as well has hydraulic modelling and rock size calculations. The intent of the assessment was to verify existing projects, which were designed prior to the current project would remain stable during a 160,000 cfs flood event. Field investigations measured actual rock size that was placed at the project site, as well as measured rock thickness and verified rock extents. Hydraulic information developed from the baseline hydraulic model (see Section 2.3.3) run for 160,000 cfs was used to evaluate if the existing rock would remain stable during the 160,000 cfs event. Reporting was completed in April 2022.

2.3.8 Erosion Assessment

In 2020, erosion assessments were completed to help quantify the risk to the levee (Northwest Hydraulic Consultants, 2020a) (Northwest Hydraulic Consultants, 2020b). Whereas the Geomorphic Assessment delineated the river into subreaches based on river processes, the erosion assessment delineated the right and left riverbanks into segments based on bank and levee conditions. Segments were defined as continuous lengths of bankline with similar soil conditions, revetment designs, vegetation covering, hydraulic conditions, and geometry (bank slope, bench width, etc.). Subreach 3 was delineated into 14 segments, which varied in length from about 0.1 miles to 0.5 miles. Subreach 4 was delineated into 11 segments varying in length from about 0.1 miles to 0.8 miles.

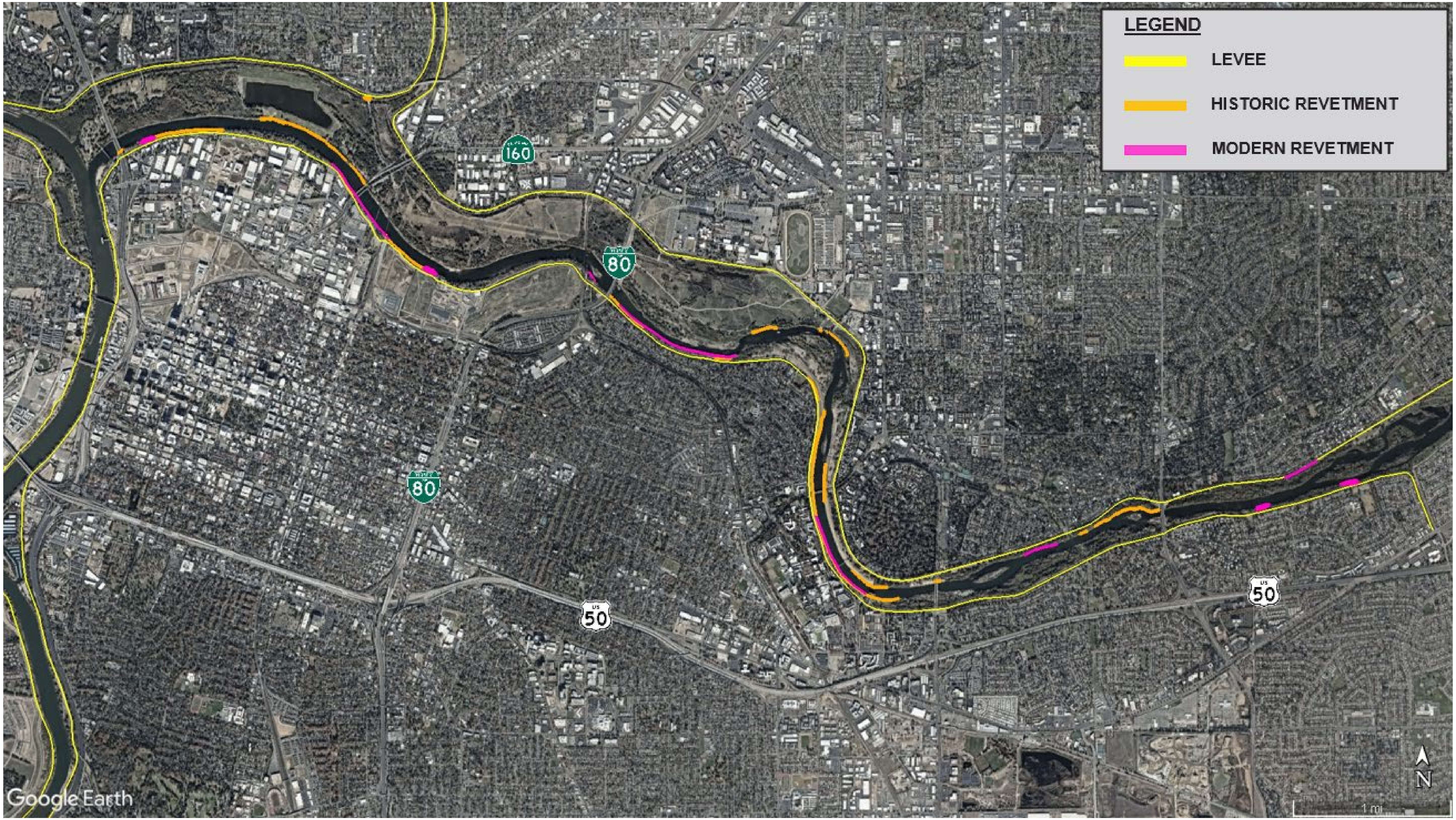


Figure 2-8. Inventory of Existing Revetment

The erosion assessment referred to channel processes identified in the geomorphic assessment and expanded on their potential impacts to individual segments. The evaluation of river processes suggest it is unlikely that long-term river processes will result in significant channel change (e.g., channel width and depth, bar migration, large scale planform changes). However, there is an imbalance between concentrated hydraulic force caused by confining levees and weak channel bank soils that are highly dependent on vegetation for erosion protection. Localized bank erosion could occur during high flow events if vegetation were to fail. The erosion assessment evaluated the potential for these localized failures to occur based on site conditions at each segment.

The erosion assessment focused on individual segments to compare erosive forces to resisting forces during four discrete flow events: 40,000 cfs, 80,000 cfs, 115,000 cfs, and 160,000 cfs. The lower flow events are expected to occur more frequently than the design event and were used to determine if the levee may be susceptible to erosion at more frequent flow events. Information summarized in Section 2.3 were detailed on a segment-by-segment basis to evaluate the erosion potential at each segment. Site visits to each segment were conducted to catalog current conditions, Hydraulic erosive forces were quantified at each segment for each flow of interest and estimated maximum erosion extents for a condition where vegetative cover had failed and bare soil was exposed to a given flow for a duration of three days (The bank erosion modeling described in Section 2.3.9 was completed after the completion of the erosion assessment and provided additional context to the conservative assumptions of the erosion assessment). quantified a Potential scour depth at each segment was also quantified (although long-term incision of the channel is unlikely to occur, general scour-the localized lowering of the channel bed due to channel bends or fluctuating channel geometry- could occur during high flow events). Scour depths were coupled with measured bank slopes to evaluate the potential for slope instability. The erosion assessment evaluated conditions at both the levee face and at the bank toe (see Section 2.1.5 for description of levee and bank).

The erosion analyses generally found most channel banks were subject to some erosion occurring, which is consistent with present day field and historical observations. The erosion analysis for Subreach 1 identified three locations with high risk of erosion and potential to impinge into the levee: RM 2.3 to 2.6 and RM 3.8 to 3.9 on the left (south levee) are at risk to scour and lateral erosion while RM 0.0 to RM 1.3 on the right (north) levee was at risk. For Subreach 3, predicted maximum lateral erosion extents were shown impinge into the levee foundation between RM 8.5 to 10.0 on the left (south) bank, and RM 7.8 to 8.2 on the right bank. In Subreach 4, it was found in several locations that erosion could threaten levee stability between RM 10.0 to 10.5. Installation of bank protection at RM 10.3 to 10.4 in response to mass bank failure demonstrates the vulnerability of this reach. Projected erosion into the levee template occurs in flows as low as 40,000 cfs.

The contents of these reports were utilized in the Phase I Site Evaluations. The Erosion Assessments for is LAR Subreach (i.e., Subreaches 1, 2, 3, & 4) are provided in Attachment C.

2.3.9 Biological Resource Surveys and Assessments

Environmental Science Associates (2020), on behalf of the Project Partners, completed reconnaissance-level field surveys to observe and document the potential occurrence of special status species, aquatic resources, and assess terrestrial and riparian habitats. Field surveys included aquatic resource delineation (documenting wetlands), mapping elderberry shrubs, mapping potential special status bird habitats, protocol level rare plant surveys, tree surveys (documenting species, locations, and size)

Standard Assessment Methodology, and Shaded Riverine Aquatic (SRA) Cover assessments. Environmental Science Associates data was also compiled with the 2019 and 2020 topographic survey for LAR C3B, where that effort also surveyed tree location and tree size. Both of these datasets were used to inform the LAR C3B design development as described in Section 2.5. Similar surveys were also conducted to support LAR C4A. This biological resource survey and assessment report is provided as Attachment D.

2.3.10 Bank Retreat Estimates

Lateral bank retreat estimates are a way to assess the extent of lateral erosion during a high flow event and whether the erosion threatens the integrity of the levee. The erosion assessments (Section 2.3.7) used in the Phase I Site Evaluations (see section 2.4.1) included a conservative analysis of the potential lateral bank retreat using an event-based erosion assessment methodology. This methodology includes potential for slope failure of the bank due to scour at the bank toe, erosion of the bank, slope failure of the levee due to scour, and erosion of the levee. The potential erosion extents were quantified for each flow rate at each segment as a function of the underlying soil types and applied hydraulic shear stresses. The vertical extents of scour are estimated at both the bank and levee toe. Fluvial erosion was quantified as a lateral extent into the bank or levee face. This estimate used an initial project 2D hydraulic model and the best available data at the time including published values of soil properties (e.g., soil critical shear stress and erodibility coefficient).

For Phase II Site Evaluations (see section 2.4.2), additional probabilistic lateral bank retreat estimates were developed for segments deemed as moderate to high-risk overall erosion potential to refine the bank retreat estimate for site-specific project conditions. The probabilistic bank retreat estimates for Phase II Erosion Analysis used:

1. Project-specific soil properties collected as part of this study (Section 2.3.4).
2. Vegetation cover effects on soil erodibility.
3. BSTEM (Bank Stability and Toe Erosion Model), a bank retreat estimating tool developed by USDA-ARS that can provide probabilistic bank retreat estimates.
4. Soil erosion parameters based on calibration to observed erosion (Section 2.3.4).

The previously discussed sampling and testing program (Section 2.3.4) was developed along the American and Sacramento Rivers to inform development of inputs to bank retreat estimates in partnership with the USGS, USDA-ARS, and Texas A&M University. See Rivas et al. (2021a) and Rivas et. al. (2021b) for additional details on the soil sampling and testing and development of soil erosion parameters for lateral bank retreat estimates. The lateral bank retreat analysis also included the effects of vegetation on the bank by using a vegetation cover factor. See Rivas et. al. (2021c) for additional details on application of the cover factor for bank retreat estimates.

BSTEM is a model produced by the USDA-ARSARS (Simon, Pollen-Bankhead, & and Thomas, 2011), (Klavon, et al., 2017)). The BSTEM model includes both erosion of the soil by flowing water (fluvial erosion) and slope stability failures to estimate total bank retreat. BSTEM was used to estimate the bank retreat at sites on the LAR for a number of different scenarios. BSTEM has the capability of incorporating different bank geometries and hydraulic conditions and therefore is a useful tool for determining locations in need of erosion countermeasures and informing designs of erosion countermeasures. The application of BSTEM for this project includes assessing the amount of bank retreat resulting from different Annual Chance Exceedance (ACE) events for existing bank conditions and proposed design conditions. A benefit of using BSTEM is the ability to model conditions that do not currently exist and ACE events that have not occurred and to account for the uncertainty of model inputs.

USDA-ARS developed the stochastic (i.e., "probabilistic") version of BSTEM and has adapted BSTEM for the purposes of this project (Rivas, et al., 2019). The BSTEM model was calibrated at sites with measured erosion during the 2017 flood event using an objective and repeatable calibration and validation procedure. BSTEM calibration is achieved using a constrained calibration technique at areas of measured erosion. The application of the resulting calibrated parameters to other sites within the study area with similar soil properties was successfully validated. See Rivas et. al. (2021c) for additional details. The calibration effort reduced the uncertainty of key lateral bank retreat soil properties (USDA (2021)), providing greater confidence in the results.

BSTEM has Monte-Carlo type (stochastic) model capabilities important for accounting for uncertainty of key bank retreat estimate inputs. The BSTEM stochastic version as applied to this project uses a probability distribution of the critical shear stress and erodibility coefficient developed from project specific soil sampling and testing and model calibration at sites with observed erosion. BSTEM randomly samples values of the critical shear stress and erodibility coefficient from the probability distribution to develop 500 unique model runs. The results of the 500 model runs produce estimated bank retreat profiles for different non-exceedance percentiles. For simplification, the non-exceedance percentiles will be referred to simply as percentiles. For example, the 50th percentile represents the median amount of bank retreat expected to occur while the 99th percentile represents more expected erosion where only 1% of the modeled profiles exceed this profile and most of the 500 model runs (99%) are less than this profile. The results of the BSTEM stochastic models were provided to a risk cadre during Phase II site evaluation to inform their baseline levee risk assessments (as explained in Section 2.4.2). The BSTEM results are one tool aiding in development of a final minimum erosion protection footprint.

2.4 Site Evaluations and Selection

As discussed in Section 1.8, site selection was completed in a two-phase process. Phase I included an EOE based on existing data and preliminary analysis to develop initial recommendations for sites to be repaired. The Phase II analysis included baseline risk assessments completed at each segment using additional information acquired and developed via new investigations and analyses to expand on the preliminary studies used in the Phase I analysis.

2.4.1 Phase I Site Evaluations – Relative Risk Tier Rankings

Phase I Site Evaluations were developed via an inter-agency working group referred to as the Technical Resource Advisory Committee (TRAC). The TRAC included members from USACE, NMFS, USFWS, Sacramento County Parks, NPS, DWR, SAFCA, and their consultants. The TRAC is a multi-disciplinary group, which includes water resource engineers, geotechnical engineers, geoscientists, biologists, and ecologists. The TRAC developed analysis to support the Phase I Site Evaluations including the Geomorphic Assessment, Erosion Assessment, and initial bank retreat estimates. USACE has successfully worked with similar groups on the LAR on past projects to develop bank protection designs, which reduced habitat impacts and replaced impacted habitat within the designs.

Two EOE's were conducted for LAR to help identify relative risks between levee segments and identify priority segments for erosion countermeasures. The first EOE focused solely on segments in Subreach 2 and was completed in 2017. The second EOE included all segments from Subreaches 1, 3, and 4 and was completed in 2019. Both EOE panels included the same five local experts with extensive experience working on LAR and flood control projects. USACE incorporated additional national experts onto the Subreach 1, 3, and 4 EOE. Both EOE assessments were largely based on the information presented in Appendix A of the erosion assessments developed for each subreach (Section 2.3.7), as well as additional information on past performance (Section 2.3.5), and individual experts experience and observations. After completion of the formal EOE process, the TRAC assigned a Tier ranking to each segment. Figure 2-9 shows all of the segments within the LAR with their corresponding tier ranking. As already discussed in Section 1.8, Tier 1 includes segments that have the highest risk of erosion and are subject to an immediate threat to the levees during high flows. Tier 2 includes segments that are not subject to an immediate threat to the levee but are anticipated to reach that condition after one or more high flow events (during the 50-year design service life of the project). Tier 3 includes the remaining segments that are not considered subject to an erosion threat that could lead to levee breach (during the 50-year design service life[5] of the project).

2.4.2 Phase II Site Evaluations – Risk-informed Site Selection

Baseline risk assessments were completed for all the segments in subreaches 1, 2, 3, and 4 between November 2019 and December 2020. Baseline risk assessments determine the levee breach flood risk without any new construction of erosion countermeasures. The baseline risk assessments relied on similar information as the Phase I Site Evaluations, but included additional information developed after the Phase I Site Evaluations. This information included additional geologic information on soil erodibility (Sections 2.3.4 and 2.3.6), probabilistic bank retreat estimates (Section 2.3.10), further assessments of the existing revetment (Section 2.3.7), and continued refinements to the hydraulic model (Section 2.3.3). The baseline risk assessments assigned annual probability of failure due to erosion to each levee segment. Uncertainty associated with risk estimates along the LAR was generally higher because the performance of the system at design flood levels has not been proven, whereas on the Sacramento River the levees have experienced design flood flows on several occasions. After reviewing all available information from the Phase I and Phase II site evaluations, USACE identified segments for erosion protection where the probability of failure exceeded project objectives.

The findings of the baseline risk assessment completed during the Phase II Site Evaluations confirmed the recommendations of Tier 1 segments identified by the Phase I Site Evaluations. The baseline risk assessment also identified three additional locations that did not meet risk objectives. The additional sites identified in the baseline risk assessment were identified after more detailed modeling was completed for sites after completion of the Phase I Site Evaluations.

[5] The 50-year design service life is based on the life cycle established within the GRR feasibility report.

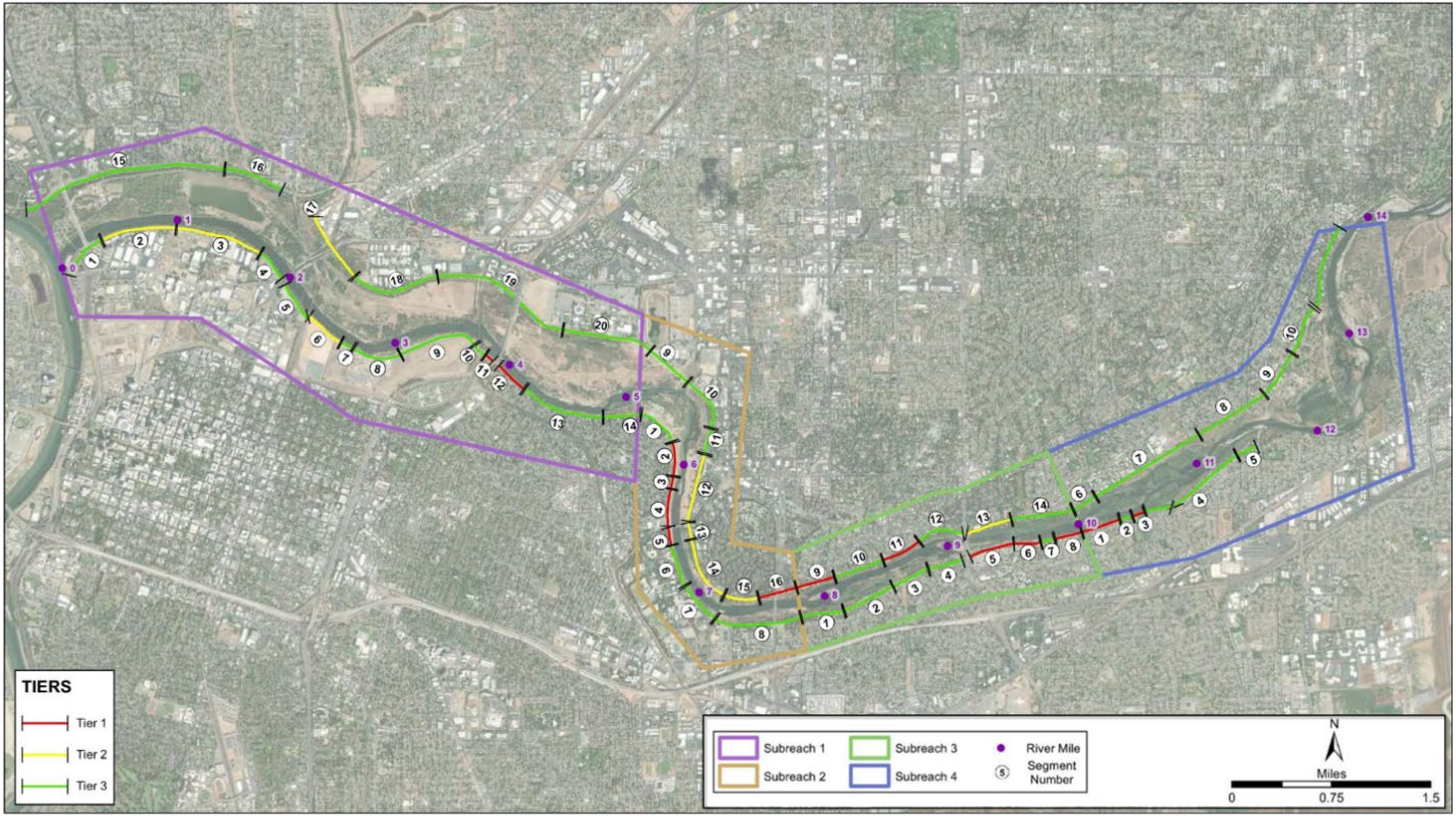


Figure 2-9. LAR segment ranking result

2.4.3 Summary of Site Selection

Based on the results of both the Phase I and Phase II Site Evaluations, USACE Sacramento District identified which segments required erosion protection improvements and developed its implementation strategy for design and construction of erosion protection at those locations along LAR. The overall strategy was to construct improvements at the highest risk sites first. Table 2-1 summarizes the segments that were identified for erosion protection and their corresponding repair site and contract. Figure 2-10 identifies the locations of erosion protection improvement contracts. All the LAR erosion protection projects, including those constructed (Contract 1 and Contract 2) and under construction (Contract 3A), will result in 6 of the 11 authorized miles being improved along LAR. The remaining 5 miles authorized for improvement were determined to meet project risk objectives as they currently exist.

Table 2-1. Final site selection

Contract	Site	Segment
LAR C1[1]	Site 2-1	Subreach 2, Segment 2 (a.k.a. Segment 2-2)
	Site 2-1	Subreach 2, Segment 3 (a.k.a. Segment 2-3)
	Site 2-1	Subreach 2, Segment 4 (a.k.a. Segment 2-4)
	Site 2-1	Subreach 2, Segment 5 (a.k.a. Segment 2-5)
LAR C2[1]	Site 2-3	Subreach 2, Segment 12 (a.k.a. Segment 2-12)
	Site 2-3	Subreach 2, Segment 13 (a.k.a. Segment 2-13)
	Site 2-3	Subreach 2, Segment 14 (a.k.a. Segment 2-14)
	Site 2-3	Subreach 2, Segment 15 (a.k.a. Segment 2-15)
	Site 2-2	Subreach 2, Segment 16 (a.k.a. Segment 2-16)
LAR C3A[2]	Site 1-1	Subreach 1, Segment 11 (a.k.a. Segment 1-11)
	Site 1-1	Subreach 1, Segment 12 (a.k.a. Segment 1-12)
LAR C3B	Site 3-1	Subreach 3, Segment 9 (a.k.a. Segment 3-9)
	Site 3-1	Subreach 3, Segment 11 (a.k.a. Segment 3-11)
	Site 4-1	Subreach 3, Segment 5 (a.k.a. Segment 3-5)
	Site 4-1	Subreach 3, Segment 6 (a.k.a. Segment 3-6)
	Site 4-1	Subreach 3, Segment 8 (a.k.a. Segment 3-8)
	Site 4-1	Subreach 4, Segment 1 (a.k.a. Segment 4-1)
	Site 4-1	Subreach 4, Segment 3 (a.k.a. Segment 4-3)
	Site 4-2	Subreach 3, Segment 14 (a.k.a. Segment 3-14)
	Site 4-2	Subreach 4, Segment 6 (a.k.a. Segment 4-6)
	Site 4-2	Subreach 4, Segment 7 (a.k.a. Segment 4-7)

Contract	Site	Segment
LAR C4A	RM 2.0	Subreach 1, Segment 17b (a.k.a. Segment 1-17b)
LAR C4B[3]	Site 3-1 and Site 4-1	Subreach 3, Segment 8 (a.k.a. Segment 3-8)
	Site 3-1 and Site 4-1	Subreach 3, Segment 11 (a.k.a. Segment 3-11)
	Site 3-1 and Site 4-1	Subreach 4, Segment 1 (a.k.a. Segment 4-1)

[1]LAR C1 and C2 have already been constructed and are not subject to the contents of this SEIS/SEIR
[2]LAR C3A is currently under construction and is not subject to the contents of this SEIS/SEIR.
[3]LAR C4B considers similar segments to those in LAR C3B but focuses on protecting trees within the USACE designated Vegetation Free Zone which requires additional review from USACE Headquarters as discussed in Section 2.5.4.

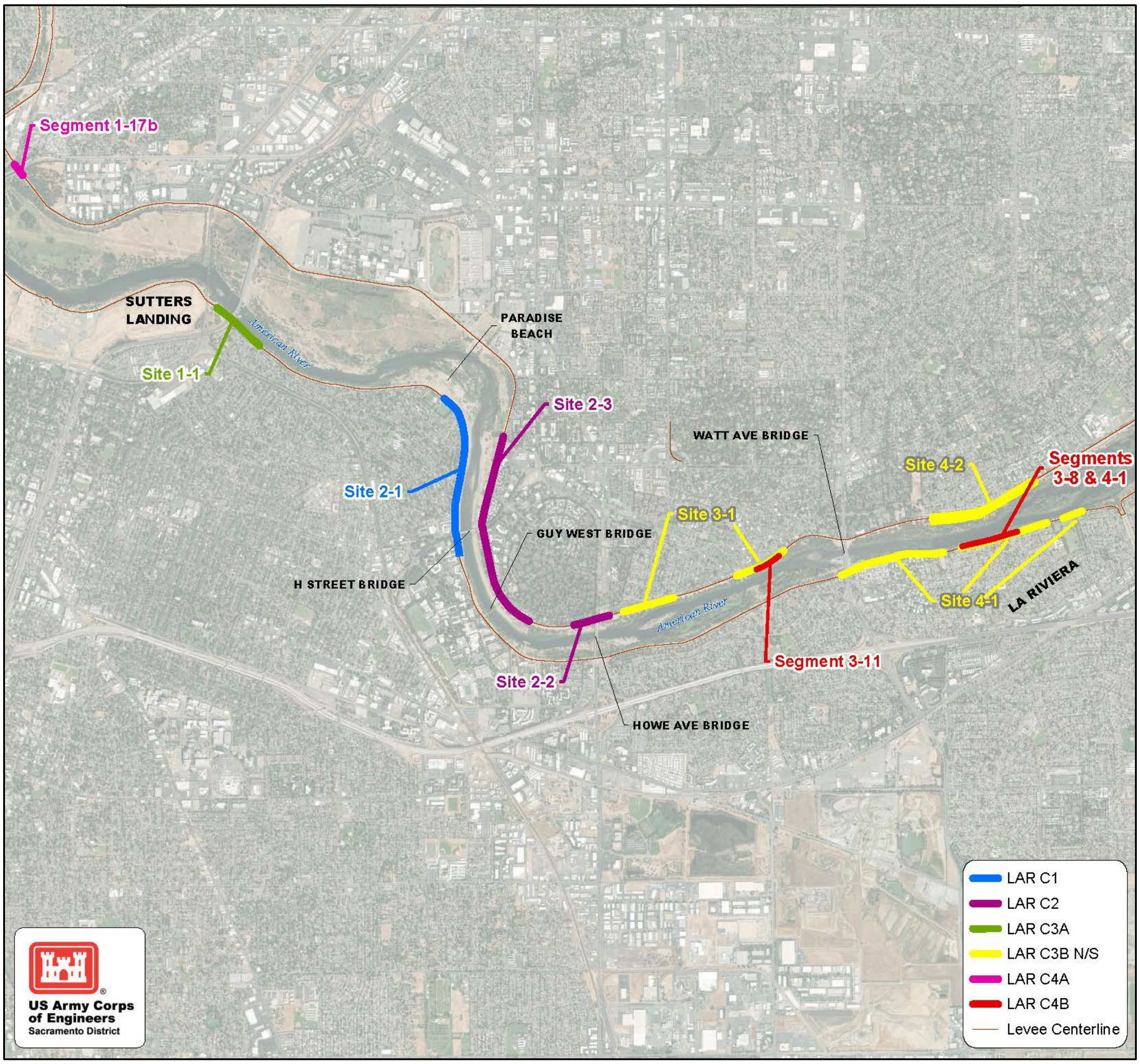


Figure 2-10. Summary of ARCF 2016 erosion projects on LAR

The identified sites include some locations that are not currently experiencing bank failure or accelerated erosion. Rather these sites have local conditions where the risk of erosion occurring and compromising levee stability during a high flow event are unacceptably high given the potential public safety risk if the levee were to fail. Some of these sites appear well vegetated under existing conditions and it was recognized by the expert panel and Risk Cadre that trees and other vegetation do reduce risk to bank erosion. However, failure of vegetation during high flow events can expose underlying erodible soils to erosion, and the affects of vegetation often does not extend much below summer water levels. Both the expert panel and the Risk Cadre considered the potential for vegetation to remain in place during high flow events, the potential for vegetation to fail due to being undercut on steep banks, toppled by high velocities or otherwise. This information was coupled with the potential for erosion to progress to a point where it compromised levee stability to determine where erosion protection is required. Section 2.5 provides a summary of the design process, and further details the risk drivers identified at each segment and the approach to address these conditions.

2.5 Design Development

2.5.1 Overview and Process

Erosion protection designs were developed incrementally with key milestones at the 10%, 35%, 65%, 95%, and 100% plans. The intent of each milestone was to provide the project partners with an opportunity to review and comment on the design. Each subsequent submittal adds additional detail to the design, in addition to addressing comments from previous submittals. Both LAR C3B and LAR 4A were developed from the initial alternative selection to their current design working with multi-disciplinary and multi-agency stakeholder groups. The entities involved in these reviews and design development are discussed further with each contract, below. In addition to these groups, the designs were also reviewed by the Risk Cadre to ensure proposed design conditions met project risk reduction objectives, internal USACE reviews for consistency with design standards (Section 1.7.2) and regulatory requirements (Section 1.7.3 and 2.2.1). Since LAR C4B is still refining the footprint, outreach to discuss development has not yet occurred but will begin in 2025 as site specific information is developed.

2.5.2 Contract 3B

Erosion protection and on-site habitat mitigation designs for LAR C3B were initially developed via the TRAC, advanced by a multi-disciplinary USACE design team, and subsequently reviewed by TRAC members and other multi-agency review staff at design milestones. The TRAC provided initial recommendations for design approaches and provided review and comment throughout the design process.

The TRAC developed initial recommendations for LAR C3B in 2019 based on a comprehensive subreach approach to address erosion concern at each Tier 1 and Tier 2 river segment). Initial concepts were developed for Tier 1 and Tier 2 segments and their hydraulic and resource impacts were quantified. The

TRAC evaluated which combination of conceptual designs or alternatives would limit short-term impacts and provide the best long-term resource conditions without having impacts to the conveyance capacity of the LAR (e.g., not increase the likelihood of overtopping). The final recommended design approach for each segment within LAR C3B was provided by the TRAC as 10% designs. All designs included rock protection.

The hydraulic benefits from other project features including the Sacramento Weir improvements and Site 2-3 (designed under Contract 2 of this project) were still being quantified at the 10% design completion for LAR C3B. These two projects feature lower water surface elevations upstream and at the LAR C3B Contract sites. This reduction in water surface allowed designs from the start of the 65% design phase in LAR C3B to have additional flexibility to incorporate design features that created minor increases in water surface elevations (e.g., wider planting benches, etc.)) that were not considered originally by the TRAC at the 10% milestone. This hydraulic assessment was completed in part by the cumulative hydraulic modeling efforts discussed in Section 2.3.3.

Between the 10% and 35% design, the LAR C3B design footprint increased to account for site access (e.g., haul routes for constructability) and included review feedback from Risk Cadre elicitation. This increase in footprint was primarily at segments where a buried launchable trench feature was proposed in the overbank. A part of the LAR C3B 35% submittal and every subsequent design submittal included assessing the habitat impacts for that design proposal. Several TRAC member representatives and SAFCA, DWR, and USACE Project Delivery Team (PDT) members held a LAR C3B design Charrette with representatives of DWR, NPS, NMFS, USFWS, and Sacramento County Parks after completion of the 35% designs to revisit the assumptions of the 10% design, account for updated program design criteria, and identify if alternative design concepts would reduce short term habitat impacts. Ultimately, LAR C3B designs at Site 3-1, and in Site 4-1 were adjusted at the 65% design phase to reduce habitat and resource impacts. These improvements are discussed in Section 2.5.2.4 below.

The placement of revetment and project features was limited to locations needed to address the primary risk drivers at each segment based on local site features and attributes. The PDT presented information to the review teams, TRAC, and Risk Cadre for input and evaluation as more detailed information of design conditions and refinement of analysis tools (e.g., hydraulic modeling, slope stability modeling, bank retreat estimates, vertical scour analysis, ERM stratigraphic modeling, etc.) at critical and nominally spaced sections of the project sites were developed. This allowed for a further reduction in the design footprint throughout the design development phases, while ensuring the design would meet the life-safety objectives of the project (Section 1.7.1). Effectively the Risk Informed Design is included and was utilized to find the minimum erosion protection footprint to meet flood risk objectives.

In additional to the design accounting for erosion protection features, on-site habitat design features are also included and leverage assessment of past erosion protection projects within the basin. LAR C3B on-site habitat features include planting benches designed for ecological based flow conditions and include in-stream woody material, soil filled revetment, placing a topsoil lift above the soil filled revetment, a replanting plan. The rock-based bank protection will not only protect the levee from erosion, but it will also protect existing vegetation left undisturbed by construction from erosion, too, and will also expand the bankline waterward and provide more space for vegetation to establish than previously existed. Gravel will also fill in gaps of larger angular launchable toe on the waterside face of planting benches. The surface of the planting bench above the summer water levels will include coir fabric in place of cobble while vegetation is established. This change in design from cobble to coir fabric was based on review comments received from Sacramento County Regional Parks at the 95% design phase.

2.5.2.1 Design Coordination and Collaboration

The LAR erosion protection improvements are being designed and implemented in stages (i.e., multiple construction contracts). To ensure that the design contracts are developed consistent with the requirements of the Federal and State WSRA's, the Endangered Species Act, and other requirements, the C3B design team coordinated with NPS, Sacramento County Parks, NMFS, USFWS, and other regulatory agencies throughout the design process and when designs reached 10%, 35%, 65%, and 95% levels. This collaboration and coordination results in an iterative conversation between the design team and the other agencies – presentation of design, receipt of suggestions and other feedback from reviewing agencies, design adjustments and additional engineering analysis, followed by a new agency review of the refined design. Table 2-2 highlights concerns raised by reviewing agencies and strategies adopted by the design teams to address the concerns.

Table 2-2. Influence of collaboration on the Lower American River Designs

Concern	Strategy
Habitat loss	• Minimized footprint • Replant habitat onsite - Revegetate with native species • Replant habitat offsite • NMFS collaboration to ensure design meets requirements for anadromous fish and fishery • Establish planting benches with variable elevation to enhance fish habitat • Instream Woody Material for aquatic habitat • Selection of native plants to be used for revegetation • Native plant selection to restore habitat and aesthetics (consistent with American River Parkway Plan)
Recreation short term impacts	• Design user friendly pedestrian and bike detours • Consistent with American River Parkway Plan for recreation
Aesthetic impacts	• Design buried erosion control features to minimize exposed rock • Cover rock with topsoil and revegetate with native species
Tree removal	• Selective, minimal tree removal • Preservation of most heritage oaks by footprint adjustments • Replant with native species
Noise/Vibration Dust & Traffic impacts	• Temporary construction impacts mitigated through various contractor controls and protocols

2.5.2.2 Tying into Existing Modern Revetment

The LAR C3B project footprints tie-in to four modern revetment sites that were constructed to stabilize active erosion occurring on the stream banks. These existing, modern revetment sites include are found in Segment 3-10 (called site 8.7R in historic documentation), Segment 3-7 (called Site 10.0L in historic documentation), Segment 4-2 (called Site 10.6L in historic documentation) and Segment 4-6 within Project Site 4-2. These revetment sites were constructed between the years 1999 and 2011.

- Segment 3-10 is located approximately between RM 8.1 and 8.5 on the north bank and includes an existing revetment feature (also called Site 5 or 8.7R). The existing revetment was installed in 1999 due to the 1997 flood event, which had a peak flow of 117,000 cfs. This segment includes the existing cobble lined bank with an angular riprap toe.
- Segment 3-7 is located approximately between RM 9.7 to 9.8 on the south bank and is an existing revetment site (also referred as 10.0L). The existing revetment site includes soil-filled riverbank revetment and a planting bench with launchable rock toe installed in 2011.
- Segment 4-2 is located approximately between RM 10.3 and 10.4 and is an existing revetment site (also referred as 10.6L). The existing revetment site includes soil-filled riverbank revetment and a planting bench with launchable rock toe installed in 2011.
- Segment 4-6 is located approximately between RM 10.0 and 10.2 on the north bank.

2.5.2.3 Contract 3B Site 3-1

Contract 3B Site 3-1 is located on the right (north) bank upstream of Howe Avenue. Figure 2-11 shows the location of Site 3-1 and the proposed bank protection footprint based on the 95% designs.

2.5.2.3.1 Identified Risk Drivers

As discussed in Section 1.6, the probable failure modes related to erosion with the ARCF16 Project include: PFM2 (Erosion of the levee leading to a levee breach),) and PFM3 (Erosion of the levee foundation). At Site 3-1, the primary risk driver is PFM3 erosion into the levee foundation. The existing site, approximately 1,200-ft upstream of the Howe Avenue Bridge, has a narrow bench that is less than 100 feet in areas with steep banks 30 feet in height. Vegetation being undercut along the toe of the bank, and vegetation toppling on the bank were observed in the field. The levee prism is located within 50 feet to 100 feet of the bank toe along much of the site. Hydraulic conditions at 160,000-cfs are sufficient to initiate erosion of the silty sand riverbank and levee foundation material.

At the downstream extent of Contract 3B Site 3-1, the risk driver includes both PFM3 and PFM2.

2.5.2.3.2 Design Alternatives

For each river segment within Site 3-1, the genesis of designs included TRAC developing 10% design concepts for the USACE design team to advance, and 35% review by the TRAC, partners, and review teams. Based on input from the TRAC and other reviewers on the 35% design, the 35% design footprint was determined to be too expansive and would cause an unacceptable level of impacts to habitat and recreational features within the parkway. To address this problem, the PDT worked with members of the TRAC, project partners, and Risk Cadre to adapt designs at the start of the 65% design phase to meet risk objectives but minimize habitat impacts. A design charette was held with engineers and resource managers at USACE, SAFCA, DWR, NMFS, USFW and Sacramento Regional Parks to discuss, evaluate and select a preferred type of erosion protection treatment for each river segment to minimize habitat impacts and meet erosion risk objectives. In general, resource managers evaluated that a feature constructed along the riverbank would preserve or protect the bench/overbank and parkway amenities and the constructed erosion protection feature would include on-site habitat mitigation and a robust revegetation plan. The outcomes of the design charette at the start of the 65% design phase were also briefed at TRAC and Bank Protection Working Group forums to identify fatal flaws and gain additional input before 65% designs were advanced. During the 65% and 95% design phases, a variety of field visits with partner inclusion were held to refine design layout to minimize local impacts. Subsequently each design phase included assessing habitat impacts and completing formal review from multiple review

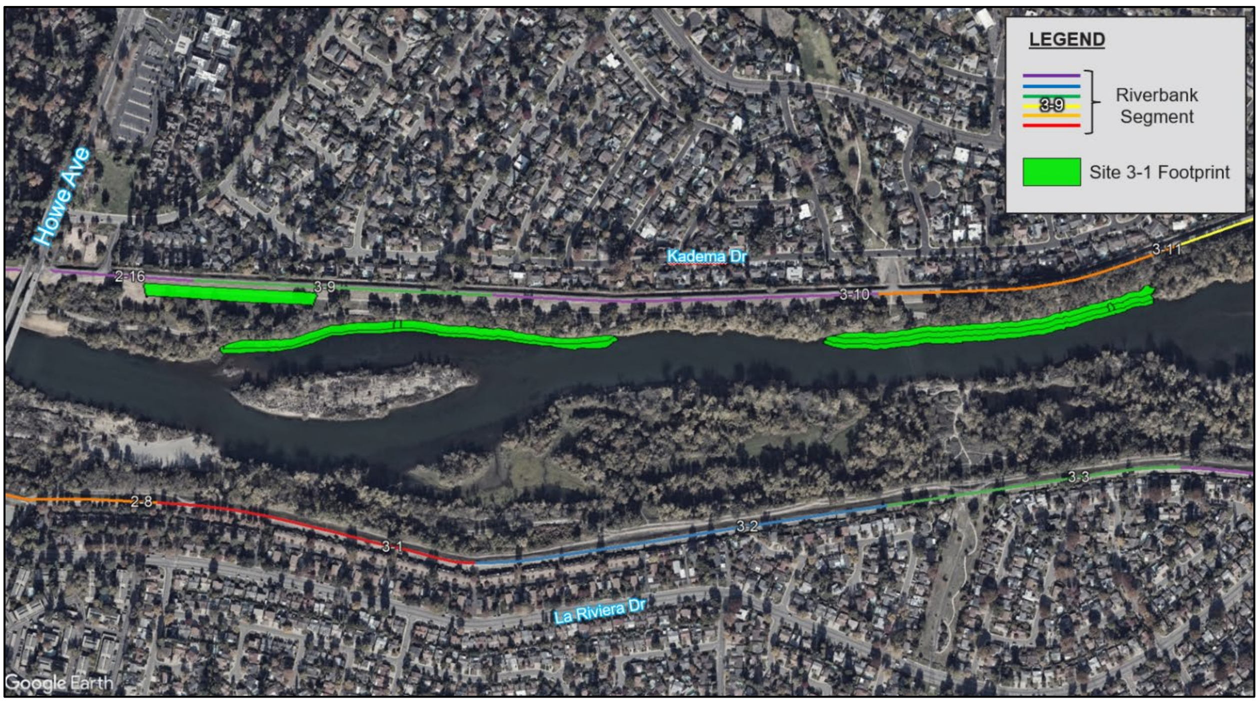


Figure 2-11. Site 3-1 overview map

teams and agencies. Incrementally from the 10%, 35%, 65%, 95% to 100% design phase, design features and analysis tools were evaluated and refined to arrive at the minimally sized erosion protection feature to meet flood risk objectives and minimize impacts. A more detailed discussion of design alternatives considered and advanced for each river segment is discussed below.

At segment 3-9, three alternatives were originally considered by the TRAC at the 10% concept phase: (1) buried launchable trench at the levee toe, (2) launchable toe with planting bench and soil filled riverbank revetment along the riverbank, and (3) excavating the existing in-channel island and placing cut material to widen the existing bench while moving the river further away. The initial TRAC recommendation was to remove the island (i.e., Alternative 3) and widen the existing bench as this provided some hydraulic relief to the project and could reduce the need for rock along the edge of river. Due to the high impacts of removing the island, the additional channel conveyance from downstream

Site 2-3 allowing some hydraulic impacts at the site, and the inclusion of rock protection in the 35% design, the USACE design team adjusted the design concept at Segment 3-9 at the start of the 65% design phase to include a planting bench and soil filled revetment along the riverbank (e.g., TRAC option 2 above). This design adjustment was vetted at the 65% design charette and subsequent briefings to the TRAC and Risk Cadre.

At Segment 3-11, the TRAC only considered two alternatives at the 10% concept phase: (1) buried launchable trench at the levee toe, and (2) launchable toe with planting bench and soil filled riverbank revetment along the riverbank. The TRAC recommended Alternative 2, the launchable toe with planting bench and soil filled riverbank revetment, for the design team to advance.

At both Segment 3-9 and Segment 3-11, the footprint for the buried launchable trench feature at the levee toe would require the removal of most, if not all, vegetation on the bench/overbank and was not preferred at this location due to the high short-term impacts and lack of long-term resource benefits. TRAC members considered and evaluated that for the buried launchable trench feature placed away from the riverbank, the overbank bench and parkway amenities could still be lost after a high flow event and the end state would be a rock bankline.

2.5.2.3.3 Proposed Design

Segment 3-9 includes a soil-filled levee embankment revetment feature for the most downstream portion of the levee embankment slope within this segment. The feature is similar to the proposed revetment in Site 4-2 and illustrated in Figure 2-29 below in Section 2.5.2.5.3. This feature will protect the levee embankment from PFM 2 erosion into the levee face. Soil-filled rock will be placed on the levee face and toe, be covered with one-foot of topsoil and be re-seeded with native grasses. The layout of this erosion protection feature limits removal of existing trees.

In Segment 3-9 and in Segment 3-11 the design also includes bank protection focused features, specifically a launchable toe with planting along the river margins and soil filled riverbank revetment extending up for a portion of the existing riverbank height. The soil-filled revetment includes a 12-inch soil lift and will be replanted. These designs are similar to the intent and layout of the 10% designs developed by the TRAC. The planting bench and revetment will be vegetated via a separate greening contract. The revetment is designed to remain stable during large events and prevent erosion of the bank toe from compromising the upper bank or extending into the levee foundation and the levee embankment itself. The top elevation of the rock was limited to what was needed to meet the flood risk objective and minimize resource impacts. Although erosion could occur above the top of rock, the erosion would be unlikely to extend into the levee and induce levee failure per Risk Cadre assessments and output from analysis products. Reducing the revetment height limits project impacts to the existing resources. The planting bench extends down to typical summer water levels and replaces vegetation that must be removed to implement the project. Planting bench rock tiebacks will be placed periodically on the planting benches to minimize longitudinal erosion or scalloping between the tiebacks if it occurs and allow for variability in the top elevation of the planting benches. Instream woody material (IWM) will be installed on top of the planting benches to provide habitat for salmonids until planted vegetation establishes.

Figure 2-12 to Figure 2-15 provide example renderings of bank protection designs on the riverbank within Site 3-1, showing the launchable toe with planting bench and soil filled riverbank reverent feature, and maturation of the revegetation effort. It also depicts protected vegetation and recreational amenities above the proposed bank protection feature. This rendering does not show the proposed 925-ft section of work along the levee embankment closer to Howe Avenue discussed earlier in this Section. In the plan view graphic for each segment, the existing trees that are to be preserved in place are depicted as green circles.

Figure 2-12. Layout of Segment 3-9 erosion protection features and cross section location

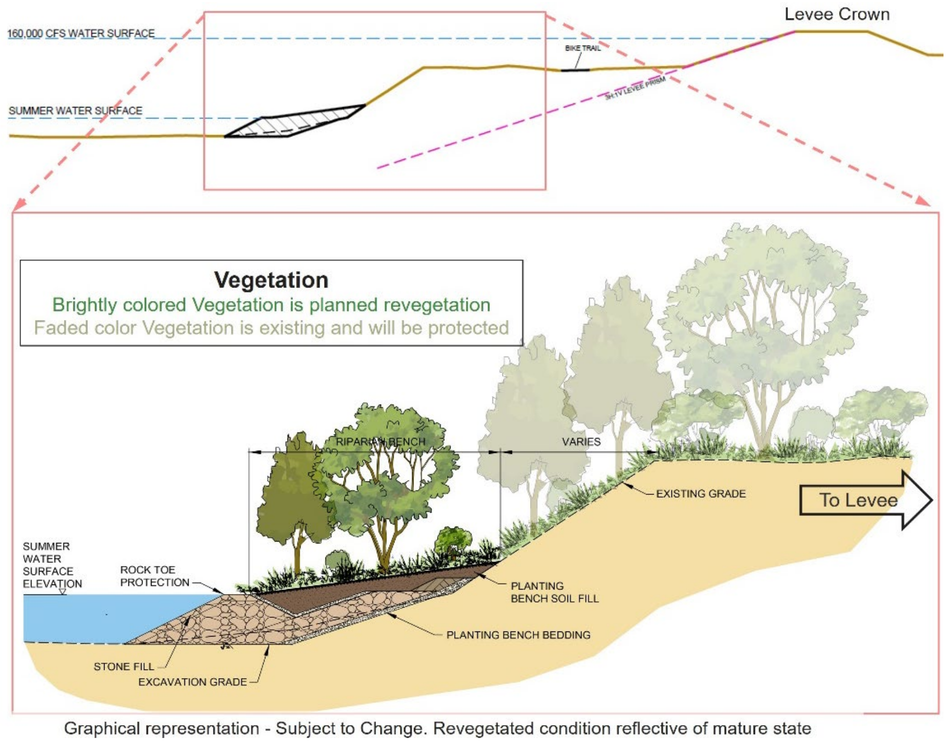
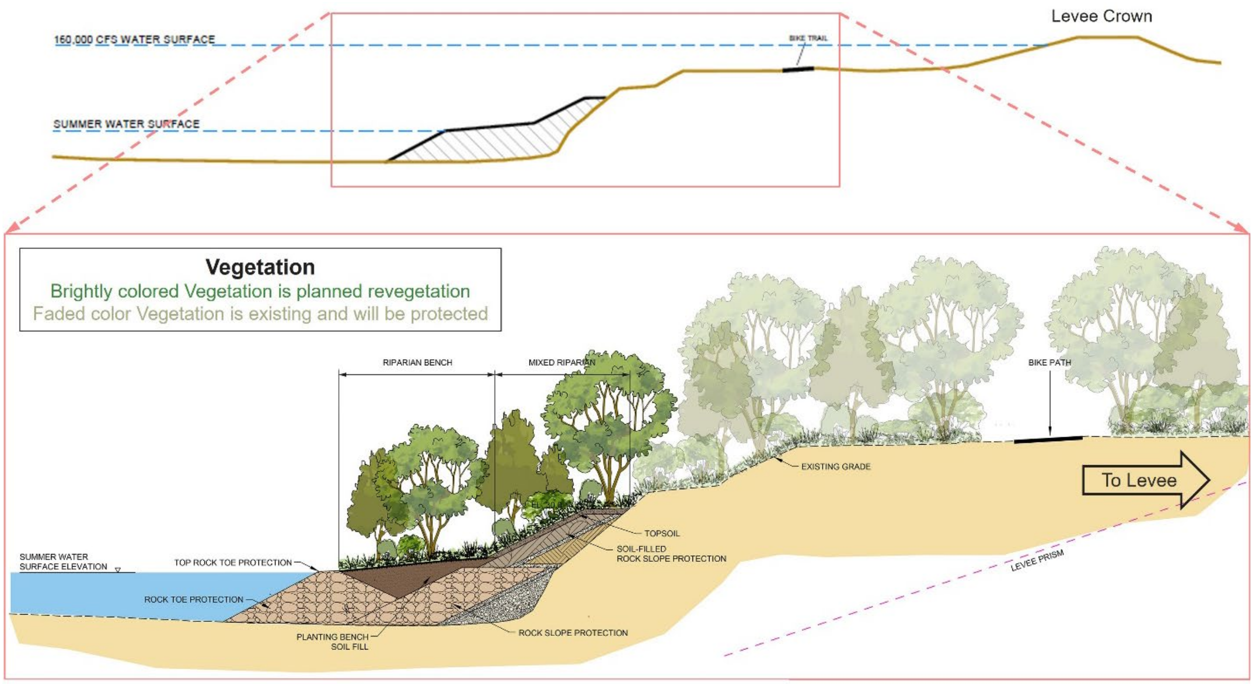


Figure 2-13. Segment 3-9 rendering of erosion protection feature

Figure 2-14. Partial Layout of Segment 3-11 erosion protection feature and cross section location



Graphical representation - Subject to Change. Revegetated condition reflective of mature state

Figure 2-15. Segment 3-11 rendering of erosion protection feature

2.5.2.4 Contract 3B Site 4-1

Contract 3B Site 4-1 is located on the left (south) bank upstream of Watt Avenue. Figure 2-16 shows the location of Site 4-1 and the proposed bank protection footprint based on the 95% designs.

2.5.2.4.1 Identified Risk Drivers

Site 4-1 includes five separate river segments for repair. The segments each have different site conditions resulting in unique risk drivers and erosion mitigation approaches. At Segment 3-5, both PFM 2 and PFM 3 (erosion of the levee embankment and embankment foundation, respectively) were identified as erosion risk drivers because high velocities concentrate along the waterside levee toe exacerbated by bridge constriction effects. At Segment 3-6, both PFM 2 and PFM 3 were identified with high velocities in the channel reaching the levee with a narrow overbank bench between 50 feet to 100 feet wide. Segment 3-7 was previously repaired in 2011, found to meet flood risk objectives for this program and is not included in the design. Segment 3-8 was found to be at risk for PFM 3 due to the steep bank, narrow overbank bench, and high in-channel velocities. Segment 4-1 has an outcropping of erosion resistant material (ERM), also referred to as the Pleistocene Fair Oaks Formation. At Site 4-1, the distance between the river toe and levee embankment toe is wider than immediate upstream or downstream river segments. However geologic inspection suggests erodible materials underly the material behind the riverbank toe resulting in potential for PFM 3 erosion into the levee foundation to occur. Segment 4-2 was previously repaired, in 2011, found to meet flood risk objectives for this program and is not included in this design. Segment 4-3 is at risk of PFM 3 erosion into the levee foundation due to the steep and high banks, narrow overbank bench width, and impinging flows from the river.

2.5.2.4.2 Design Alternatives

For each river segment within Site 4-1, the genesis of designs included TRAC developing 10% design concepts for the USACE design team to advance, and 35% review by the TRAC, partners, and review teams. Based on input from the TRAC and other reviewers on the 35% design, the 35% design footprint was determined to be too expansive and would cause an unacceptable level of impacts to habitat and recreational features within the parkway. To address this problem, the PDT worked with members of the TRAC, project partners, and Risk Cadre to adapt designs at the start of the 65% design phase to meet risk objectives but minimize habitat impacts. A design charette was held with engineers and resource managers at USACE, SAFCA, DWR, NMFS, USFW and Sacramento Regional Parks to discuss, evaluate and select a preferred type of erosion protection treatment for each river segment to minimize habitat impacts and meet erosion risk objectives. In general, resource managers evaluated that a feature constructed along the riverbank would preserve or protect the bench/overbank and parkway amenities and the constructed erosion protection feature would include on-site habitat mitigation and a robust revegetation plan. The outcomes of the design charette at the start of the 65% design phase were also briefed at TRAC and Bank Protection Working Group forums to identify fatal flaws and gain additional input before 65% designs were advanced. During the 65% and 95% design phases, a variety of field visits with partner inclusion were held to refine design layout to minimize local impacts. Subsequently each design phase included assessing habitat impacts and completing formal review from multiple review teams and agencies. Incrementally from the 10%, 35%, 65%, 95% to 100% design phase, design features

Figure 2-16. Site 4-1 overview map

and analysis tools were evaluated and refined to arrive at the minimally sized erosion protection feature to meet flood risk objectives and minimize impacts. A more detailed discussion of design alternatives considered and advanced for each river segment is discussed below.

On Segment 3-5, the TRAC at the 10% design considered two alternatives: (1) buried launchable trench at the levee toe, and (2) launchable toe with planting bench at the riverbank. Alternative 1, the buried launchable trench, was preferred as the revetment could be placed below the existing parking lot and road and minimize impacts to the existing channel and riverbank. The wide bench at this segment and PFM 2 and PFM 3 both being risk drivers would also require revetment at along the riverbank and levee embankment, whereas the buried launchable trench at the levee toe only required revetment to be placed at a single location, minimizing impacts. The TRAC based design (i.e., Alternative 1) was advanced to final design.

On Segment 3-6, the TRAC considered three alternatives at the 10% design phase: (1) buried launchable trench at the levee toe, (2) launchable toe with a planting bench and soil filled riverbank revetment along the riverbank, or (3) launchable toe with a planting bench and soil filled riverbank revetment bench that would excavate back into the existing riverbank. Alternative 1, buried launchable trench at the levee toe, was eliminated because of the amount of existing vegetation removal required to construct this feature. Alternative 2, launchable toe with a planting bench and soil filled riverbank revetment along the riverbank, was initially eliminated because of the associated hydraulic stage impacts this feature caused. Alternative 3, launchable toe with planting bench and soil filled riverbank revetment along the riverbank that would excavate back into the existing bank, reduce hydraulic impacts and result in less fill placed into the river system, but had increased impacts to existing vegetation and habitat on the bench. The TRAC ultimately recommended Alternative 3 at the 10% phase for the design team to advance. However, during the 35% design phase, the hydraulic stage restrictions or concerns were lessened as channel capacity from Site 2-3 (a part of LAR Contract 2) and the Sacramento Weir were accounted for. The Segment 3-6 design was revised at the start of the 65% design phase based on the outcome of the design charette held with partners to include a launchable toe with a planting bench and soil filled riverbank revetment along the riverbank; aligning closer to Alternative 2 evaluated during the 10% TRAC phase. Segment 3-6 designs vary along its longitudinal length where narrower overbank locations with high velocities require soil filled revetment along the riverbank and levee embankment. In areas with a wider overbank, designs that address PFM 3 and 2 are being advanced that includes partial revetment along the riverbank and revetment with scour protection volumes placed near the levee toe.

At Segment 3-8, the TRAC at the 10% design phase considered two alternatives: (1) launchable toe with a planting bench, soil filled riverbank revetment along the riverbank and a buried launchable trench feature at the levee toe, and (2) launchable toe with a planting bench, soil filled riverbank revetment along the riverbank that would excavate back into the existing riverbank, and a buried launchable trench feature at the levee toe. The amount of revetment needed to create a buried launchable trench feature at the levee toe and the associated impacts to existing vegetation in this immediate area in the overbank was not strongly considered by the TRAC. The intent of the buried launchable trench feature at the levee toe was to allow some existing vegetation to remain on the bench and not carry continuous rock from the riverbank toe up to the levee toe. The TRAC selected the design that did not excavate into the existing bank to avoid additional impacts to existing vegetation, Alternative 1 described above. This design solution (i.e., bank protection feature placed along the river toe and riverbank) also was evaluated and selected during the design charette at the start of the 65% design phase. However, via additional analysis and review, the buried launchable trench feature placed near the levee toe was eliminated and in isolated locations in the overbank replaced with a buried rock tie-back features field fit to minimize habitat impacts.

At Segment 4-1, the TRAC considered three alternatives at the 10% design: (1) launchable toe with a planting bench, soil filled riverbank revetment along the riverbank and a buried launchable trench feature at the levee toe, (2) launchable toe with a planting bench, soil filled riverbank revetment along the riverbank that would excavate back into the existing riverbank, and a buried launchable trench feature at the levee toe, or (3) soil filled riverbank revetment without a planting bench and a buried launchable trench at the levee toe. Since the existing riverbank toe is an outcropping of erosion resistant material (ERM) at this location, the TRAC preferred a design that would not impact this existing feature and selected Alternative 3, soil filled riverbank revetment without a planting bench and a buried launchable trench for design advancement. Furthermore, the armored riverbank feature was to be limited to localized areas where the bank slopes are steep. Design options of placing the erosion protection feature in the overbank (i.e., between the levee toe and riverbank) were evaluated and selected at the start of the 65% design phase via a design charette with partners considering this segment's overbank is wider than other river segments in the immediate area. During the 65% design phase, the PDT worked with Sacramento Regional County Parks, NMFS and USFWS to discuss erosion protection layout options in this overbank section and conducted field visits with partners to refine the location of this feature in an effort to minimize habitat impacts. Options were vetted by the Risk Cadre to confirm design meets flood risk objectives.

At Segment 4-3, the TRAC at the 10% design considered three alternatives: (1) launchable toe with a planting bench, soil filled riverbank revetment along the riverbank and a buried launchable trench feature at the levee toe, (2)) launchable toe with a planting bench, soil filled riverbank revetment along the riverbank that would excavate back into the existing riverbank, and a buried launchable trench feature at the levee toe, and (3) buried launchable trench at the levee toe. The TRAC selected Alternative 1, launchable toe with a planting bench, soil filled riverbank revetment along the riverbank and a buried launchable trench feature at the levee toe for design advancement. The PDT worked with the TRAC members at the start of the 65% design phase to re-evaluate the preferred concept. Based on the design charette and additional analysis and review, the 10% feature of a buried launchable trench at the levee toe was eliminated. The proposed design includes a launchable toe with a planting bench and soil filled riverbank revetment along a portion of the riverbank to minimize habitat impacts for high quality vegetation in the overbank. Effectively the footprint was reduced over the course of design phases and designs still meet minimum flood risk objectives.

2.5.2.4.3 Proposed Design

The proposed design at Site 4-1 varies through the site as site conditions and resource values change. Considerable attention was applied to Site 4-1 design based on the habitat quality and identification of high flood risk and risk drivers based on this constrained section of LAR. Design accounted for the presence of and characteristics of ERM that is a predominant geologic feature in this section of the river. Multiple ERM forums with a subset of members of the TRAC, project partners, and local and national subject matter experts were held by USACE staff for design application. The presence of and characteristics of ERM was accounted for in the design layout primarily for Site 4-1. ERM is a key design variable in this section of the river where ERM outcrops are identified along the river and river margins. The presence of ERM was also accounted for in vertical scour analysis.

The downstream section of the site (i.e., Segment 3-5) incudes a buried launchable trench below the existing parking lot and road to avoid most impacts to existing vegetation. The feature mitigates PFM 3 concerns. Further upstream where the overbank narrows and high-quality riparian habitat exists, the design shifts to focus erosion protection features to be placed along the riverbank to avoid impacts to the overbank and the presence of heritage oaks. The launchable toe placed near the shoreline and soil filled revetment along the riverbank will prevent significant erosion and overbank loss that could threaten the levee foundation. Planting benches will include soil-filled tiebacks, Instream-Woody Material (IWM), and will be planted with native species to replace habitat lost. In addition, 12 inches of soil will be placed on top of the soil filled revetment to allow areas outside the vegetation free zone to be replanted with woody species. Revegetation of native grasses are included for C3B work within the vegetation free zone. Erosion protection features were designed based on lessons learned from successful reestablishment sites built for LAR erosion projects over the last few decades.

The erosion protection feature is limited to locations where erosion could impair levee stability and targets local site concerns. In locations the soil filled revetment extends only a portion of the riverbank height where the design avoids additional impacts to existing vegetation. In isolated section, such as in Segment 3-6, erosion protection features are included along both the riverbank and levee embankment based on site characteristics. Design layout was based on collecting field data, identification of erosion risk drivers at each location and included an array of refined analysis tools, field visits and incremental review and engagement with partners for design refinement.

In Segments 4-1 and 3-8 buried rock tie-back features (aka, spurs made up of revetment) that extend from the riverbank bank protection features landward to the levee toe are included to account for flanking concerns during high flow events, are based on localized hydraulic conditions and Risk Cadre input. Careful attention was applied to the locations and layout of these buried rock tie-back features. Tree survey data (i.e., location, specie type, tree size) was reviewed coupled with field visits attended by Sacramento County Regional Parks staff to minimize habitat impacts.

Figure 2-17 to Figure 2-26 provide plan view and cross-sectional example renderings of each Site 4-1 segment's proposed erosion protection and on-site habitat mitigation design features. The renderings illustrate the general location of the feature (e.g., riverbank vs overbank), inclusion of on-site habitat mitigation elements such as planting benches, soil filled revetment with soil a lift and maturation condition of the revegetation effort. It also depicts protected vegetation and recreational amenities above or below the proposed bank protection feature. Existing trees that are to be preserved in place are depicted as green circles in the plan view figures.

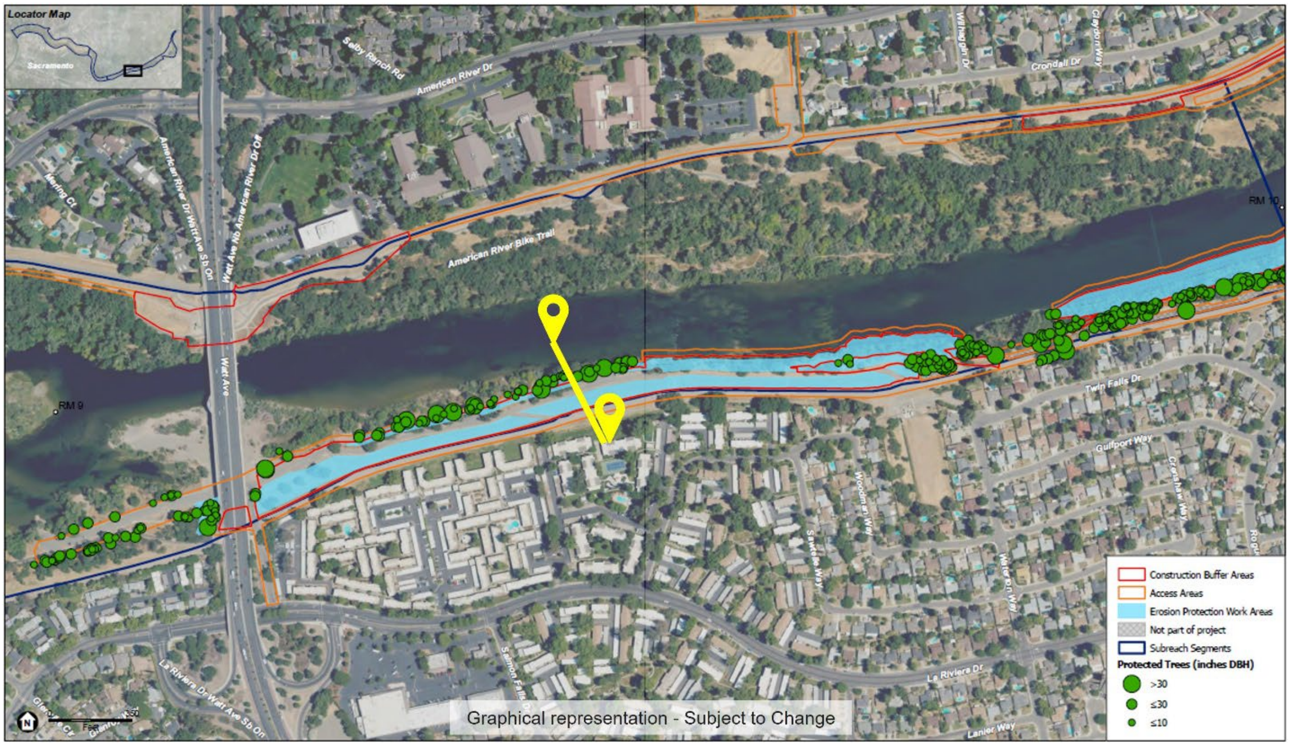
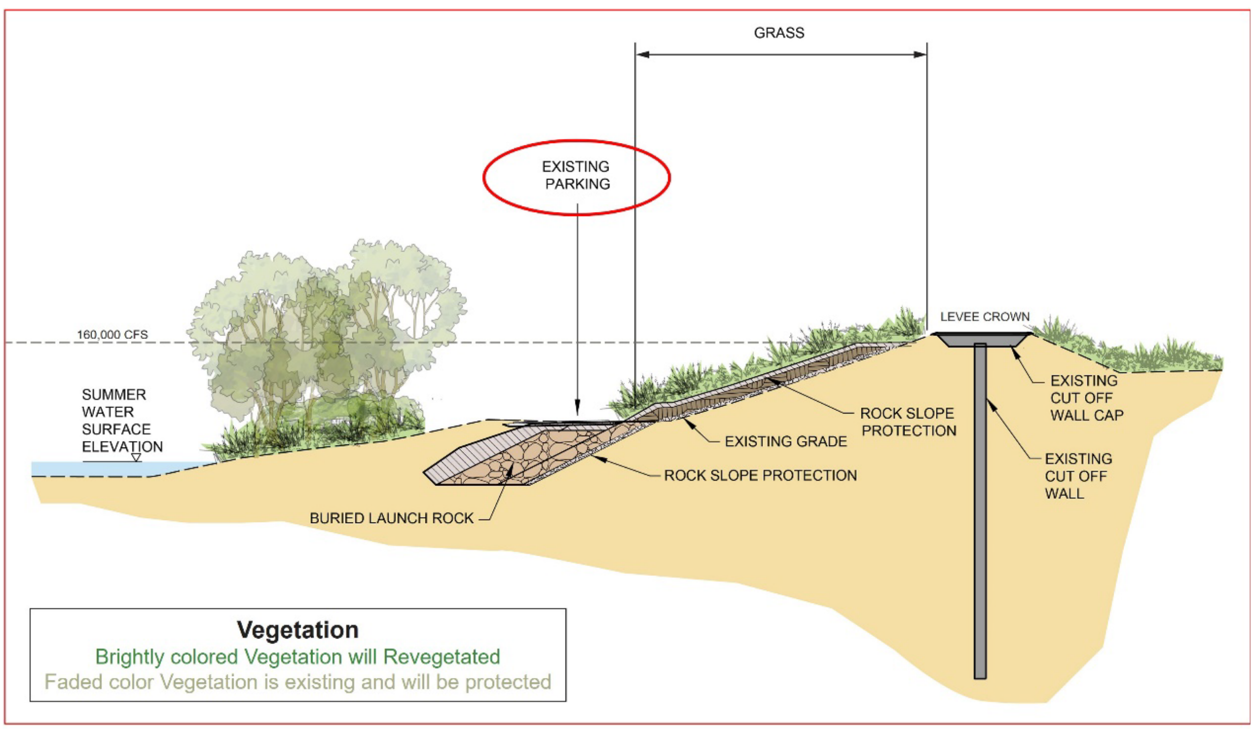


Figure 2-17. Layout of Segment 3-5 erosion protection feature and cross section location



Graphical representation - Subject to Change. Revegetated condition reflective of mature state

Figure 2-18. Segment 3-5 rendering of erosion protection feature

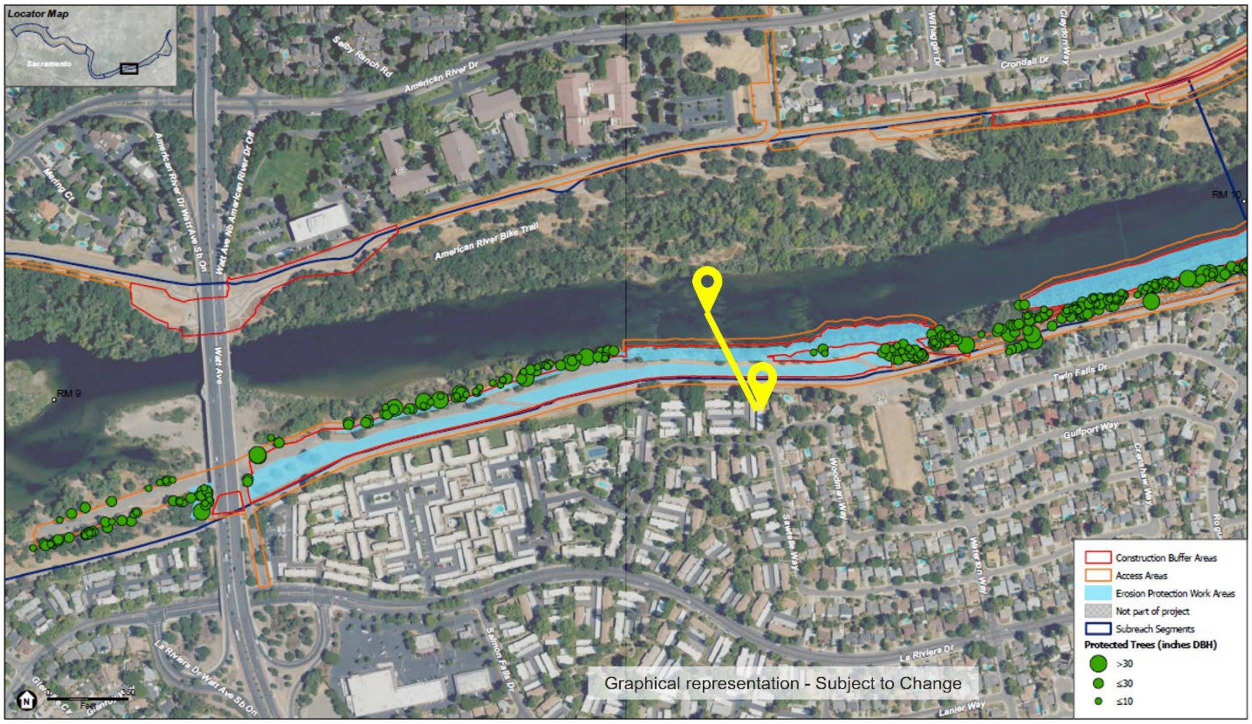
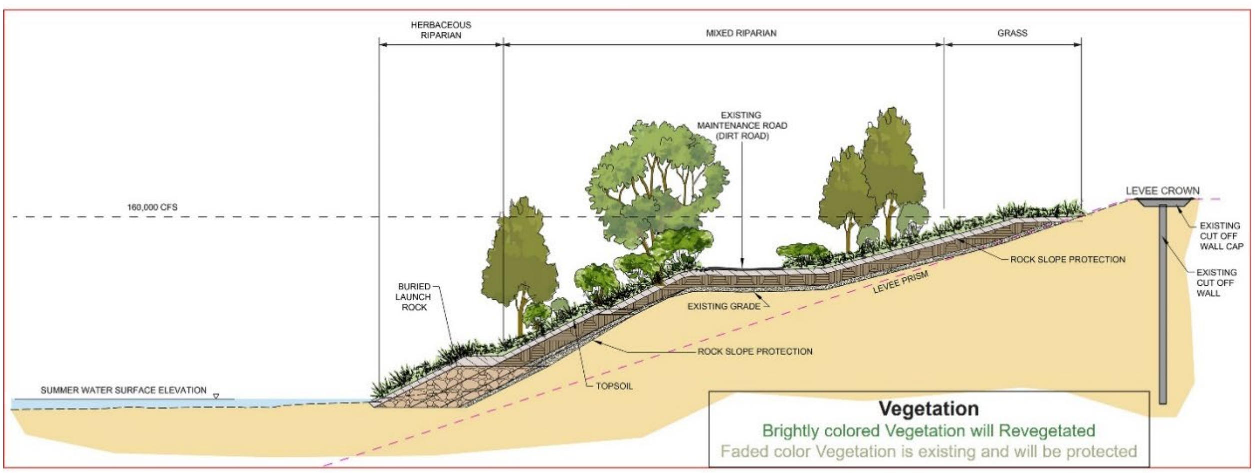


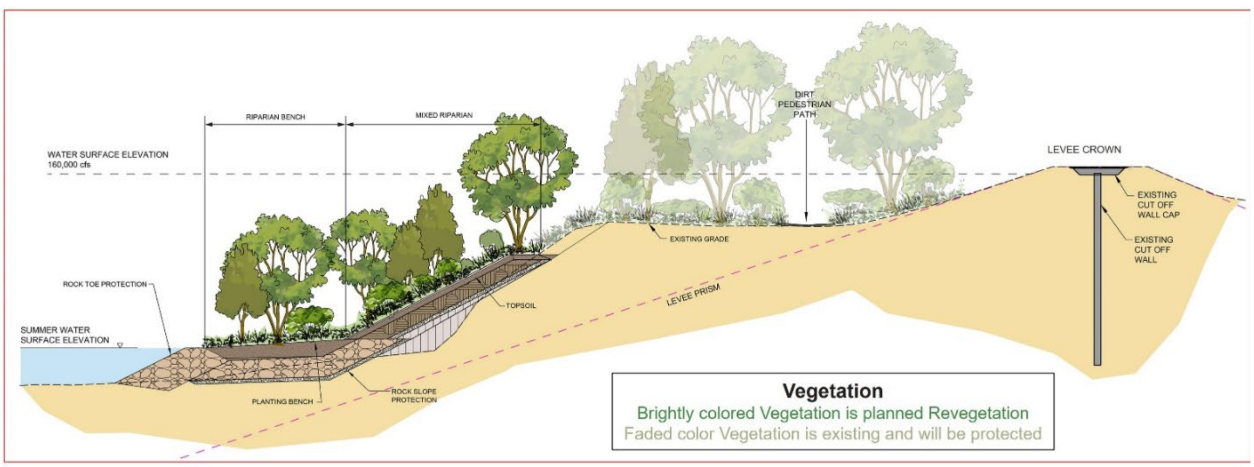
Figure 2-19. Layout of Segment 3-6 erosion protection feature and cross section location



Graphical representation - Subject to Change. Revegetated condition reflective of mature state

Figure 2-20. Segment 3-6 rendering of erosion protection feature

Figure 2-21. Partial Layout of Segment 3-8 erosion protection feature and cross section location



Graphical representation - Subject to Change. Revegetated condition reflective of mature state

Figure 2-22. Segment 3-8 rendering of erosion protection feature

Figure 2-23. Layout of Segment 4-1 erosion protection feature and cross section location

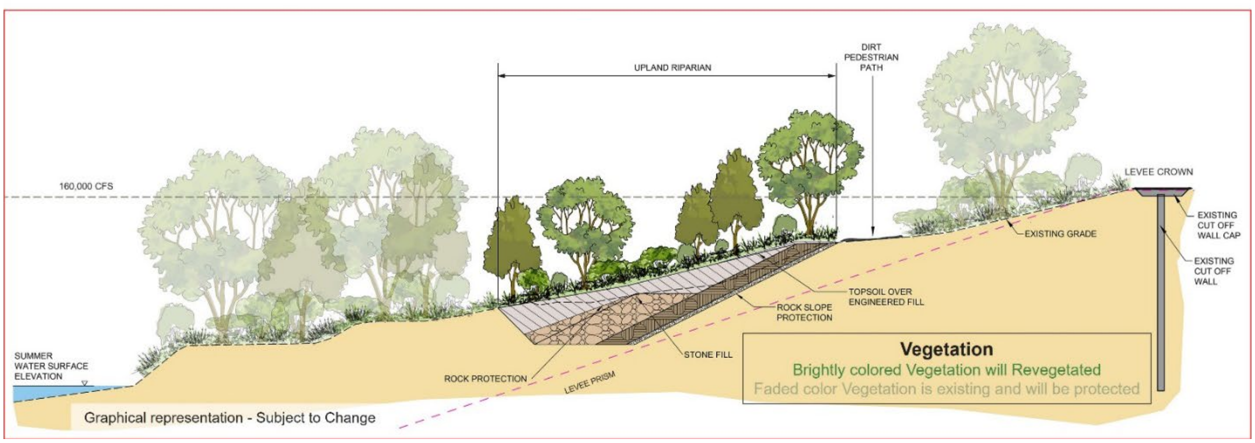


Figure 2-24. Segment 4-1 rendering of erosion protection feature

Figure 2-25. Layout of Segment 4-3 erosion protection feature and cross section location

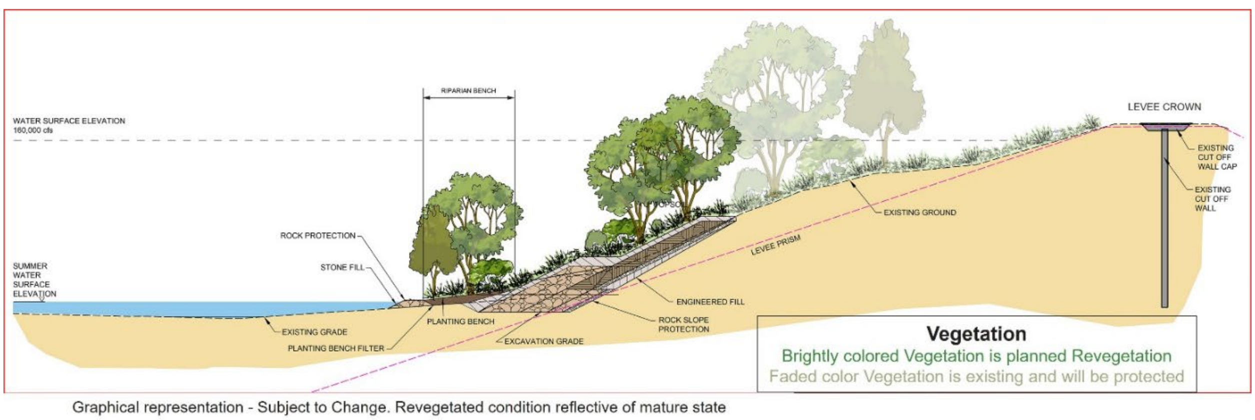


Figure 2-26. Segment 4-3 rendering of erosion protection feature

2.5.2.5 Contract 3B Site 4-2

Contract 3B Site 4-2 is located on the right (north) bank upstream of Watt Avenue. Figure 2-27 shows the location of Site 4-2 and the proposed erosion protection footprint.

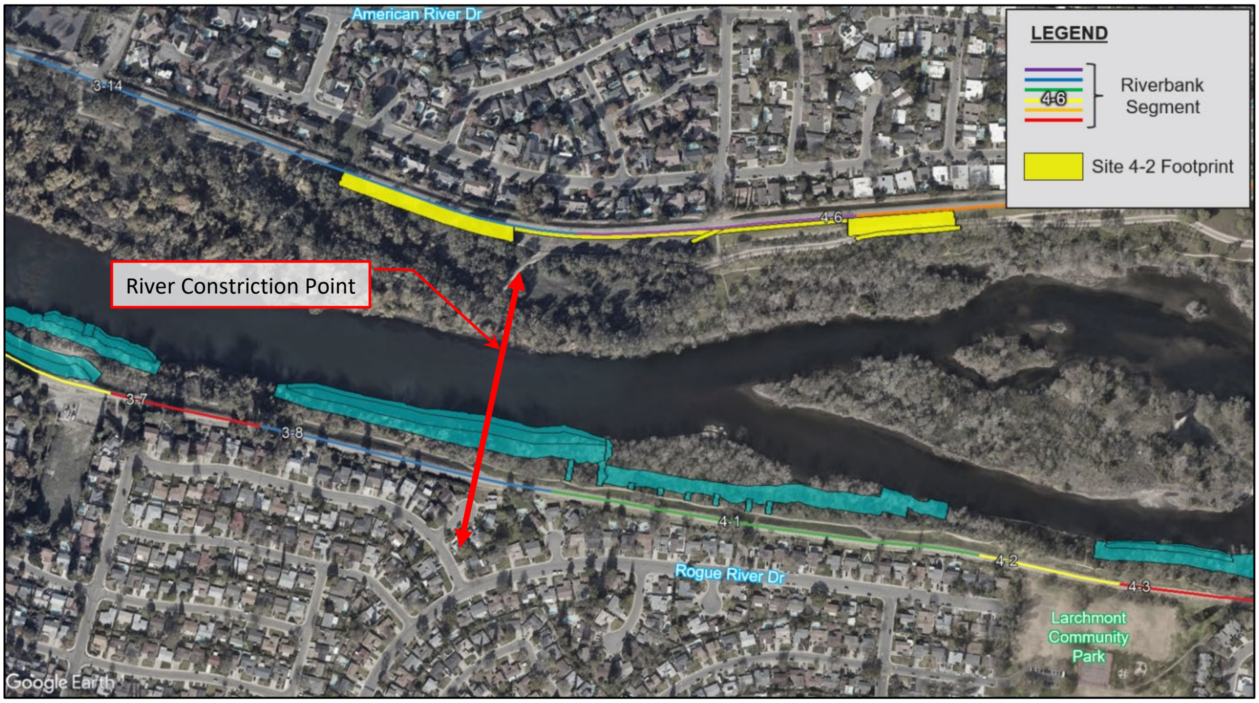


Figure 2-27. Site 4-2 overview map

2.5.2.5.1 Identified Risk Drivers

Site 4-2 expands a previous design that was installed at this site in 2004. The primary risk driver at the site is PFM 2 due to high velocities located along the levee embankment and toe. The American River makes a mild right bend at the project location, and the width of flow area between the north and south levee decreases at this location relative to upstream and downstream. This constriction, depicted in Figure 2-27 above, causes a localized increase in velocities on the levees where velocities may exceed the shear strength of the grass covered levee and induce erosion. The levee at this location is constructed to minimum required dimensions, and progression of erosion will remove material critical to levee stability.

2.5.2.5.2 Design Alternatives

This site was originally identified as a Tier 3 site by the Phase I Site Evaluation and was not evaluated by the TRAC for a recommended approach at the 10% C3B design. However, after acquiring more site-specific data and performing additional hydraulic analysis, the Phase II baseline assessments evaluations determined this segment did not meet project erosion risk objectives based on hydraulic conditions; specifically, the increased velocities induced along the north levee by the constriction point described above. Thus, USACE Sacramento District determined erosion protection was necessary at this site and added it to the scope of LAR C3B in July 2021. The PDT developed an initial design concept that was reviewed by the TRAC with additional discussions and refinement options discussed with Sacramento County Regional Parks staff. Design alternatives were developed and weighed with the PDT and Sacramento County Regional Parks participation to minimize impacts to recreational and habitat amenities. The design includes increasing the revetment height of the existing revetment features to account for the design objective flow condition (i.e., 160,000 cfs). In addition, the design extends levee embankment protection both upstream and downstream of the existing revetment features based on hydraulic conditions for the design objective flow.

2.5.2.5.3 Proposed Design

The proposed design installs soil-filled revetment on the levee embankment and will cover the soil-filled rock with one foot of topsoil to be reseeded with native grasses. The revetment is sized to resist erosion during the design event. Covering the revetment with topsoil and reseeding the topsoil will screen the project from public view and provide a naturalistic view to the project. The levee embankment is currently vegetated with grasses and will be replanted with native grasses. Design for the sections upstream and downstream of the existing revetment feature also include a volume of buried launchable trench at the levee toe to address scour potential. The layout of the buried launchable trench was designed to minimize impacts to the recreational trail in proximity as well as minimize impacts to existing vegetation. Figure 2-28 and Figure 2-29 provide an example rendering of erosion protection design within Site 4-2. The plan view also depicts vegetation to be protected as green circles.

Figure 2-28. Layout of Site 4-2 erosion protection feature and cross section location

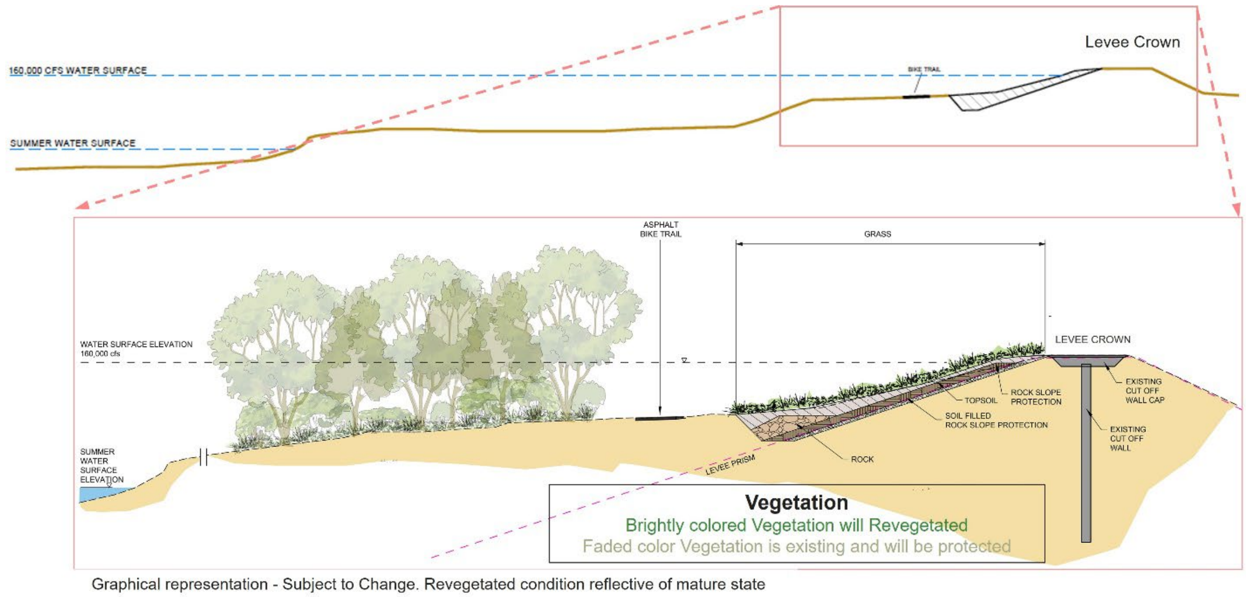


Figure 2-29. Site 4-2 rendering of erosion protection feature

2.5.3 Contract 4A

Contract 4A includes one site located on the right (north) levee at the Highway 160 bridge. Figure 2-30 shows the location of Contract 4A and the proposed erosion protection footprint. This location was identified initially as a Tier 2 segment by the Phase I Site Evaluation with a concern for localized high velocities under the bridge. It was not originally recommended for repair by the TRAC. However, the Phase II Site Evaluation baseline risk assessment quantified the risk of erosion levee failure to exceed the project objectives. The concerns documented in the risk assessment include:

1) High velocities along the levee (up to 5.0 fps).
2) Erodible soils within the levee embankment (sands, silts, and clays).
3) No erosion countermeasures to protect the levee with areas of exposed, unvegetated soil beneath the bridges.
4) Potential for debris blockage on the railroad bridge bents causing isolated higher velocity flows against the levee.

Figure 2-30. LAR C4A project overview map

This levee is about 1,800 feet from the American River main channel. There are three bridges crossing the American River at this location; State Highway 160 West Bound, State Highway 160 East Bound, and a UPRR bridge. Embankments constructed on the floodplain for these bridges partially block floodplain flows, forcing more flow into the main channel and into a narrower opening between the bridge embankments and the levee. This results in accelerated flow between the bridge embankments and the levee with higher velocities near the ARN levee as shown in Figure 2-31.

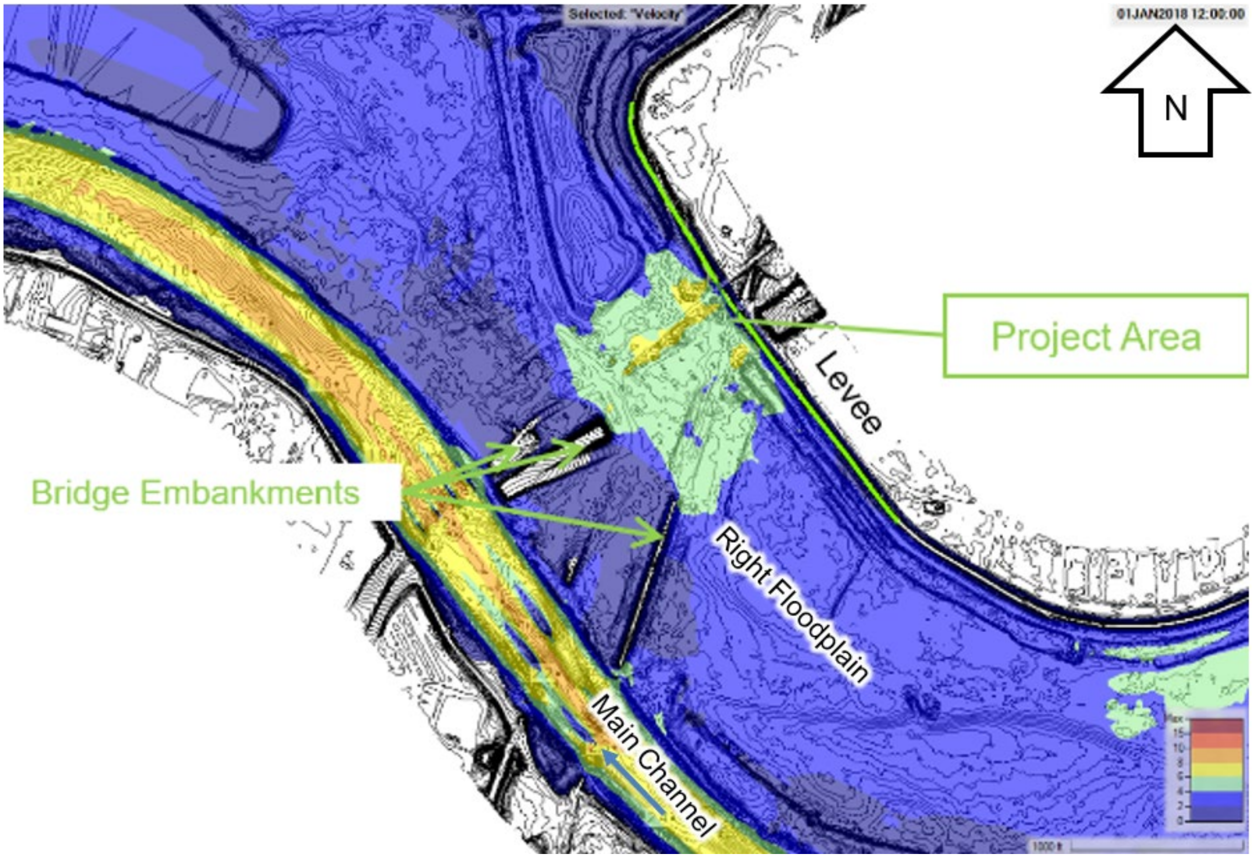


Figure 2-31. Plot showing velocities increase in the floodplain near LAR Contract 4a levee

The flow around the bridge columns and posts creates turbulent vortices. These turbulent vortices increase the erosive forces on the soil locally adjacent to these features and impact the levee. The embankment along the levee supporting the UPRR bridge abutment projects into the flow, locally contracting and accelerating the flow while creating turbulent vortices. This is illustrated in Figure 2-32. Velocity tracers are shown as purple lines around the UPRR bridge abutment for the design flow. The higher local velocity and turbulence can lead to local abutment scour in addition to the local pier scour previously described.

The relatively close spacing of the UPRR bridge bents, their angled orientation relative to the flow of the water, and the relatively low elevation of the lowest elevation of the superstructure (i.e., “low chord”) below the top of levee contribute to the potential for debris to accumulate around the bridges. The debris can block flow, creating higher velocities through the remaining openings, possibly including higher velocities on the levee itself. The debris can also re-direct flow toward the levee and contribute to erosion of the levee. Therefore, debris can increase the likelihood of erosion of the levee.

The soils immediately below the levee are mostly clays and silts that are susceptible to scour and erosion from the high velocities and turbulence. Erosion testing of soil samples indicate that soils in

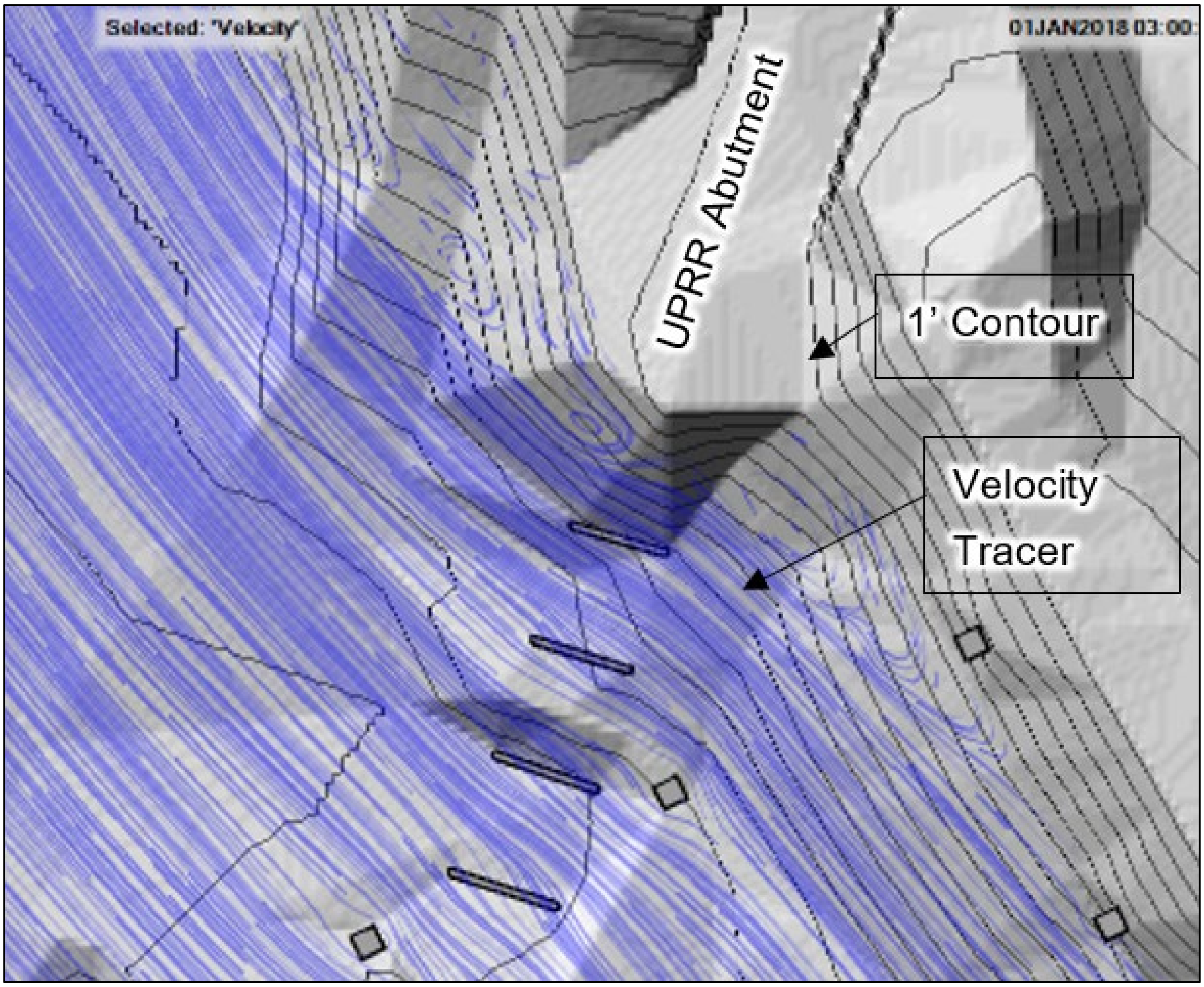


Figure 2-32. Plot showing flow contracting around UPRR bridge abutment

erosion category II (High Erodibility) to category I (Very High Erodibility). See Figure 2-33 for example soil test results showing high erodibility for a silty clay soil sample collected within the levee at the project site. While clay soils typically classify in the moderate or even low erodibility category, the levee soils at LAR C4a were tested and almost all tests found the soils in the project area to be near the boundary between very high erodibility and high erodibility, categories typically associated with sand. This confirms the risk cadre's concern about the presence of erodible soils at this site.

Because of the high and potentially turbulent velocities against the levee and the presence of erodible soils, the Sacramento District determined erosion protection was necessary at this location.

USACE began the repair design by hosting design charrettes with a multi-disciplinary group from various agencies with a similar but not completely consistent membership to the TRAC to discuss design alternatives. USACE has continued to work with this group during design development The designs at each milestone have been reviewed by TRAC members and other review staff. The design development is discussed further in the following sections.

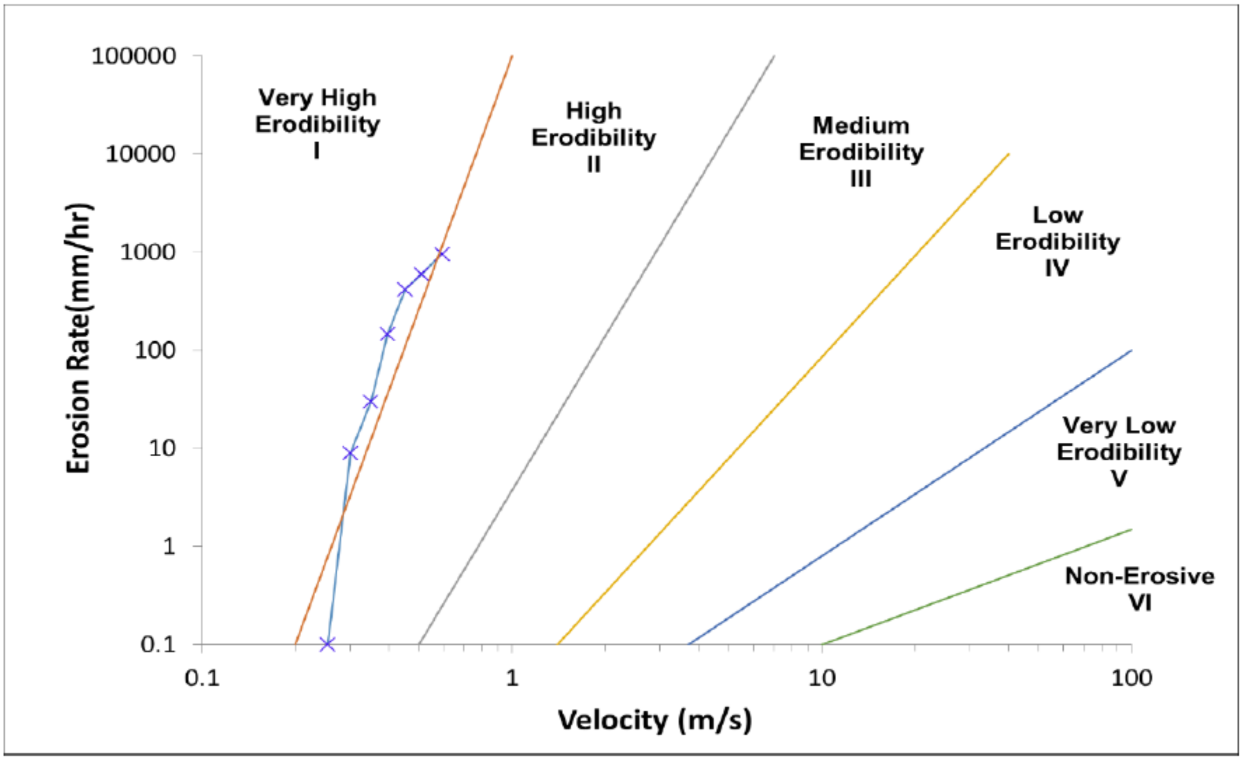


Figure 2-33. Example soil test results

2.5.3.1 Identified Risk Drivers

Contract 4A at RM 2.0 is located on the right levee under the highway 160 bridge. The primary risk driver at the site is PFM 2 erosion into the levee caused by high velocities impinging into the levee, and the presence of the Highway 160 bridge and Union Pacific Railroad bridge piers inducing local scour near the levee. Velocity is increased at the site by the large railroad and highway 160 encroachments in the floodway locally constricting flow.

2.5.3.2 Design Alternatives

The PDT worked with representatives from USFWS, NMFS, NPS, Sacramento County Regional Parks, DWR, and SAFCA to evaluate alternative designs at the site at two design charettes. The initial design charette identified alternatives to be considered including:

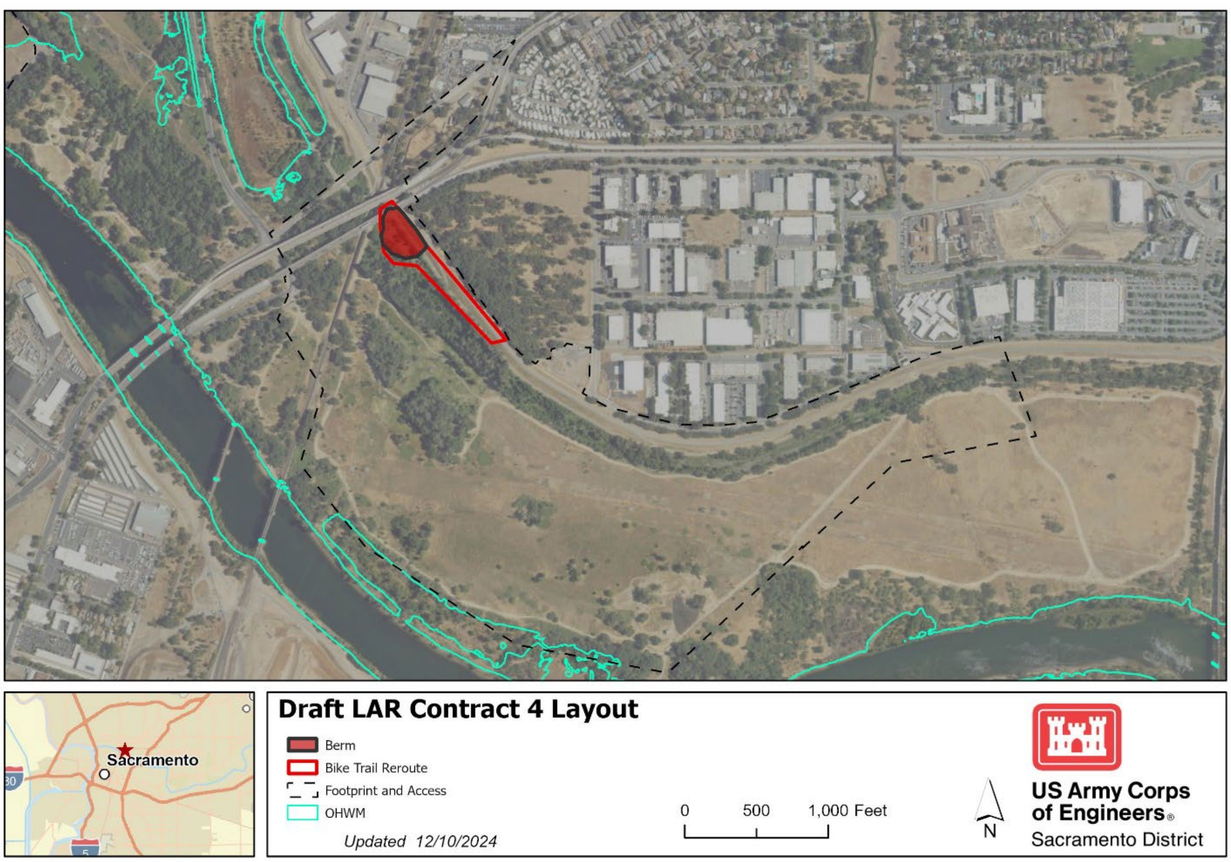
1. Groin (deflector spur or berm) or jetty system upstream of bridges or under bridges to deflect flow away from the levee.
2. Rock blanket on ground surface near levee and on levee and at piers.
3. Buried rock layer within levee prism and into levee toe; rebuild to existing lines/grades.
4. Launch rock under bike path; Build soil filled rock at bike path alignment and relocate bike path on top or in another location.
5. Select rock revetment at high velocity areas/piers but not along entire levee slope.

6. Grouted rock or concrete lined riprap on levee slope/toe.
7. Articulated concrete blocks.
8. Pave the levee slope and toe up to the bike path.

After the initial design Charette, the PDT further analyzed and developed these alternatives prior to a second design charette to discuss the alternatives in detail. The group ultimately identified a preferred alternative to construct a large deflector spur (berm) upstream of the Highway 160 bridge to deflect flow away from the levee. This alternative required the relocation of the bike trail as the berm blocks the existing bike path location. An alternative bike path alignment was identified working with Sacramento County Regional Parks including a third design Charette.

2.5.3.3 Proposed Design

The features of the proposed design for LAR C4A include construction of a deflector berm, relocation of a portion of the existing Jedediah Smith Memorial Bike Trail, and relocation of part of a 12-inch waterline. These features are shown on the overview map (Figure 2-30).



The proposed design will construct a berm upstream of the Highway 160 bridge that will deflect flow away from the levee preventing the flow from impinging on the levee and reducing velocity on the levee face to reduce erosion risk. The berm will be constructed of soil-filled quarry stone, covered with 1-foot of topsoil, and seeded with native grasses. Adjustment of the berm was considered to avoid more trees, but no additional modifications could be done to the berm that wouldn't have either increased flood risk, increase the project footprint, or encroach into adjacent properties. In addition, to avoid wetland impacts, the design minimizes the project footprint as much as possible while still meeting flood risk objectives.

The berm will block the alignment of the existing bike trail. Therefore, the bike trail alignment will be moved to a location around the berm. that bypasses the deflector berm. This bike trail alignment was agreeable to Sacramento Regional County Parks.

The berm is also located above an existing City of Sacramento 12-inch waterline. As a result, approximately 210 feet of waterline will be relocated around the berm to allow for simpler maintenance and remove the risk of a waterline break beneath the berm.

Soil filled quarry stone fill will be placed in part of an old abandoned borrow pit (which has been delineated as a wetland) running approximately parallel with the existing bike path to support construction of the berm and parts of the bike path and waterline relocations. This soil-filled quarry stone also provides erosion and scour protection to the berm and bike path foundations and the relocated waterline. The soil-filled quarry stone will be topped with 1-foot of topsoil and seeded with native grasses.

Construction of the project will occur in phases so that at least one lane of the bike path will be open to the public during construction at all times to reduce impacts of bikeway closure to the public.

2.5.4 Contract 4B

Lower American River (LAR) Contract 4B is located on the right (north) bank upstream of Howe Avenue and on the left (south) bank upstream of Watt Avenue. Contract 4B is located immediately adjacent to Contract 3B; specifically, in between the footprint of Contract 3B and the levee crown. Figure 2-34 shows the location of Contract 4B in relation to the locations of the other American River Common Features (ARCF16) Project erosion protection improvements along the LAR. Contract 4B is focused on addressing two key erosion risks along the Lower American River, specifically in river Segment 3-11 on the north bank upstream of Howe Avenue and Segments 3-8 and 4-1 on the south bank upstream of Watt Avenue. The first erosion risk being addressed by Contract 4B pertains to lone tree scour, which is detailed in Section 2.5.4.1 below. The second erosion risk Contract 4B is addressing is the potential for erosion to outflank the Contract 3B design is Segment 4-1 on the south bank of the river; this second erosion risk is detailed in Section 2.5.4.2 below.

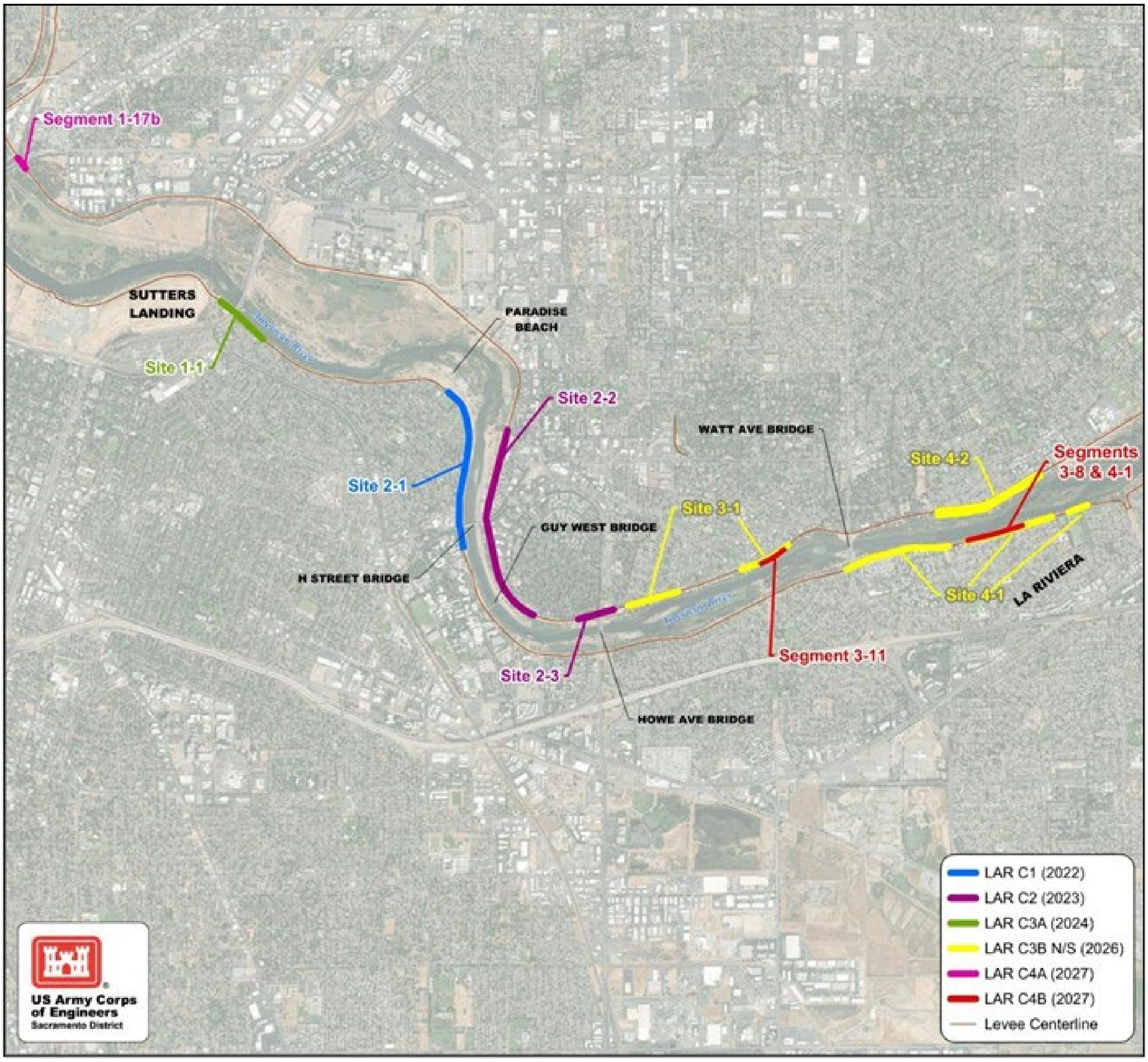


Figure 2-34. ARCF 2016 Project erosion protection improvements on LAR

2.5.4.1 Lone Tree Scour

A risk assessment completed in 2022 determined certain trees on or near the levee embankment adjacent to the Contract 3B erosion protection footprint pose an unacceptable risk to the levee's integrity. The purpose of Contract 4B is to address this risk to the levee while protecting these trees in place by installing erosion protection around the base of the trees. However, if engineering analyses demonstrate that a design solution to protect a given tree in place is not achievable, or if based on input from landscape architects and arborists a design solution would likely result in a given tree's death, tree removal may be required.

The risk assessment identified trees within Segments 3-8, 3-11, and 4-1 which pose a risk of riverside erosion above the levee toe in the levee embankment (PFM 2). Tree trunks are obstructions in the middle of incoming flow, which could cause flow acceleration around these tree trunks and lead to localized scour similar to bridge piers (U.S. Army Corps of Engineers, 2016). Figure 2-35 shows an example of this tree scour that occurred in the 1986 flood event while Figure 2-36 shows an example of lone tree scour, which occurred on the Big Sioux River, a Missouri River tributary, in 2024. Observed lone tree scour hole depth and extent varies widely. And more detailed analysis is needed to isolate the impact of lone tree scour effect as outline in 2.5.4.1.1. The scour excavates a depression around a given tree that, for trees located near or on the levee embankment, can extend into the levee embankment and narrow the levee inducing levee failure. The magnitude of scour is directly related to the diameter of the tree, the depth of flow, the erodibility of the soil, and the flow velocity. Trees of concern are large diameter trees (greater than 18-inch diameter at breast height (DBH)) located on or immediately adjacent to the levee at locations where the levee is not overbuilt, and at locations with relatively deep flow depths and higher velocities. With Contract 3B's Sites 3-1 and 4-1 designs optimized to address erosion of the riverbank, not lone tree scour, and the lone tree scour risk being identified late in the C3B design process, the lone tree scour risk potential is being addressed as a separate contract to allow for a more selective approach to address this unique risk driver.

Figure 2-35. 1986 Lower American River flood event aftermath - localized lone tree scour

Figure 2-36. 2024 Big Sioux River flood aftermath. Example - localized lone tree scour

2.5.4.1.1 Lone Tree Scour Risk Scope

The intent of lone tree scour evaluations and remediation is to address the risk of erosion jeopardizing the levee while protecting all native tree species in place. Non-native tree species which pose a threat will be reviewed on a per tree basis with the Technical Resource Advisory Committee (TRAC) to determine preference for removal or protection. The TRAC is a multi-disciplinary group, that includes water resource engineers, geotechnical engineers, geoscientists, biologists, and ecologists, along with local stakeholders (county parks & others), regulating agencies and Subject Matter Experts (SME) who advise on design decisions.

USACE is working through a four-step process to identify individual trees which pose a risk to the levee and to develop approaches to reduce the erosion risk. Steps two and three focus on minimizing the footprint of the project to ensure only trees that are immediate threats to levee safety during a high flow event are included in Contract 4B. USACE will complete this process following the following four steps:

Step 1: Identify individual trees in close proximity to the levee which may threaten the levee if scour were to occur. USACE completed an initial assessment and identified 81 trees for study. These trees include all trees located on the waterside slope of the levee and within 25 feet of the waterside levee toe. Figure 2-37 and Figure 2-38 show the locations of these 81 trees.

Step 2: Estimate maximum scour expected to occur around each tree during a design event and determine which trees could create scour that could extend into the levee or levee foundation. USACE completed an initial analysis of the 81 trees identified in Step 1 and identified 31 trees did not need further action due to limited scour depths and/or the potential scour not extending into the levee.

Step 3: Evaluate the scoured condition to determine the effect on levee stability. The remaining 50 of 81 trees will be further evaluated to understand if the scoured condition around the tree could threaten the integrity of the levee. The evaluations will include geotechnical studies of seepage and stability and detailed risk assessments to verify which trees pose an immediate threat to levee safety. Trees determined to not pose an immediate threat to the levee's integrity during a single high flow event will be considered safe and will be removed from further evaluation. USACE is currently working on this step to finalize the scope of Contract 4B and determine exactly which trees require action to mitigate the erosion risk. It is anticipated this step will be completed in late 2025.

Figure 2-37. Contract 4B trees under evaluation within Segment 3-11

Figure 2-38. Contract 4B trees under evaluation within Segments 3-8 and 4-1

Step 4: Develop solutions to mitigate erosion risk working with certified arborists and the TRAC. Only trees determined to pose an immediate threat to the levee's integrity will be considered. USACE will work with the TRAC to develop design criteria for addressing the erosion risk for these trees, develop a range of treatments for each tree, and select the final preferred treatment. The final array of design solutions will need to demonstrate that USACE flood risk reduction objectives are met. USACE will continue to consult with the TRAC throughout the design development cycle and comply with requirements for arborist determinations regarding tree preservation, trimming, and removal.

2.5.4.1.2 Potential Actions

The intent of the Contract 4B design is to protect all native species inside the vegetation free zone in place; however, if the engineering analyses demonstrate that a given tree poses an unacceptable erosion risk to the levee and a design solution which can protect the tree in place is not achievable, its removal may be required. Non-native species will be reviewed on a per tree basis with the TRAC to determine preference for removal or protection. For each tree, the considered potential actions to mitigate the erosion risk will include:

- No Action. Detailed engineering analyses concludes that the tree is not a risk to the levee.
- Erosion Protection. This action would place erosion resistant material around the tree to prevent, or limit, the local scour from occurring similar to scour countermeasures placed near bridge piers. Unlike bridge piers, the health of trees can be impaired if the tree roots are damaged thereby limiting excavation to place materials and total fill depth that can be placed over roots to prevent erosion. Unique treatments for different tree types and loadings will be developed for each tree type and loading condition.
- Tree Removal. This action carefully considers the types of trees (native versus non-native), the size of scour depth, and the potential impact of the scour to the levee prism above the levee

toe. Removal of trees is not preferred due to the short and long-term loss of riparian habitat and would likely be limited to non-native invasive vegetation or trees of poor health.

2.5.4.1.3 Vegetation Design Deviation

The trees within Contract 4B's scope are located within the Vegetation Free Zone (VFZ) established in ETL 1110-2-583 (U.S. Army Corps of Engineers, 2014). Design solutions which propose anything other than removal of woody vegetation within the VFZ require a Vegetation Design Deviation (VDD) be approved by USACE Headquarters (USACEHQ). The approval process is expected to take approximately 2-years to complete once the final scope of Contract 4B is finalized. As the native oak and walnut trees in the project footprint are important to the visual aesthetic, habitat values, and natural setting of the American River Parkway, design solutions will be developed to protect the trees as well as the levee from erosion in consultation with Non-Federal sponsors and TRAC. The PDT is working toward an approval from USACE Headquarters by completing additional analyses considering the soil profile, vegetation type, and local three-dimensional hydraulics developed with site specific three-dimensional hydraulic models.

2.5.4.2 Tieback Extensions

Within Contract 3B Segment 4-1 on the south bank of LAR, upstream of Watt Avenue, part of the erosion protection planned includes installation of rock tiebacks which serve to prevent erosion from outflanking the revetment installed at the riverbank's edge (i.e., eroding the bank/levee landward of the riverbank's edge revetment). These tiebacks can be seen in Figure 2-39 below. It is anticipated this step will be completed by late 2025 or early into 2026. 2.5.4.1.3�2.5.4.1�.

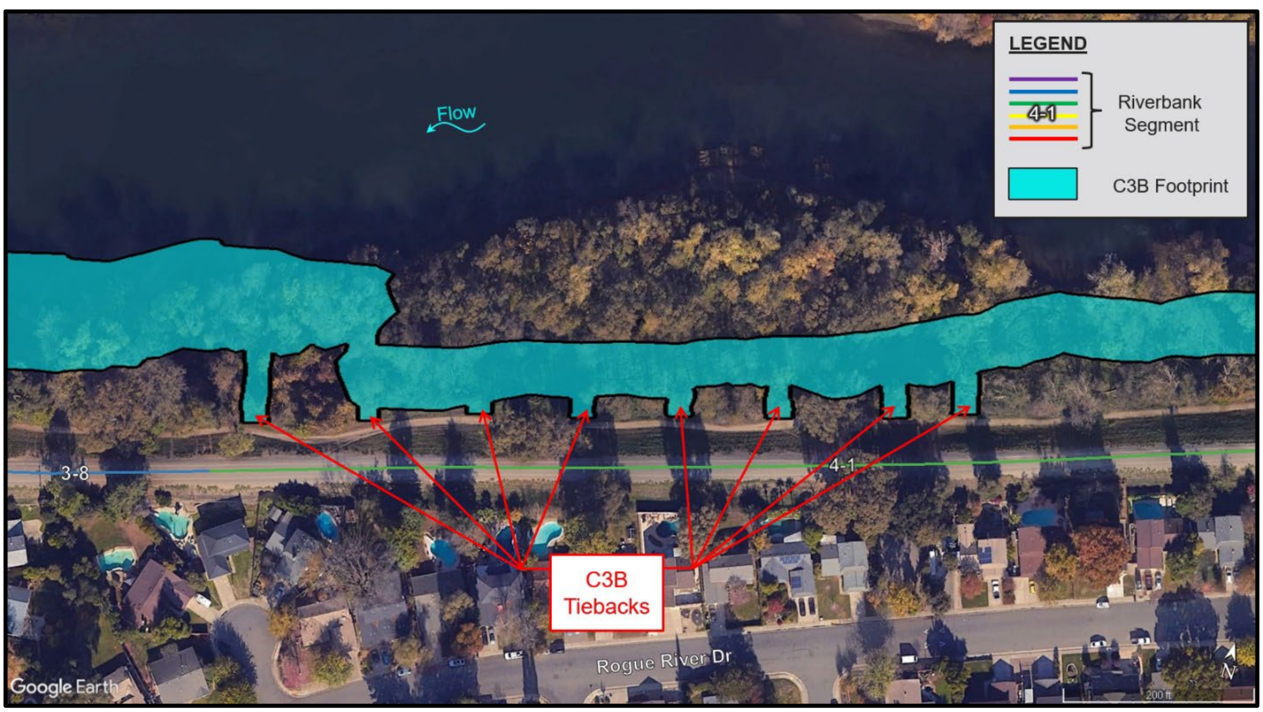


Figure 2-39. Contract 3B Tiebacks

2.5.4.2.1 Tieback Extension Scope

The Contract 3B tiebacks are fully buried and constructed using soil filled rock. For Contract 4B, the eight tiebacks depicted in Figure 2-39 above will be extended further landward and be constructed in the same manner as Contract 3B. The exact length of each tieback extension is still being determined but the tiebacks will extend into the VFZ and into the levee embankment. A typical cross section of the tiebacks is shown in Figure 2-40 below. A rough estimation of the extended tieback footprints is shown in Figure 2-41 below.

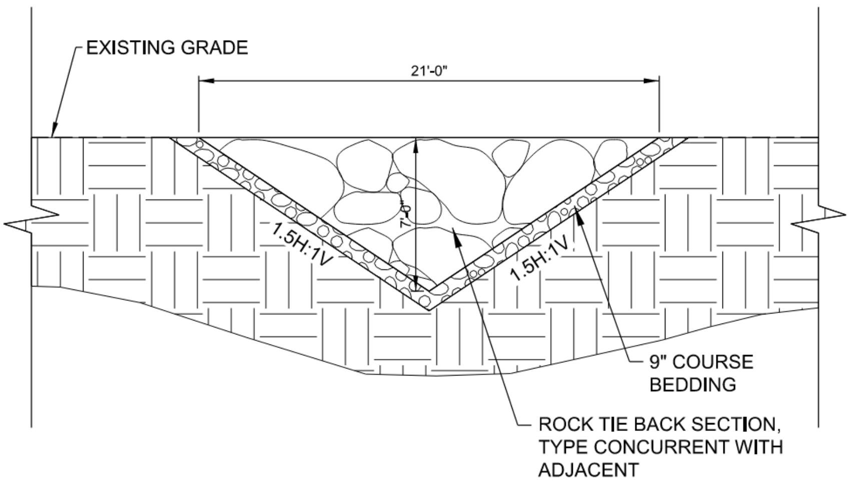


Figure 2-40. Rock Tieback Typical Cross Section

Figure 2-41. Estimated maximum footprint of tieback extensions

2.6 Design Implementation

2.6.1 General Schedule and Overview

Table 2-3 below provides a summary of planned implementation activities for each contract. The Projects are generally implemented in three phases further described below: Vegetation Clearing and Elderberry Transplant, Civil Construction, Revegetation. Separating the project components into phases better facilitates working within regulatory windows, avoiding project delays, and using the best available contractors for each type of work. The overall schedule is generally based on completing construction during the in-water work window specified in the NMFS BO. Site 3-1 and Site 4-1 are to be constructed over two years to ensure completion of in-water work during the in-water work window. Some civil construction activities for features that are above the ordinary high-water mark may start as early as April 16 each year.

Table 2-3. Schedule for Implementation

Contract / Site	Vegetation Clearing/ Transplant	Target Construction Year	Revegetation
LAR C3B	Y1: Fall/ Winter 2025/2026 Y2: Fall/Winter 2026/2027	Y1: Summer 2026 – Fall 2026 Y2: Summer 2027 – Fall 2027	Y1: Spring 2026 Y2: Spring 2027
LAR C4A	Fall/Winter Preceding Construction	Spring – Fall 2027 or 2028	N/A
LAR C4B	Fall/Winter Preceding Construction	Spring – Fall 2028	Spring 2029

2.6.2 Vegetation Clearing and Elderberry Transplant

Large vegetation will be removed from the project footprint the fall and winter ahead of construction to avoid nesting bird season. For contracts expected to be constructed over multiple construction seasons, such as LAR C3B, vegetation removal in the preceding fall/winter will be limited to areas where construction will occur in each construction season. Vegetation is removed from above ground, and roots are left in place to provide erosion protection for the winter and spring months. Vegetation is removed during this period to facilitate transplanting elderberry shrubs within the footprint as USFWS BO requires the relocation of elderberry shrubs between November 1 and February 15. Generally, relocation of elderberry shrubs requires some clearing of other vegetation for access. Clearing of vegetation during the winter months also helps reduce the potential for impacts to nesting birds and construction delays from nesting birds. Vegetation clearing will be completed by a pre-qualified contractor under a contract which also includes the establishment of the elderberry shrubs at the transplant locations.

2.6.3 General Civil Construction

The general civil construction work includes all excavation, grading activities, rock and soil placement for both levee erosion protection and on-site habitat mitigation efforts. The general civil contractor will be a prequalified contractor with experience working near rivers and with required worker education on the environmental and cultural permit requirements at the site. Construction monitoring for sensitive biological and cultural resources may be required and is site dependent. At the conclusion of the work, the contractor will install temporary erosion control and seed the footprint with native grasses and sedges.

2.6.4 Revegetation of Sites

Once the general civil contractor has completed on-site work, a revegetation contractor will start work the following year to revegetate the site with native plants. The revegetation contractor will be required to install plants per the revegetation plans, and to irrigate and maintain plants through an establishment period. The establishment period is a performance-based requirement that will likely vary in duration from three to five years based on plant survival rates. During this time, the revegetation contractor will remove and replace failed vegetation, remove any invasive species from the site, and maintain any temporary erosion control features at the site. Once plant establishment requirements have been met, the contractor will remove temporary features (such as irrigation piping).

The vegetation being replanted at the site are species reviewed by project partners and includes native trees, shrubs, sages, and grasses. Table 2-4 below provides a list of Container Plants and Cuttings Species which will be included in the revegetation plantings. Table 2-5 provide a list of Seed Mix Species which will be used on the sites following construction completion.

Once established, the vegetation will continue to grow and mature. Figure 2-42 and Figure 2-43 provides examples of similar bank protection projects completed on the LAR since the late 1990s. Planting pallets and plant densities have been revised based on lessons learned from these previous projects as summarized by (GEI, 2019). These lessons learned have included reduced plant densities relative to previous designs which tended to overplant the site, and the inclusion of more shade tolerant ground cover. The designs are intended to provide natural regeneration once the site is established.

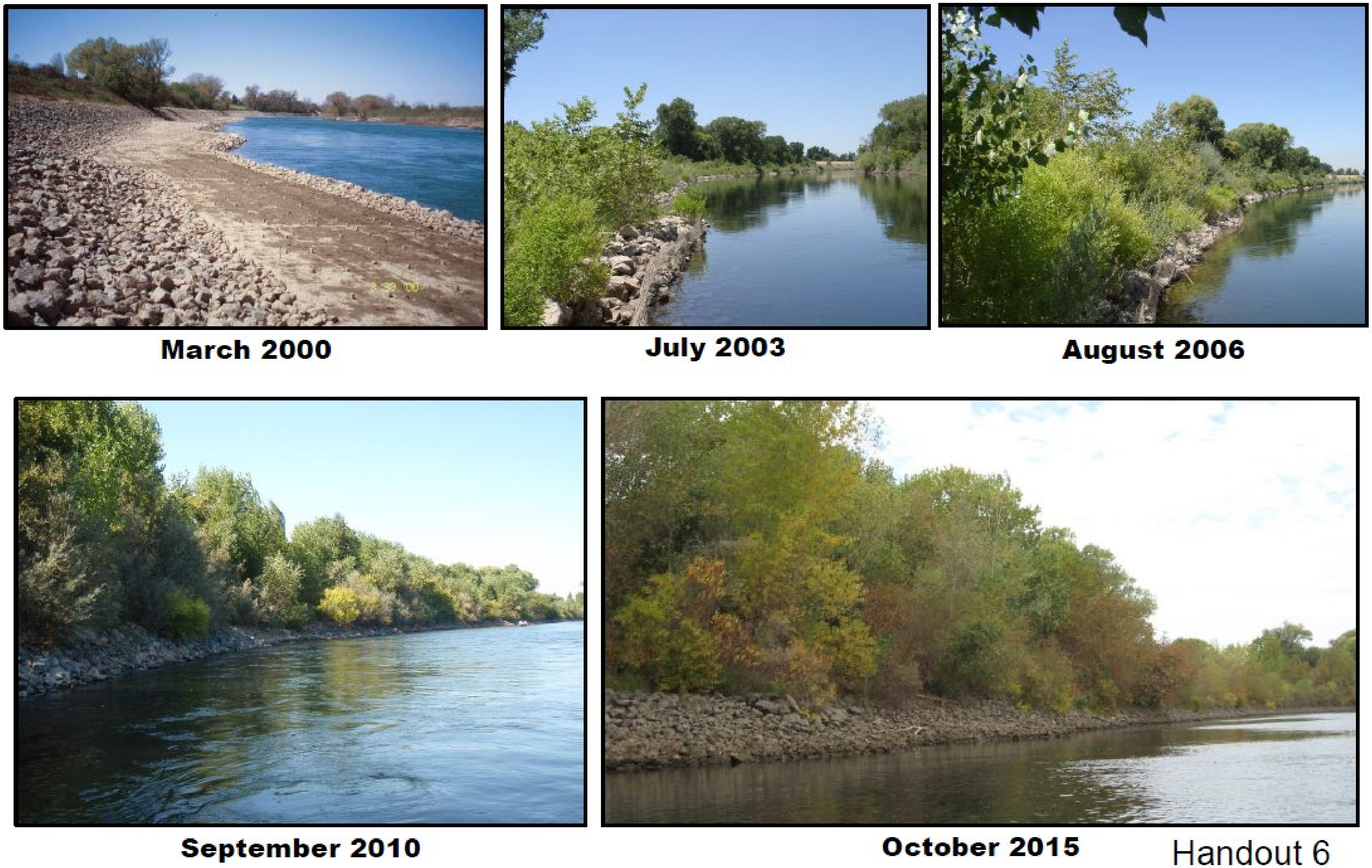
Table 2-4. Container Plants and Cuttings Species

Botanical Name	**Common Name**
Acer negundo	boxelder
Achillea millifolium	Yarrow
Alnus rhombifolia	white alder
Aristilochia californica	Pipevine
Artemesia douglasiana	mugwort
Baccharis pilularis	coyote brush
Baccharis salicifolia	mulefat
Carex barbarae	Santa Barbara sedge
Cephalanthus occidentalis	button bush
Cercis occidentalis	western redbud
Clematis lingustifolia	clematis
Dicheolostemma capitatum	blue dicks
Equisetum hyemale ssp. Affine	horsetail
Euthamia occidentalis	western goldenrod
Frangula calilfornica	coffeeberry
Fraxinus latifolia	Oregon ash
Grindelia camphorum	gum plant
Heteromeles arbutifolia	toyon

Botanical Name	Common Name
Isolepis cernua	low bulrush
Juglans hindsii	California walnut
Juncus balticus	Baltic rush
Juncus effusus	common bog rush
Leymus triticoides	creeping wildrye
Lupinus albifrons	silver bush lupine
Mara macrocarpa	wild cucumber
Muhlenbergia rigens	deergrass
Oenothera hookerii	evening primrose
Platanus racemosa	western sycamore
Populus fremontii	Fremont cottonwood
Quercus lobata	valley oak
Quercus wislizeni	interior live oak
Rosa Californica	western wild rose
Rubus ursinus	California blackberry
Salix lasiolepis	arroyo willow
Salix exigua	sandbar willow
Salix exigua	Sandbar willow
Salix gooddingii	black willow
Salix Laevigata	red willow
Salix lasiandra	pacific willow
Salix lasiolepis	arroyo willow
Sambucus mexicana	blue elderberry
Schoenoplectus acutus var. occidentalis	tule
Schoenoplectus californicus	california bulrush
Solidago velutina spp. Californica	california goldenrod
Stipa Pulchra	purple needlegrass
Symphoricarpos albus var. laevigatus	common snowberrry
Vitis californica	California wild grape

Table 2-5. Seed Mix Species

Botanical Name	Common Name
Achillea millifolium	Yarrow
Agrostis exarta	spike bentgrass
Ambrosia psilostachya	western ragweed
Artemisia douglasiana	California mugwort
Bromus carinatus	California Brome
Clarkia purpurea	purple clarkia
Clarkia unquiculata	elegant clarkia
Croton setigerus	turkey mullein
Elymus glaucus	blue wildrye
Eschscholzia californica	California poppy
Euthamia occidentalis	western goldenrod
Festuca microstachys	six weeks fescue
Grindelia camporum	gum plant
Hordeum brachyantherum	meadow barley
Hordeum brachyantherum ssp. californicum	California barley
Koeleria macrantha	june grass
Leymus triticoides	creeping wild rye
Lupinus bicolor	minature lupine
Lupinus microcarpus	chick lupine
Madia elegans	common madia
Poa secunda spp. Secunda	one sided bluegrass
Stipa Pulchra	purple needlegrass
Trifolium wildenovii	tomcat clover



Handout 6

Figure 2-42. Establishment of vegetation at RM 4.4L bank protection site after planting in 2000

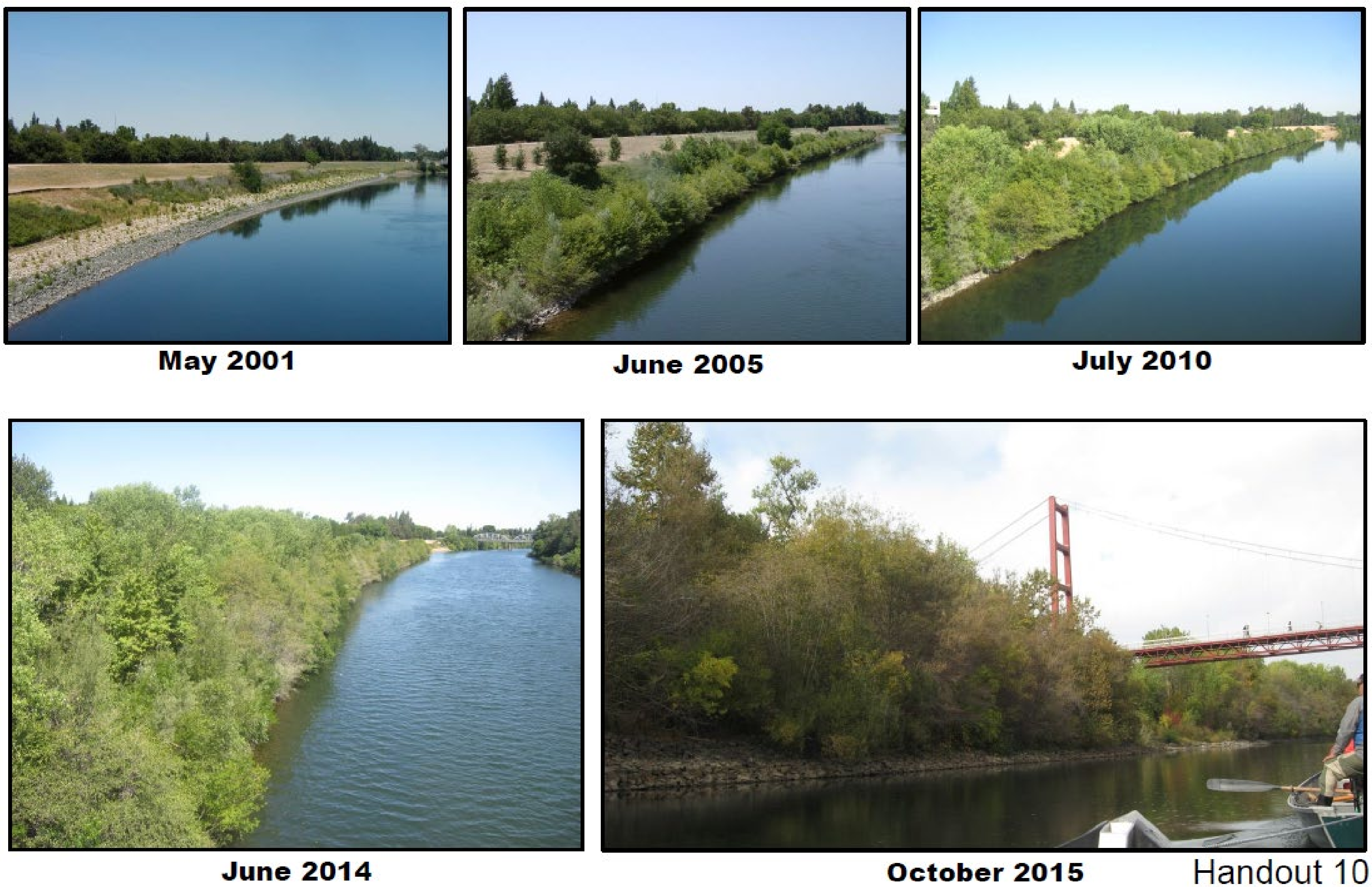


Figure 2-43. Vegetation establishment at RM 6.4 L bank protection site after planting in 2001

3 SACRAMENTO RIVER EROSION PROTECTION

3.1 Background

The Sacramento River downstream of LAR has tight levees and is tidally influenced. The location of the channel has been relatively stable for the past 150 years (although local scour and erosion can still be an issue). A large percentage of this reach has already been armored with riprap. This area has heavy wave action from recreational boats and wind, and the banks are heavily used by the general public since the banks are heavily occupied by private residences and commercial structures that limits public access along the levees. The general public use in this reach often creates local erosion by walking directly on the levee and banks. Many of the levees are constructed of dredged soils from the bottom of the channel. This reach does not have significant waterside structures such as private and commercial buildings but has some sections of heavy vegetation and many boat docks. The causes of erosion in this reach are boat wake, wind-wave, mass failure, fluvial processes, and public use.

This section provides detailed information about past performance of the levee, the selection of sites for repair, and the design process to develop designs for Contract 3 on the Sacramento River. Section 3.3 includes a summary of key data sources relied on in the site identification and design, as well as a summary of tools developed for analysis. Section 3.4 provides a summary of how sites requiring improvements were identified. Section 3.2 summarizes the design process and designs at each location in the Sacramento River Erosion Contract 3. Section 3.5 summarizes the implementation process for the proposed projects.

3.1.1 Historical Performance

The history of the Sacramento River has been greatly impacted by the influx of people into the Central Valley. Prior to 1800's the Sacramento River had insufficient capacity to carry large winter and spring flows, resulting in floodplains that extended for miles beyond the channel banks. The overbank velocities were low and much of the sediment eroded from the mountain and foothill areas would drop out, resulting in floodplain deposition (vertical accretion) and the development of natural levees through the rapid deposition of coarse particles as flow velocities decreased. Hydraulic mining, particularly in the Yuba and Bear Rivers, resulted in an excess of sediment load being washed into the Sacramento River and resulted in reduced channel flow and increased flooding in the low elevation areas.

In addition to the hydraulic mining, increased agriculture in the area resulted in landowners building low levees along the river to protect their cultivated fields. The levees were built in piecemeal fashion, without coordination between landowners, which led to competition between landowners to continually raise and strengthen their section of the levee to induce flooding on someone else's land.

During the time of hydraulic mining and agricultural development (1850 to 1900), the Sacramento River saw 13 large flood events. The flood of 1862 flooded the city of Sacramento and resulted in loss of life and destruction of property. The levees protecting the city of Sacramento were subsequently raised following this flood. The floods of 1881 resulted in numerous levee breaks on both sides of the Sacramento River, downstream of the city of Sacramento. After the 1800's, significant floods occurred in 1904, 1907, 1909, and 1928 on the Sacramento River.

Following the floods of the 1800's and early 1900's, early planning for the modern Sacramento River flood protection system started and consisted of dams, bypasses, channel widening and deepening, and levee enlargement. Construction of the Sacramento River Flood Control Project began in 1918 and was completed in 1953. The major features that were constructed included levees along the Sacramento River channel, leveed bypasses, and weirs.

The levees along the Sacramento River south of the confluence with LAR were constructed by a private mining and dredging company with the purpose of reclaiming and selling thousands of acres of farmland. The levees were constructed using large "clam shell" dredging machines. The work began in 1912 and was completed by the end of 1915. Based on typical construction schematics shown on basin-wide maps and historical literature, the levees along the Sacramento River were constructed in the following manner:

- A dragline was used to excavate a trench about 6 to 12 feet deep along the centerline of the levee alignment. The trench bottom width ranged from about 12 to 28 feet. The excavated material was deposited along both sides of the trench forming two small containment dikes.
- Hydraulic dredging operations placed material from the adjacent Sacramento River bottom into the excavation area between the dikes. This material consisted predominately of sands.
- The final levee configuration was achieved by covering the dredged sand with the adjacent dike materials. These materials consisted predominately of silt, clay, and fine sand.

It should be noted that because of the construction history outlined above, the upper portion of the semi-pervious blanket beneath the center of the levee has been removed and commonly replaced with sand. Typically, the sand core extends to a greater depth beneath the center of the levee than beneath either of the flanks or the surrounding ground. Most of the levee material was hydraulically dredged from the Sacramento River and piled or pushed into place with no mechanical compaction. Some mechanical shaping of the upper and outer portions of the sand core likely occurred during establishment of the general levee geometry.

The levees along the Sacramento River south of the confluence with LAR were constructed by local interests using clamshell dredges excavating material from the Sacramento River in the early 1900's. This method of construction usually resulted in a levee constructed on the channel banks with loose, sandy fill material that is deepest below the center of the levee. The materials within the levee embankment are predominantly sands, silty sands, and cohesionless materials. Since the construction of the original levee embankment in the early 1900's the levee has been remediated and improved several times. Levee remediation and improvements have consisted of embankment reconstruction and or enlargement, floodwalls, waterside rock slope protection, shallow through seepage cutoff wall, deep under seepage cutoff walls, seepage berms, and relief wells.

The 1955 flood was the first test of the new Sacramento River Flood Protection system. At the Sacramento Weir, 30 gates were opened with the peak flow reaching 48,000 cfs sent into the bypass. The peak flow in the Sacramento River at I Street was about 95,000 cfs. During the 1964 flood, the peak flow on the Sacramento River at I Street was about 100,000 cfs, just below the channel capacity of the reach. The flood of 1969 was largely controlled by the reservoirs, flood channels, and bypasses. The flood of 1974 saw a peak of 95,000 cfs at the I Street gage; the Sacramento Weir gates were not opened.

In 1960, Congress authorized the Sacramento River Bank Protection Project (SRBPP) for the construction of bank erosion control works and setback levees within the limits of the existing levee system. This project is intended to maintain the integrity of the levee system to continue the degree of protection for which it was designed.

The flood of 1986 had a peak flow of 117,000 cfs at the Freeport gage, just south of the city of Sacramento. The levees on the Sacramento River were severely stressed from high water and seepage. The levees near the Garden Highway required extensive repairs during the flood and nearly failed. The north bank along Arcade Creek was overtopped and 500 homes were inundated.

Since the completion of the Sacramento River Flood Control Project, significant floods have caused considerable erosion related damage to the levee system. Erosion in the Sacramento River has even occurred during lower flow events, as documented by SRBPP. Numerous emergency bank repairs and repairs done by SRBPP (over 800,000 linear feet) have been constructed in the last 50 years. Erosion continues along the Sacramento River banks and levees and there are currently numerous sites that are in need of repair.

3.1.2 Sacramento River Mileage

River mileage (RM) is measured from the mouth of the Sacramento River along its centerline, with mile zero located at the confluence with the Pacific Ocean. The reference mile markers used in this study are from the USGS quadrangle maps. They have also been used in other studies recently prepared for USACE and were considered to be the most consistent set of markers.

Descriptions of project locations refer to levee stationing (STA) along the centerline of the Sacramento River East Levee (SREL). The stationing refers to lineal feet moved along the centerline and is consistent with other levee improvement projects completed on the Sacramento River. For design and plan sheet creation, a simplified version of the provided levee alignment was created for each site. This simplified site alignment was developed to closely follow the existing alignment with fewer curves and points for the Contractor. Therefore, it should be noted that in some areas there could be up to one foot of error when comparing these two alignment sets; however, that should not hinder comparison between past reference data and proposed designs.

3.2 Background Data and Ancillary Studies

3.2.1 Bathymetric and Topographic Surveys

DWR’s North Central Region Office collected bathymetric surveys between 7/19/2019 and 8/19/2019. They used a multibeam echosounder and used the NAD83 (California State Plane Zone II) horizontal (Epoch 2017.5), NAVD88 vertical datums. Topographic survey and cross sections were collected every 50 feet at each project site in early 2020. The surveys were combined the topographic survey with the bathymetric survey. The combined surveys were Quality Controlled by USACE and were used as the existing surface for civil design work.

3.2.2 Hydrology

Two river stage and discharge gages are located within the project area. DWR operates the gage (#A02100) just upstream of the I-Street Bridge at RM 59.5. USGS operates the gage (#11447650) near Freeport Bridge at RM 46.0. The gages provide historic flow and stage data; however, changes to Folsom Dam operations may impact future releases relative to historic releases, and ongoing improvements to the Sacramento Weir will affect how upstream flows are split between the Yolo Bypass and the Project Reach of the Sacramento River. USACE developed two hydraulic models to support the project (See Section 3.2.3) – ARCF 16 1D SPK Release 6.2 and WCM 1D Model – to help assess the impacts these changes had on the period of record data and full datasets.

The Freeport gage was analyzed to develop typical daily flows through the reach throughout the year. These flows were used to help inform appropriate elevations of resource features to be included in the design such as planting benches and instream woody material where the added resources would be available during migratory windows when juvenile salmonid were present. The gage analysis also identified a range of typical flow conditions when vessel generated traffic was most frequent to inform designs. Historic gage information was compared with hydrology from the updated Folsom Water Control Manual routed through the WCM 1D model (See Section 3.2.3.1) to evaluate potential changes in future conditions relative to historic observations. The gage record was also used to develop a flow rating curve to be used as a downstream boundary condition for hydraulic modelling analysis (see Section 3.2.3.2).

Initial hydrology datasets for this project were adapted from the CVHS which provides a range of hydrographs from the 1/2 AEP event to the 1/500 AEP, including the peak emergency discharge of 160,000 cfs at Folsom Dam. The design discharge for LAR is 160,000 cfs and will be the primary discharge used to evaluate metrics when designing erosion countermeasures, which coincides to a flow of around 117,700 cfs on the Sacramento River.

3.2.3 Hydraulic Model Analysis

Existing one-dimensional (1D) hydraulic models were used to route combined Sacramento River and American River flows into the Project reach to support the hydrologic analysis. The 1D model was used to assess the impacts of water surface of the entire ARCF project. See Section 3.2.3.1.1 for more detail on the 1D model.

Two-dimensional depth averaged models (2D) were used to evaluate more detailed hydraulic conditions such as water velocities, and scour estimations through the reach under baseline and project conditions. These values were used to estimate the required rock size and bank protection thickness. Hydrologic Engineering Center's River Analysis System (HEC-RAS), version 5.0.7, was chosen for all detailed hydraulic analyses initially. However, the more recent release of HEC-RAS, version 6.1 resulted in quicker run times of high definition two-dimensional (2D) models. Therefore, the existing 2D model and rise analysis was run through version 6.1 to reduce the time for analysis. See Section 3.2.3.2 for more detail about the 2D model.

3.2.3.1 1D HEC-RAS Model

3.2.3.1.1 ARCF 16 1D SPK Release 6.2 Model

This 1D unsteady model was developed in HEC- RAS version 5.0.7 to determine design water surface profiles using the best available data, tools, and engineering methods. The model expands upon the model developed for the GRR by including updated basin hydrology, improved modeling resolution near levees, known basin changes and levee improvements, and is consistent with requirements in the State of California Urban Levee Design Criteria. The model also accounts for sea level change, super-elevation, debris blockages, and the 65% design of the Sacramento Weir expansion (there were no Sacramento Weir expansion design changes between 65% and 100% design that needed to be captured in this hydraulic model). Coverage for this model includes planned erosion protection project sites on both LAR and Sacramento River. The model evaluates flows developed by CVHS (See Section 3.2.2).

3.2.3.1.2 WCM 1D Model

The Folsom Dam Water Control Manual (WCM) HEC-RAS model extended from Nimbus Dam on LAR and Verona on the Sacramento River, downstream to river mile (RM) 40 on the Sacramento River. This model did not include the proposed widened Sacramento Weir; however, the model was used to evaluate lower magnitude flows where the weir would be less effective (Northwest Hydraulic Consultants, 2019). The general intent of this model is to support the design of habitat-based features. The model provided hourly outflows from Folsom Dam for a 73-year period of record (1929-2002) and can compare previous records to new operations of the Folsom Dam. Additionally, NHC used this model to evaluate and compare the 0.5 AEP discharge relative to the value used in the ARCF 16 1D SPK Release 6.2 Model and to evaluate stream power and effective discharge on the Sacramento River for sediment transport estimates and relative changes to bank erosion from changing operations of Folsom Dam.

3.2.3.2 2D HEC-RAS Model

Contractors, on behalf of SAFCA and the U.S. Army Corps of Engineers, A 2D HEC-RAS hydraulic model of the Sacramento River from the Sacramento Weir downstream through Freeport was developed and calibrated to further design of the Sacramento River erosion protection (cbec, 2020). The report covers the development, calibration, and validation of the 2D hydraulic model.

The model begins at approximately RM 61.5 on the Sacramento River and RM 0.75 on the Lower American River (LAR) and extends 17 miles downstream near the Freeport gage. This allows the Freeport stage data to drive the downstream boundary conditions while the upstream hydrographs can be routed from the two 1D models.

The 2D mesh consists of mostly square elements in a curvilinear 20-feet grid that follows flow paths and includes banklines along steep gradients, bridge piers, and topographic high points. The mesh was further refined with smaller cell sizes along the levee crest, levee toes, channel banks, and bridge pier banklines. Lastly, a refinement region was included along the entire left bank of the Sacramento River from below the LAR to the end of the model domain. This region spans from the channel edge to the levee crest and uses and increased model resolution of 5-feet grid spacing to support high resolution bank protection design projects. The average channel width of the Sacramento River within the ARCF16 Project extents is approximately 800-ft.

Manning's n-values for five land cover classes were calibrated to high water marks (HWM) of the 2006 event (Peak Flow: 65,000 cfs). The model was then validated to the 1997 event (115,000 cfs). A velocity distribution validation test at the I-St Bridge shows reasonable agreement of modeled velocities based on the selected eddy viscosity.

3.2.3.3 Cumulative Impact Analysis

In addition to the hydraulic modeling done for each individual site, overall cumulative impacts to the river system were analyzed. This analysis was looked at from two different aspects, the first being understanding the cumulative impact of building multiple projects to the entire river system. The second aspect was to understand if the project was maintaining or reducing the potential risk of overtopping.

3.2.3.3.1 Cumulative Impacts Hydraulic Modeling

A Two-Dimensional HEC-RAS model covering 17 miles of the Sacramento River, from River Mile (RM) 61.74 to RM 44.49 and 0.75 miles of the Lower American River were simulated containing all the repair sites and habitat restoration sites, including changes to the Sacramento Weir. These models were run for multiple large flows and compared to modeling efforts of the current system (without repair sites or weir widening) to ensure that the addition of the repairs and habitat restoration did not cause significant (increase greater than 0.1 ft[6]) increases to water surface elevations throughout the entire modeled river system. If results demonstrated an increase in water surface elevations greater than 0.1 ft, a risk assessment would be required to determine the impacts to the system; however, as noted below the model results showed there was a reduction in water surface elevations, so a risk assessment was never required to address that issue.

This modeling effort showed that the implementation of the Sacramento Weir Widening reduced the peak water surface elevations by approximately 0.5 ft or more within all the repair sites on the Sacramento River for the 0.5% AEP event. The only significant change in inundation is a ponding area adjacent to the Marina Way River Access in West Sacramento. This area, which is located within the leveed portion of the system, was typically flushed with fresh water from a 1 in 2-year event, the overall stage reduction from the project means the pond area will not experience as frequent of flooding. This area will likely still fill from rain events, but the inflow of water into the pond from the river will be less frequent.

3.2.3.3.2 Cumulative Impacts Probability Information

While the hydraulic modeling showed that the overall project would not result in an increase in water surface elevation for the large events, the project also checked that the project would be either maintaining the existing overtopping probability or reducing the overtopping probability (AOP – Annual Overtopping Probability – not accounting for geotechnical failures) and levee performance (AEP – Annual Exceedance Probability – accounting for geotechnical failures). Probability for failure was analyzed using the HEC-FDA (Flood Damage Reduction Analysis) model.

[6] 0.1 ft is considered significant because it is a measurable increase; changes less than 0.1 ft are considered within the margin of error of the hydraulic models.

The HEC-FDA program was used to compute the expected AOP, at six critical index locations, assuming the levee does not fail prior to overtopping. This data represents the probability of levee failure outcome solely dependent on the effects of changes in conveyance capacity for a given scenario against the current levee height. The AOP results show a slight reduction in some locations to a larger reduction in other areas for the probability of overtopping, meaning the ARCF16 Project was maintaining or improving the flooding potential to the area behind the levees.

The HEC-FDA program was also used to compute the expected AEP, at four index locations, to demonstrate how the assumed levee fragility affects levee system performance. In addition to failure due to overtopping, the AEP incorporates information on the levee's susceptibility to failure prior to overtopping due to erosion, seepage, and slope instability probabilities at a given index location based on levee specific characteristic (such as soil type, hydraulic loading, river velocities, etc.). This data provides a more realistic representation of the overall levee system performance as it can account for both changes in conveyance capacity and the levee improvements proposed under the ARCF16 Project. The AEP results show that the project improvements provide an overall reduced probability of levee failure to the Sacramento River east levee system.

3.2.4 Geology

The study area has been mapped by a number of geologists on a regional scale, most recently, the study area was mapped by Fugro William Lettis & Associates (FWLA, 2010) for DWR's ULE project. FWLA mapped surficial geologic units at a scale of 1:20,000 and developed the most detailed geologic mapping available for the study area.

The geomorphic processes and stratigraphic distribution of the soils in the study area are described in detail by FWLA. Their mapping was based on data and findings from past published works in conjunction with review of aerial photographs and topographic, surficial geologic, and soil maps, but was not correlated to explorations performed for the ULE project. GEI/HDR reviewed the FWLA geomorphology together with subsurface data from borings and CPTs to develop an interpretation of subsurface conditions. In general, the FWLA geomorphology was found to be reasonably consistent with foundation conditions.

3.2.5 Existing Bank Revetment Assessment

A revetment condition assessment of all existing revetment sites on the east levee between Freeport and the LAR confluence, see Figure 3-1, was completed in 2021. The study included reviews of as-built drawings, field investigations, as well has hydraulic modelling and rock size calculations. The intent of the assessment was to verify existing projects which were designed prior to the current project would remain stable during a 117,000 cfs flood event. Field investigations measured actual rock size that was placed at the project site, as well as measured rock thickness and verified rock extents. Hydraulic information developed from the baseline hydraulic model (see Section 3.2.3.2) run for 117,000 cfs was used to evaluate if the existing rock would remain stable during the design event.

3.2.6 Biological Resource Surveys and Assessments

Data collection, analysis, and reporting in support of the ARCF16 project along the 15-mile-long section of the east bank of the Sacramento River, from the confluence with LAR south to Cliff's Marina, near

Freeport (AECOM, 2020). Surveys to support this report included collecting data and mapping vegetation communities, elderberry shrubs, and SRA cover across the entire reach. These surveys were collected from December 2019 to April 2020. This survey was used to create the vegetation removal plan for trees to be removed or trimmed and elderberry shrubs to protect in place as part of Contract 2 and Contract 3 construction. Additionally, environmental staff used the canopy analysis to calculate impacts and mitigation requirements.

3.2.7 Geomorphic Assessment

A geomorphic assessment was completed in 2019 of the Sacramento River Sacramento River from the confluence with LAR (River Mile (RM) 60.1) to Freeport (RM 46) (Northwest Hydraulic Consultants, 2019). The intent of the report was to support engineering analyses of erosion and stability by identifying key geomorphic processes affecting channel stability. The report documented the geologic setting and historic anthropogenic impacts to the study reach, historic anthropogenic impacts to the reach, identified historical trends in channel forming processes up to the present, and assessed the potential for geomorphic change. Overall, the geomorphic assessment identified the study reach to be generally both vertically and laterally stable. The elevation of the sand bed channel is likely to continue to fluctuate several feet in elevation into the future as sediment is conveyed through the reach and ephemeral scour holes develop in high flow events and fill; however, the long-term trend is for the reach to continue to be a conveyance. The Geomorphic Assessment for the Sacramento River is provided in Attachment B.

3.2.8 Erosion Assessment

An erosion assessment of the Sacramento River east bank was completed in 2019 to help quantify the risk of erosion to the levee (Northwest Hydraulic Consultants, 2019). Whereas the Geomorphic Assessment (discussed in previous section and included in the document) evaluated the historic and long-term trends of the channel and noted that the channel is generally stable, the assessment also noted the historic and ongoing efforts to address erosion. The levees through this reach are generally constructed on or in close proximity to the riverbank with relatively steep waterside slopes. Development of ephemeral scour holes during high flow events can undercut the levee foundation, ongoing wind wave erosion induces erosion along summer water levels, while the potential for velocities to erode the levees continues to exist.

The assessment delineated the study reach into 33 river segments based on geomorphic, structural, or other physical features. Each river segment was characterized and evaluated for erosion potential. The erosion assessment set the stage for future evaluation and prioritization of potential erosion countermeasures. The Erosion Assessment for the Sacramento River is provided in Attachment C.

3.2.9 Existing Bank Revetment Condition Assessment

A revetment condition assessment of all existing revetment sites was completed in 2021 on the Sacramento River (cbec, 2021). Figure 3-1 shows the locations of all revetments which existed prior to implementation the ARCF16 Project improvements. Historic revetment refers revetment installed prior to the 1990s and was typically just bare rock and often used rounded cobble stone as revetment, which is more susceptible to slope failure and more easily mobilized during flood events.

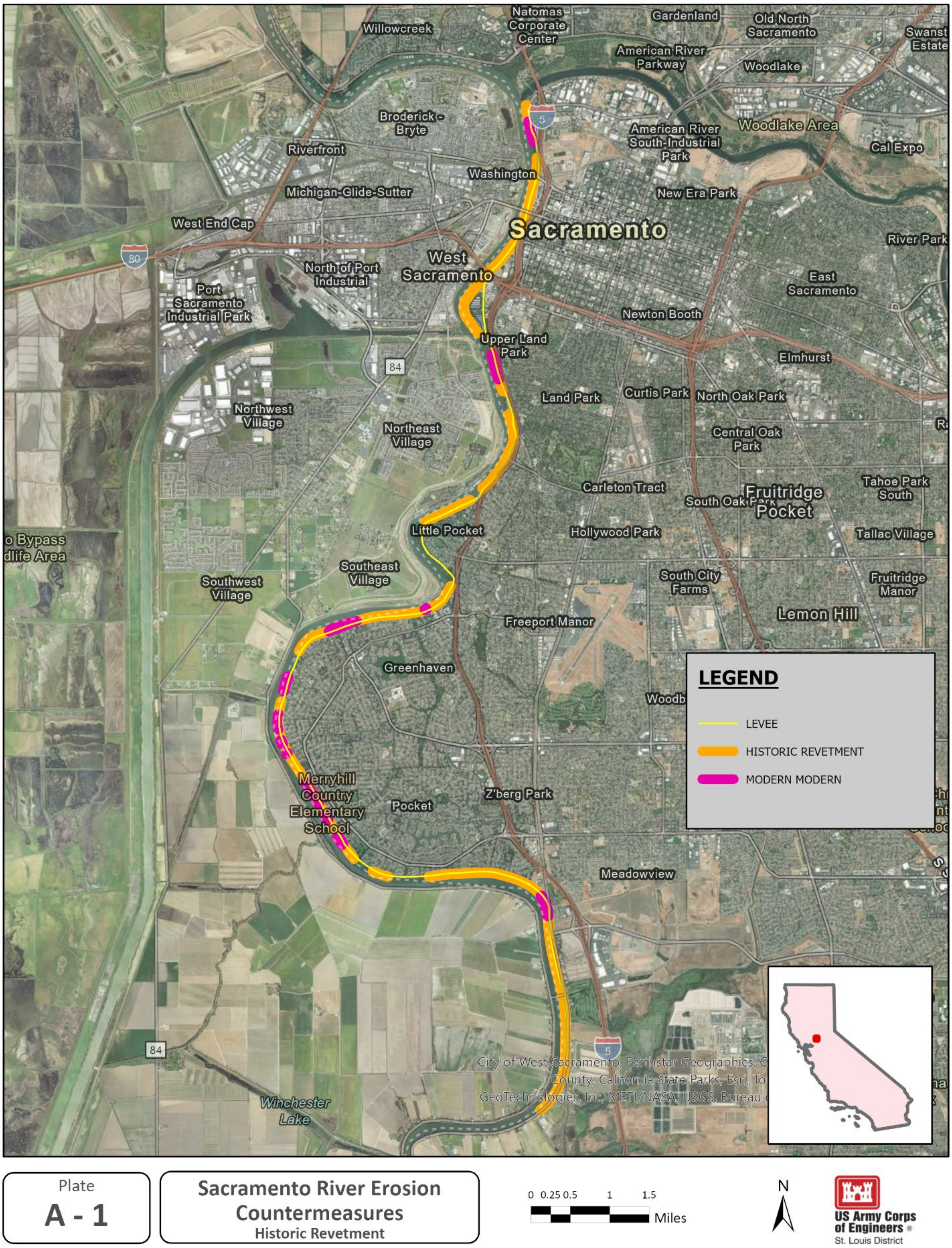


Figure 3-1. Existing revetment along the Sacramento River

Modern revetment refers erosion repair sites which utilized angular quarry stone and included more nature-based features such as planting benches, soil-filled quarry stone, soil cover, and ultimately plantings of native vegetation.

The study was broken out into three phases and included reviews of as-built drawings, field investigations, as well has hydraulic modelling and rock size calculations. The intent of the assessment was to verify existing projects which were designed prior to the current project would remain stable during a 160,000 cfs flood event. Field investigations measured actual rock size that was placed at the project site, as well as measured rock thickness and verified rock extents. Hydraulic information developed from the baseline hydraulic model (see Section 2.3.3) run for 160,000 cfs was used to evaluate if the existing rock would remain stable during the 160,000 cfs event. Reporting was completed in April 2022.

3.3 Site Evaluation and Selection

As discussed in Section 1.8, site selection was complete in a two-phase process. Phase I included an EOE based on existing data and preliminary analysis to develop initial recommendations for sites to be repaired. The Phase II analysis included baseline risk assessments completed at each segment using additional information acquired and developed via new investigations and analyses to expand on the preliminary studies used in the Phase I analysis.

3.3.1 Phase I Site Evaluations- Expert Opinion Elicitation

An EOE was completed for the Sacramento River in August 2020 through November 2020. The EOE panels included four local experts with extensive experience working on the Sacramento River and adjacent flood control projects. USACE incorporated additional national experts onto the team. The EOE assessments were largely based on the information presented in Appendix A of the erosion assessment, as well as additional information on past performance, and individual experts experience and observations. After completion of the formal EOE process, the EOE panel assigned a Tier ranking to each segment.

3.3.2 Phase II Site Evaluations - Baseline Risk Assessments

Consistent with USACE Engineering Regulation (ER) 1105-2-101, Risk Cadre teams re-evaluated the risk of erosion failure at each segment under baseline (pre-project) conditions. Segments were evaluated for both PFM 2 erosion into the levee, and PFM 3 erosion into the levee foundation (see Section 1.6). Segments with unacceptably high risk for failure due to erosion were recommended for repair. Key risk drivers- attributes at individual segments that led to high-risk ratings- were identified to be addressed during design.

Risk Cadre teams are multi-disciplinary teams within USACE with special training in risk assessments that assess USACE infrastructure across the nation. The Risk Cadre team completing the baseline assessment had previously completed a risk assessment of the Sacramento River to support the GRR and had foundational knowledge of the river system. The Risk Cadre teams were augmented with local experts from the Non-Federal sponsors with experience working on the Sacramento River that also participated in the EOE. The Risk Cadre based their evaluations on information in the Erosion Assessment and other background information included in Section 3.2.

The Risk Cadre evaluated the potential for PFM 2 fluvial erosion of the levee and PFM 3 fluvial erosion of the levee foundation (see Section 1.6) at each segment defined in the erosion assessment during a single large storm event to determine the likelihood of levee failure. The Risk Cadre defined an event tree for each PFM that would need to occur for levee failure to occur including a flaw occurs exposing erodible soils (by either failure of vegetal cover due to excessive hydraulic force, mass slope failure, tree-fall, or other site specific conditions), erosion of bank soils, erosion extending into the levee template, the potential for intervention such as flood fighting to arrest the erosion, and finally a levee breach occurring in an eroded condition.

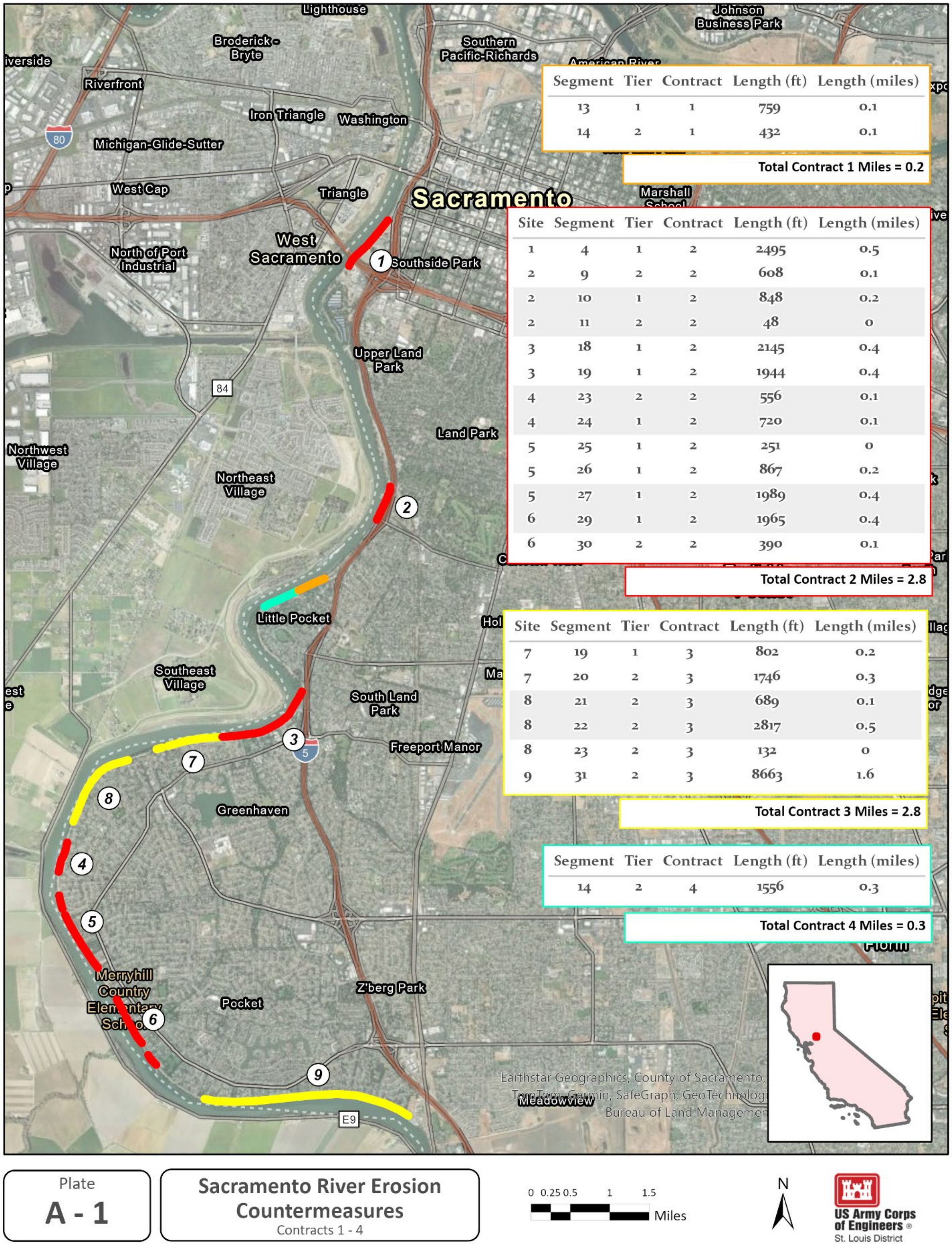
Baseline risk assessments were completed for all the segments in early spring 2020. The baseline risk assessments relied on similar information as the EOE assessments, but included additional information developed after the EOE study to inform the assessment. This information included continued refinements to the hydraulic model (Section 3.2.3.2). The baseline risk assessments assigned annual probability of failure due to erosion to each levee segment. Where the probability of failure exceeded project objectives, USACE identified the segments for erosion protection.

3.3.3 Summary of Site Selection

The findings of the baseline risk assessment confirmed the recommendations of Tier 1 segments identified by the EOE and Tier 3 segments identified by the EOE. Of the Tier 2 segments, the baseline risk assessment identified five of the nine Tier 2 segments as needing repairs to meet project risk reduction objectives. The baseline risk assessment also identified three additional locations for erosion protection would be needed to meet risk objectives. The additional sites identified in the baseline risk assessment were identified after more detailed modeling was completed of sites after completion of the EOE assessment.

Based on the results of both the EOE and Baseline Risk Assessments, USACE developed its implementation strategy for design and construction of erosion protection sites along the Sacramento River. The overall strategy was to construct the worst sites first. The Sacramento River erosion protection work was broken down into four main construction contracts, see Figure 3-2. Sacramento River Contract 1 included one Tier 1 segment, a total of 0.1 miles of bank protection. Sacramento River Contract 2 included solely Tier 1 segments for a total of 2.8 miles of bank protection. Sacramento River Erosion Contract 3 included the five Tier 2 segments identified as needing action, and an additional Tier 1 segment, which totaled approximately 2.8 miles of bank protection features on the Sacramento River and is divided into 3 separate sites. Sacramento River Contract 4 included one Tier 2 segment for a total of 0.3 miles of bank protection. Table 3-1 below provides a breakdown of the sites and segments included in the four construction contracts.

All of the Sacramento River erosion protection projects, including those already constructed (Contracts 1, 2, and 4 covered under a previous environmental document), will result in 6.1 miles of the 12 authorized miles being improved. The remaining 5.9 miles authorized for improvement were determined to meet project risk objectives as they currently exist.



Segment	Tier	Contract	Length (ft)	Length (miles)
13	1	1	759	0.1
14	2	1	432	0.1

Total Contract 1 Miles = 0.2

Site	Segment	Tier	Contract	Length (ft)	Length (miles)
1	4	1	2	2495	0.5
2	9	2	2	608	0.1
2	10	1	2	848	0.2
2	11	2	2	48	0
3	18	1	2	2145	0.4
3	19	1	2	1944	0.4
4	23	2	2	556	0.1
4	24	1	2	720	0.1
5	25	1	2	251	0
5	26	1	2	867	0.2
5	27	1	2	1989	0.4
6	29	1	2	1965	0.4
6	30	2	2	390	0.1

Total Contract 2 Miles = 2.8

Site	Segment	Tier	Contract	Length (ft)	Length (miles)
7	19	1	3	802	0.2
7	20	2	3	1746	0.3
8	21	2	3	689	0.1
8	22	2	3	2817	0.5
8	23	2	3	132	0
9	31	2	3	8663	1.6

Total Contract 3 Miles = 2.8

Segment	Tier	Contract	Length (ft)	Length (miles)
14	2	4	1556	0.3

Total Contract 4 Miles = 0.3

Figure 3-2. Sacramento River erosion protection contracts and sites

Table 3-1. Summary of site selection for all Sacramento River East Levee

Contract	Site	Segment
SAC C1[1]	RM 55.2L	Segment 13
SAC C2[1]	Site 1	4
	Site 2	9, 10, 11
	Site 3	18, 19
	Site 4	23, 24
	Site 5	25, 26, 27
	Site 6	29, 30
SAC C3	Site 7	Segments 19, 20
	Site 8	Segments 21, 22, 23
	Site 9	Segment 31
SAC C4[1]	RM 2.0	Segment 14

[1]SAC C1, C2 and C4 have already been constructed or are currently under construction and are not subject to the contents of this SEIS/SEIR.

3.4 Design Development

Sacramento River Contracts 1, 2, and 4 have already been constructed, or will complete construction in 2024 and none of which are subject to the contents of the SEIS/SEIR. To be clear, the only Sacramento River Erosion contract subject to the contents of the SEIS is Contract 3. Thus, this design development section will focus solely on the contents of Sacramento River Erosion Contract 3, which is planned to be constructed in 2026.

3.4.1 Overview and Process

The two main design objectives of the designs are to prevent bank erosion and provide resistance against wave wash. Designs also include a launchable rock toe to provide resilience against river-bed scour. A secondary objective is to reduce impacts to habitat, as well as provide habitat mitigation wherever possible.

Bank protection designs were developed with an inter-agency working group referred to as the Technical Resource Advisory Committee (TRAC). The TRAC included members from USACE, NMFS, USFWS, DWR, SAFCA, and their consultants. The TRAC is a multi-disciplinary group which includes water resource engineers, geotechnical engineers, geoscientists, biologists, and ecologists. The TRAC provided initial recommendations for design approaches and provided review and comment throughout the design process. USACE has successfully worked with similar groups on the LAR on past projects to develop bank protection designs which reduced habitat impacts and replaced impacted habitat within the designs.

The TRAC developed an initial recommendation in 2020 and provided 10% designs to the U.S. Army Corps of Engineers. The TRAC discussions in the development of the 10% designs focused on developing designs that would optimize long-term habitat conditions at the site. Although construction of planting benches along the edge of the summer water level replaces impacted riparian vegetation and improves habitat for out-migrating juvenile salmonids, the increase in footprint to the design further impacts green sturgeon. Likewise, benches constructed below summer water levels may be more accessible to fish (especially during drought or low flow years), but more susceptible to wave wash erosion or less prone to establish wood riparian species. PDT participated in the TRAC during the development of the design, and the TRAC was briefed with each design submittal and provided an opportunity to review and comment on the project.

The PDT developed designs using established engineering design standards (summarized in Section 1.7.2). While the TRAC provided input in design decisions about resource impacts and technical review of project components, the Risk Cadre evaluated the design at each intermediate submittal to verify risk drivers were being adequately addressed to lowered to meet overall project objectives. Cadre review at each design milestone was also proceeded by or concurrent review by district quality control staff and agency technical review to ensure established engineering design standards were being applied; safety assurance review teams to ensure projects would not create unintended safety hazards; consistency review by program staff; and review by DWR and SAFCA staff. Review from the comprehensive review team includes subject matter experts across engineering disciplines, ecologist, biologists and landscape architects.

3.4.2 Sacramento River Erosion Contract 3

Sacramento River Erosion Contract 3 is composed of erosion protection on Sites 7, 8, and 9. Sites 7 and 8 are located on the north side of the big pocket are of Sacramento. Site 9 is located on the south side of the big pocket of Sacramento.

3.4.2.1 Contract 3 Site 7

Site 7 consists of Segments 19 (after Sump 63) and 20 and extends along the Left Descending Bank (LDB) of the Sacramento River from STA 1341+00 to 1389+00 (Figure 3-3). Segment 19 is classified as Tier 1; whereas Segment 20 is classified as Tier 2. The site begins downstream of the reconstructed Sump 63 and moves through a river crossing where a majority of the thalweg is aligned on the right descending bank (RDB). There is minimal to no berm width throughout the site. The levee on the opposite bank was recently set back which could reduce the hydraulic forces on the LDB.

3.4.2.1.1 Risk Drivers

At Site 7, the primary risk is PFM 3 erosion into the levee foundation. The toe of the riverbank is silty sands which is expected to be erodible at the 115,000 cfs flow event. The steep bank may allow trees to be undercut, and narrow bench width could allow erosion to undercut the levee foundation.

3.4.2.1.2 Proposed Design

The proposed design for Site 7 will include a rock toe being placed along the riverbank in the channel. The rock toe includes adequate rock volume to allow some material to launch (fall) into any channel scour, while still maintaining a stable slope to support the levee foundation. The rock will generally be placed up to about the lowest typical summer water level. Above the lowest typical summer water level, the design will vary along the site to accommodate available bankline and footprint, and limit impacts to existing infrastructure. Some of the site will typically include the rock toe, with a narrow soil-filled rock bench above it extending to the top of the typically highest summer water levels to protect against vessel induced wave wash. These sections are used to reduce impact area into the channel and to assist in providing a smooth transition between the design and its upstream and downstream extents, and existing infrastructure within the footprint. Along about 600 lineal feet of the site, a planting bench will be constructed between typical low and high summer water levels to support revegetation of riparian vegetation and provide armor against vessel-induced wave wash. IWM will be placed just below typical annual low water levels along much of the site, with the exception of design locations near existing boat docks. Figure 3-4 and Figure 3-5 show typical sections with and without planting benches respectively

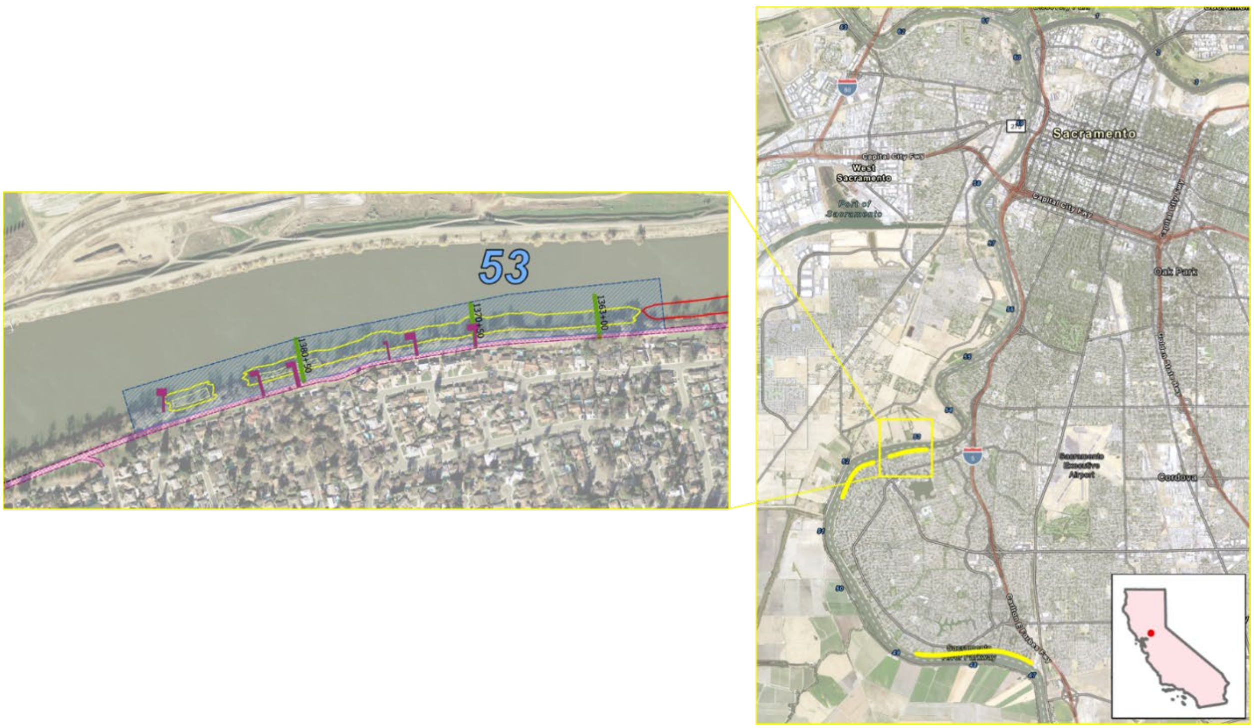


Figure 3-3. Site 7 location map

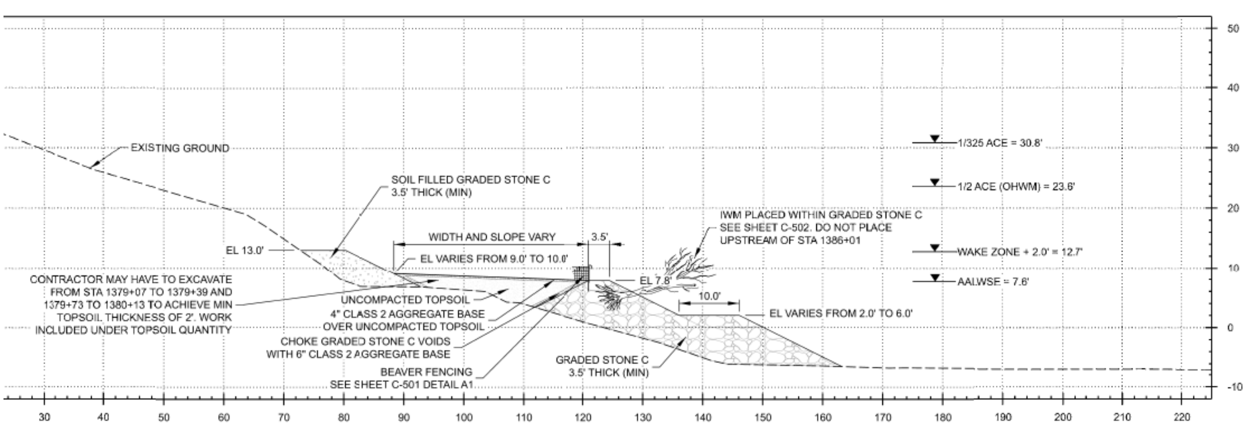


Figure 3-4. Site 7 typical section with planting bench

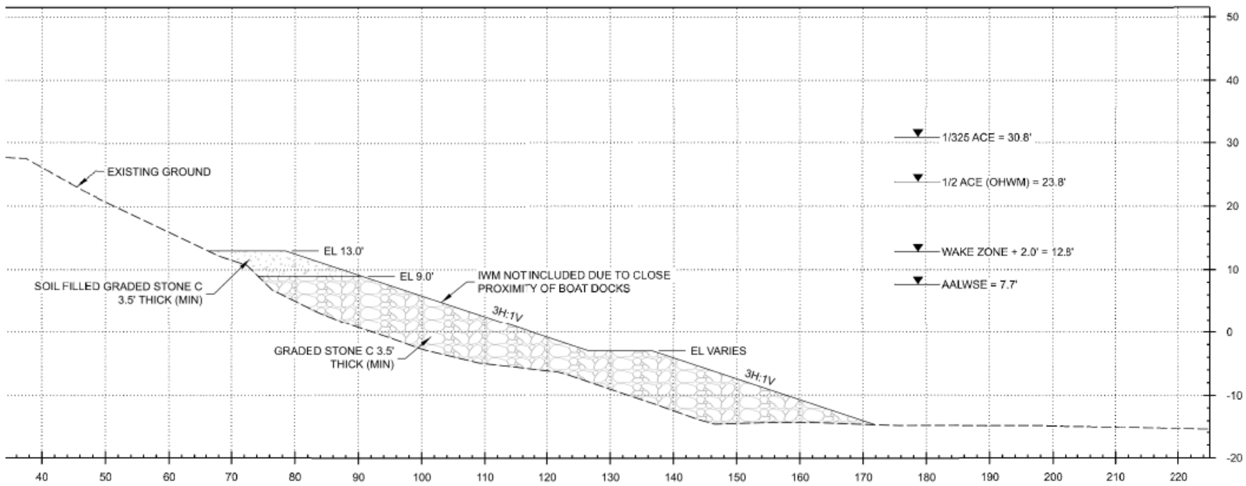


Figure 3-5. Site 7 typical section without planting bench

3.4.2.2 Contract 3 Site 8

Site 8 consists of Segments 21, 22, and 23 (Figure 3-6). Segments 21 and 22 extend along the LDB of the Sacramento River from STA 1401+00 to 1438+00, and Segment 23 extends along the LDB of the Sacramento River from STA 1446+00 to 1452+00. Segments 21, 22, and 23 are all classified as Tier 2, and there are 2006 era repairs in each of the segments. Segment 22 is located along the inside of a sharp bend, and Segment 21 is located just upstream of this bend (with the thalweg aligned along the west bank). Segment 23 is located on a straight section downstream of the bend. The berm is non-existent through Segment 21 and is less than 50 ft through Segments 22 and 23.

3.4.2.2.1 Risk Drivers

At Site 8, the primary risk is PFM 3 erosion into the levee foundation. The toe of the riverbank is silty sands which is expected to be erodible at the 115,000 cfs flow event. The existing bank is relatively steep, and the channel thalweg creates a tall bank with much of the area below where vegetation can establish to provide natural erosion resistance. The berm is narrow to non-existent allowing erosion to quickly undercut the levee. Intermittent placement of dumped rock riprap along the site suggests the site has experienced erosion during past events with hasty repairs to stabilize.

3.4.2.2.2 Proposed Design

The Site 8 design includes a rock toe being placed up to the lowest typical summer water level. The rock has adequate protection to allow some material to launch (fall) into any channel scour, while still maintaining a stable slope to support the levee foundation. Three typical designs are used on the site: a minimal rock design that reduces benthic impacts and reduces impacts to adjacent boat docks located along the site, a bench designs which install a planting bench above the summer water level, and transition sections which transition between these two locations. Instream woody material will be placed along the entire site. Figure 3-7 and Figure 3-8 show typical sections with and without planting benches respectively.

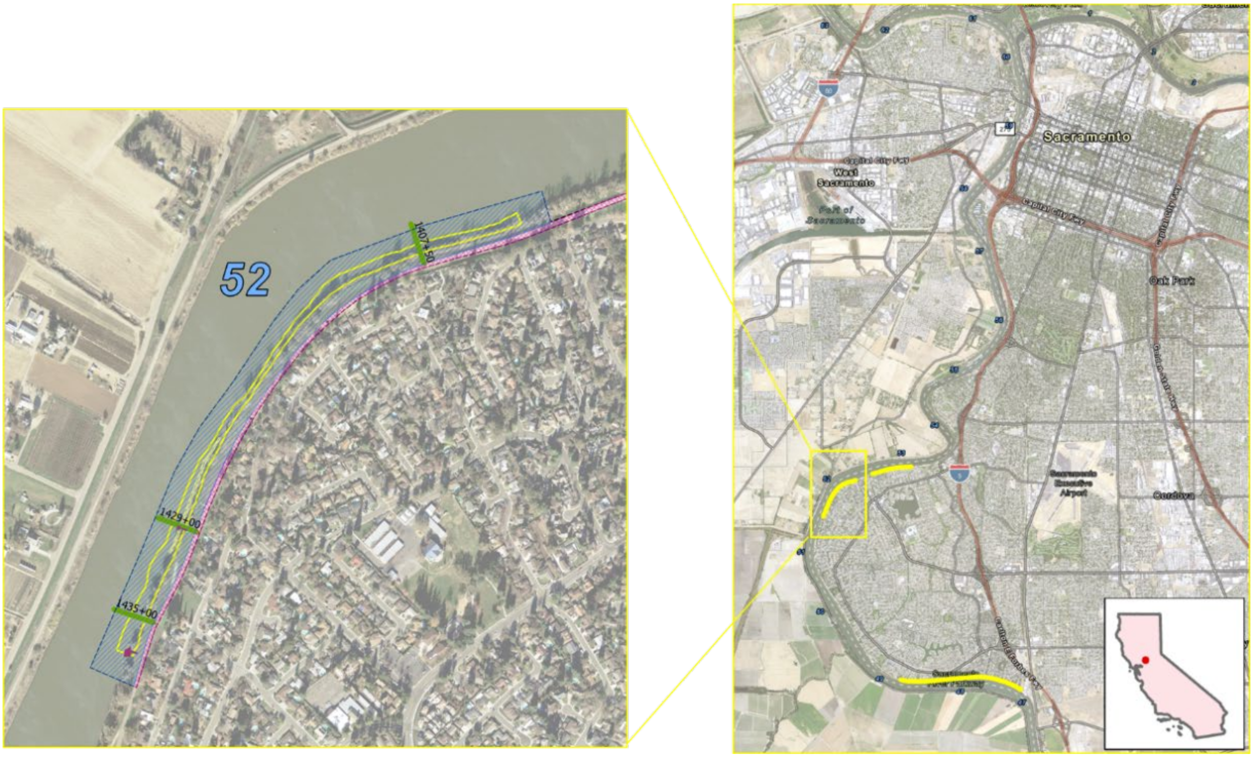


Figure 3-6. Site 8 location map

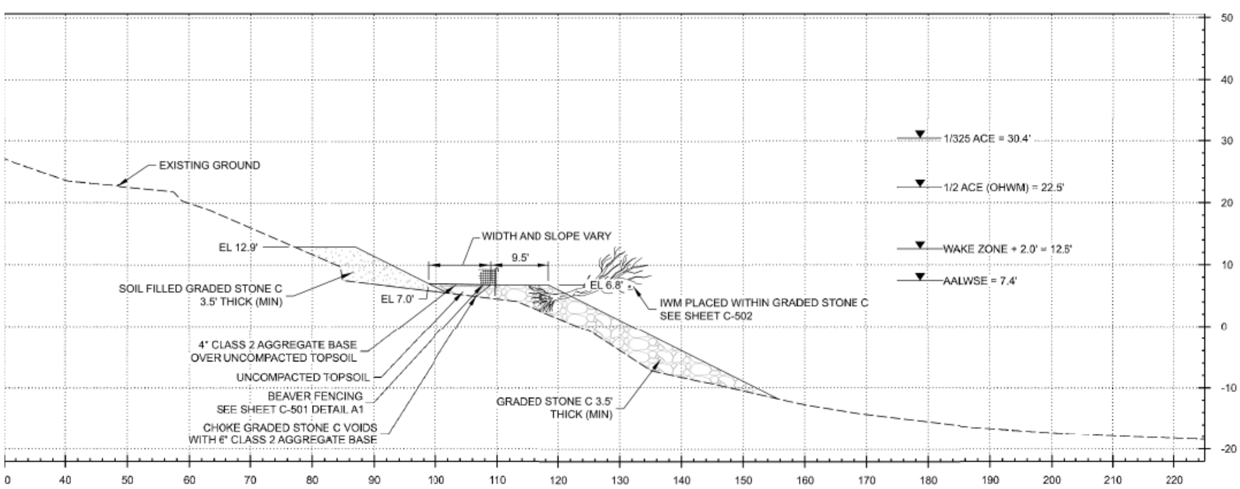


Figure 3-7. Site 8 typical section with planting bench

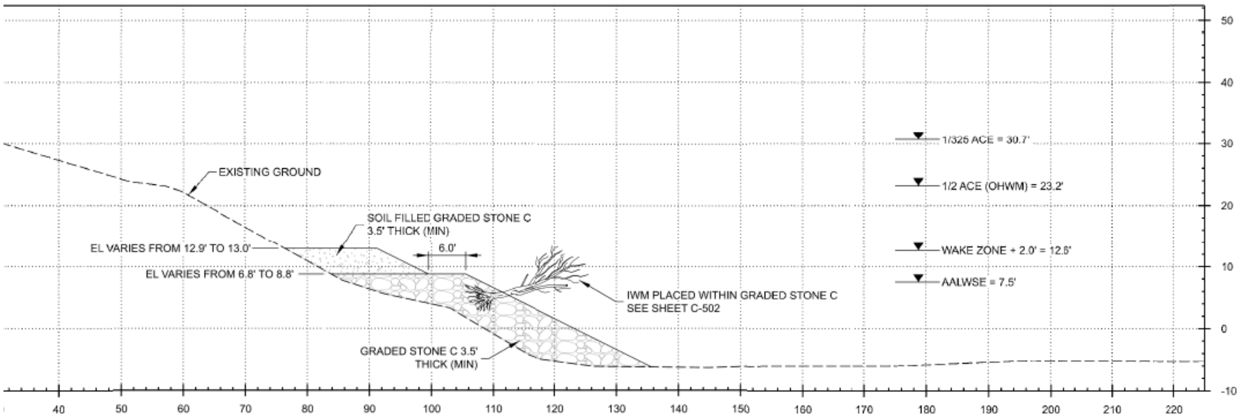


Figure 3-8. Site 8 typical section without planting bench

3.4.2.3 Contract 3 Site 9

Site 9 consists of Segment 31, which extends along the LDB of the Sacramento River from STA 1575+00 to 1662+00 (Figure 3-9). There is minimal to no berm width throughout the site, and there were extensive rip rap installations in the 1970s. Since the installations, many large trees have been lost and gaps have been filled in with rip rap. This segment has several areas with old or no bank protection and ongoing erosion.

3.4.2.3.1 Risk Drivers

At Site 9, the primary risk is PFM 3 erosion into the levee foundation. The toe of the riverbank is silty sands which is expected to be erodible at the 115,000 cfs flow event. The existing bank is relatively steep, and the channel thalweg creates a tall bank with much of the area below where vegetation can establish to provide natural erosion resistance. The berm is narrow to non-existent allowing erosion to quickly undercut the levee. Placement of dumped rock riprap along the site suggests the site has experience erosion in past events with hasty repairs to stabilize.

3.4.2.3.2 Proposed Design

The Site 9 design provides a continuous stretch of protection with quite a few changes in the actual design in between. The design transitions into existing modern revetment on the upstream of the site and into the Freeport Regional Water Facility on the downstream end. The design for Site 9 varies to follow the existing ground. Where room to accommodate a planting bench exists, planting benches are proposed. At locations where the existing levee does not have a bench, a minimal footprint of rock extending from about typical summer water levels will be installed. Similar to upstream designs, the rock toe will provide adequate rock volume to adjust to future scour within the channel, and a soil filled rock cap will be placed to the top of the high typical summer water levels to prevent wave wash and erosion. Figure 3-10 and Figure 3-11 show typical sections with and without planting benches respectively.

Figure 3-9. Site 9 location map

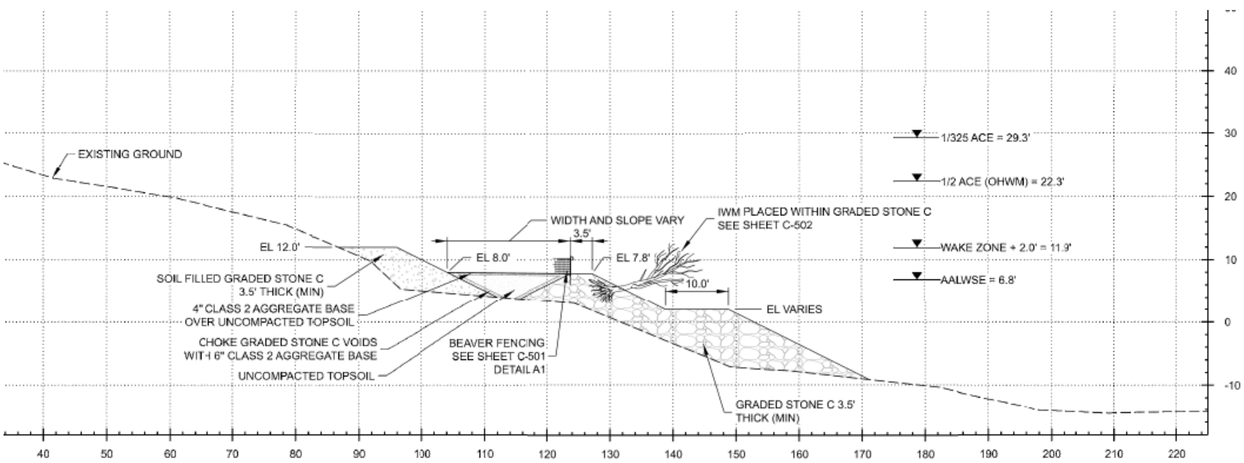


Figure 3-10. Site 9 typical section with planting bench

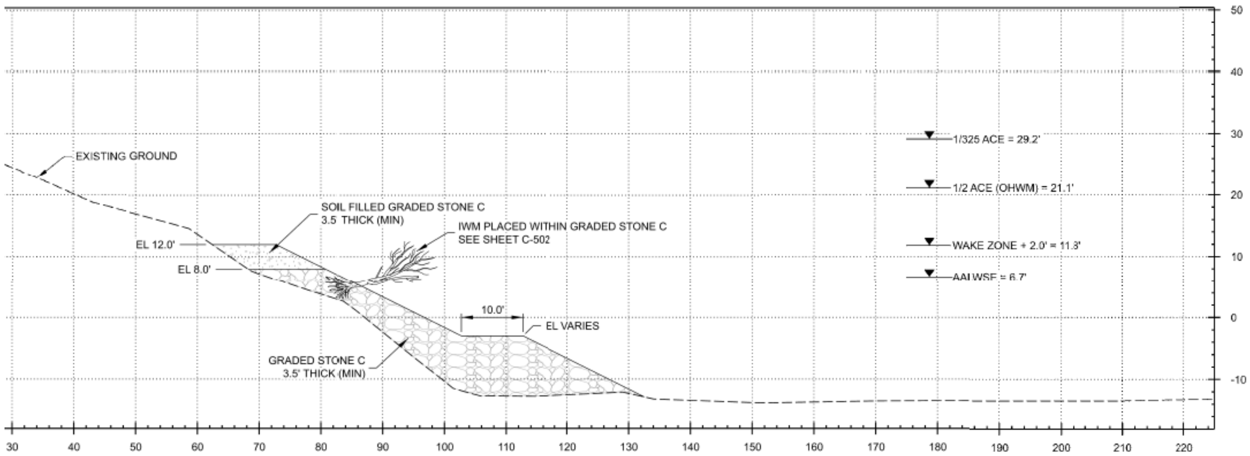


Figure 3-11. Site 9- typical section without planting bench

3.5 Project Implementation

3.5.1 General Schedule and Overview

Table 3-2 below provides a summary of planned implementation activities for each contract. The Projects are generally implemented in three phases further described below: Vegetation Clearing and Elderberry Transplant, Civil Construction, Revegetation. Separating the project components into phases better facilitates working within regulatory windows, avoiding project delays, and using the best available contractors for each type of work. The overall schedule is generally based on completing construction during the in-water work window specified in the NMFS BO. Sacramento River Erosion Contract 3 will be constructed over two years to ensure completion of in-water work during the in-water work window.

Table 3-2. Implementation Schedule

Site	Vegetation Clearing/ Transplant	Target Construction Year	Revegetation
Site 7	Fall/Winter Preceding Construction	Summer-Fall 2026	Spring 2027
Site 8	Fall/Winter Preceding Construction	Summer-Fall 2026	Spring 2027
Site 9	Fall/Winter Preceding Construction	Summer-Fall 2027	Spring 2028

3.5.2 Vegetation Clearing and Elderberry Transplant

Large vegetation will be removed from the project footprint the winter ahead of construction. Vegetation is removed from above ground, and roots are left in place to provide erosion protection for the winter and spring months. SAFCA contracted with AECOM to conduct data collection, analysis, and reporting in support of the ARCF project along the 15-mile-long section of the east bank of the Sacramento River, from the confluence with LAR south to Cliff's Marina, near Freeport. Surveys conducted by AECOM to support this report included collecting data and mapping vegetation communities, elderberry shrubs, and shaded riparian aquatic (SRA) cover across the entire reach. These surveys were collected from December 2019 to April 2020. This survey was used to create the vegetation removal plan for trees to be removed or trimmed and elderberry bushes to protect in place as part Contract 3 construction. According to the survey, Contract 3 does not have any elderberry shrubs within the construction footprint. If an elderberry bush is determined to be present by preconstruction surveys, special care and consideration is required in accordance with the USFWS BO.

Clearing of vegetation during the winter months also helps reduce the potential for impacts to nesting birds and construction delays from nesting birds. Vegetation clearing will be completed by a pre-qualified contractor under a contract which also includes the establishment of the elderberry shrubs at the transplant locations.

3.5.3 General Civil Construction

The general civil construction work includes all excavation, grading activities, rock and soil placement for both levee erosion protection and on-site habitat mitigation efforts. The general civil contractor will be a prequalified contractor with experience working near rivers and with required worker education on the environmental and cultural permit requirements at the site. Construction monitors for sensitive biological and cultural resources may be required on a site-dependent basis. The contractor place rock and soil to install project features. General civil construction will be completed primarily by barge from the Sacramento River. At the conclusion of the work, the contractor will install temporary erosion control and seed the footprint with native grasses and sedges.

3.5.4 Revegetation of Sites

Once the general civil contractor has completed on-site work, a revegetation contractor will start work the following year to revegetate the site with native plants. The revegetation contractor will be required to install plants per the revegetation plans, and to irrigate plants through an establishment period. The establishment period is a performance-based requirement that will likely vary in duration from three to five years based on plant survival rates. During this time, the revegetation contractor will remove and replace failed vegetation, remove any invasive species from the site, and maintain any temporary erosion control features at the site. Once plant establishment requirements have been met, the contractor will remove temporary features (such as irrigation piping).

The vegetation being replanted at the sites are species reviewed by project partners and includes native trees, shrubs, sages, and grasses. Planting pallets and plant densities have been revised based on lessons learned from these previous projects as summarized by (GEI, 2018). These lessons learned have included reduced plant densities relative to previous designs which tended to overplant the site, and the inclusion of more shade tolerant ground cover. The designs are intended to provide natural regeneration once the site is established. Table 3-3 below provides a list of Container Plants and Cuttings Species which will be included in the revegetation plantings.

Table 3-4 provides a list of Seed Mix Species which will be used on the sites following construction completion.

Table 3-3. Container Plants and Cuttings Species

Botanical Name	Common Name
Acer negundo	boxelder
Alnus rhombifolia	white alder
Artemesia douglasiana	mugwort
Carex barbarae	Santa Barbara sedge
Cephalanthus occidentalis	button bush
Euthamia occidentalis	western goldenrod
Fraxinus latifolia	Oregon ash
Juncus balticus	Baltic rush
Juncus effusus	common bog rush
Platanus racemosa	western sycamore
Rosa Californica	western wild rose
Salix exigua	sandbar willow
Salix lasiolepis	arroyo willow

Table 3-4. Seed Mix Species

Botanical Name	Common Name
Achillea millifolium	Yarrow
Agrostis exarta	spike bentgrass
Ambrosia psilostachya	western ragweed
Artemisia douglasiana	California mugwort
Carex barbarae	Santa Barbara carex
Deschampsia elongata	slender hairgrass
Elymus trachycaulus	slender wheatgrass
Hordeum brachyantherum ssp. californicum	California barley
Juncus Balticus	Baltic rush
Juncus effusus	Common bog rush
Leymus triticoides	creeping wild rye

4 PIEZOMETER NETWORK

A piezometer is used to measure underground water pressure and piezometers are extensively used to monitor groundwater levels and flow patterns. The purpose of installing a piezometer network is to provide an empirical data collection system to evaluate the performance of the ARCF 2016 Project and to provide real time data to water resource managers, levee maintenance agencies, and project engineers. The piezometer network would allow USACE to evaluate the long-term performance of the flood risk management features (i.e., levee systems) throughout the project following construction of the proposed levee improvements. All sites receiving piezometers were included in the ARCF GRR FEIS/EIR; however, the installation of a piezometer network was not analyzed in the original document and is considered a design refinement.

4.1 Overview

Piezometers are planned to be installed permanently along the existing levees within the authorized footprint of the ARCF GRR FEIS/EIR. These installations could occur along the Sacramento River left bank, Lower American River left and right banks, Magpie Creek left bank, and Sacramento Bypass right bank that are all project areas of the ARCF 2016 Project. The distribution of piezometers will be based on the size of the project area and the local hydrologic conditions. It is anticipated that most, but not all piezometers would be installed within the spatial limits of the construction footprint. All piezometer installation locations would require preconstruction surveys for biological and cultural resources.

Approximately 100 piezometers will be installed at various locations along the levee segments listed above with piezometers on the levee crown and/or near the landside levee toe. Piezometers will be distributed between all ARCF 2016 Project reaches (see Figure 4-1 for reach locations) and some areas may have higher concentrations of piezometers than other areas. On average, between 3 and 15 piezometers will be installed at each ARCF16 Project reach. There is an existing network of previously installed piezometers within the authorized footprint. Some existing piezometers may require abandoning and/or full replacement.

4.2 Piezometer Locations

Piezometers will be located on top of or immediately landward of the levee. At a given location along the levee, there may be as few as one piezometer or as many as three piezometers. Piezometer type and depth of installation would vary upon location and monitoring objectives. Piezometers can sit flush with the ground surface, or stick out above the ground surface, depending on site specific circumstance. A standard piezometer (vibrating wire) installation diagram, which sits flush with the ground surface, is shown in Figure 4-2. Examples of standpipe piezometers, which stick out above the ground surface are provided in Figure 4-3 and Figure 4-4.

Piezometers are recommended to be installed at the top of the aquifer, below the base of the blanket layer, to monitor the following conditions:

- Effectiveness of relief wells.
- Effectiveness of deep cutoff walls.
- Performance monitoring at transitions between deep and shallow cutoff walls.

- Verification of performance in levee segments where no remediation was installed.
- Monitoring near in-ground swimming pools close to the landside levee toe.

Following installation, each piezometer will be equipped with telemetry devices to provide real-time and remote data acquisition, which saves time and money by avoiding the need to take manual readings of each piezometer in the field.

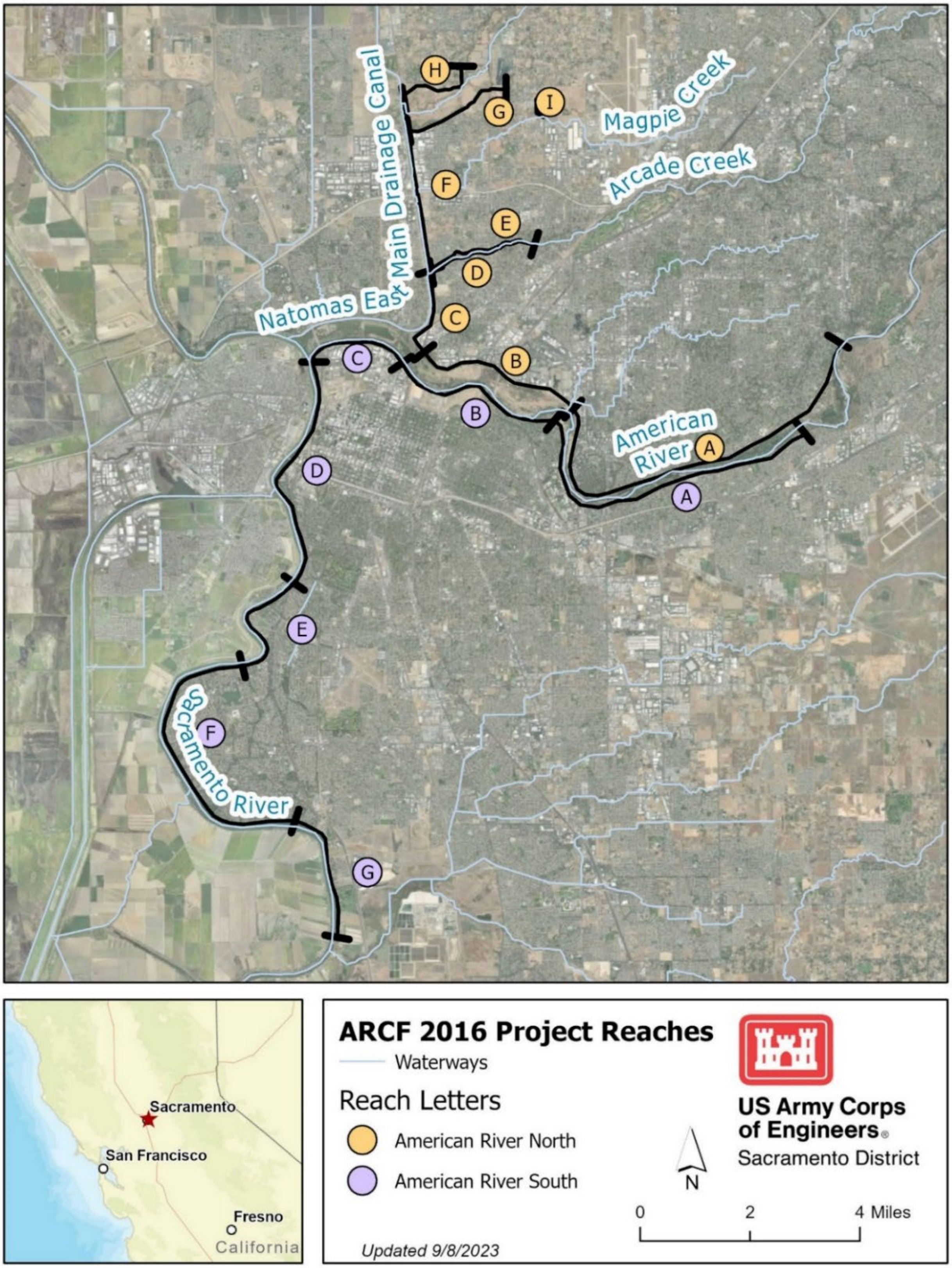


Figure 4-1. ARCF16 Project Reaches

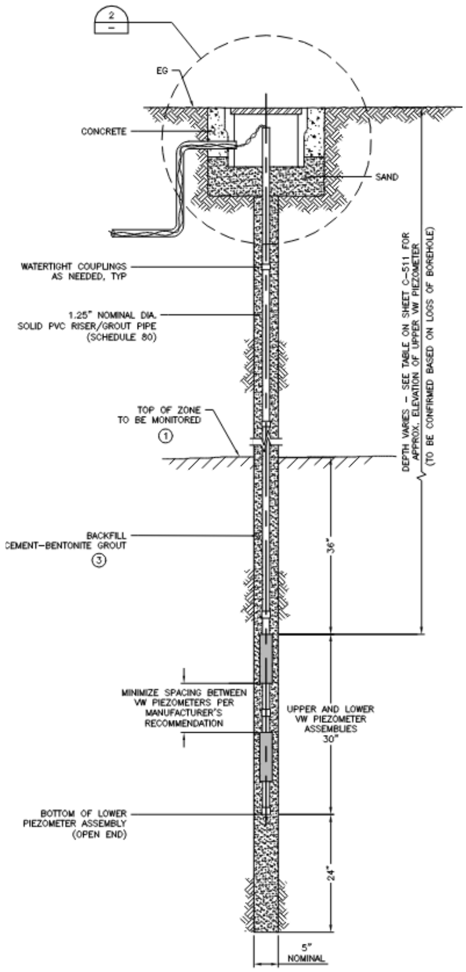


Figure 4-2. Typical Vibrating Wire Piezometer

Figure 4-3. Typical Open-Standpipe Piezometer

Figure 4-4. Dual Standpipe Piezometers

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ATTACHMENTS

ATTACHMENT A: CUMULATIVE IMPACTS ANALYSIS

(Provided as a separate document)

ATTACHMENT B: GEOMORPHIC ASSESSMENTS

(Provided as a separate document)

ATTACHMENT C: EROSION ASSESSMENTS

(Provided as a separate document)

ATTACHMENT D: BIOLOGICAL RESOURCE SURVEYS AND ASSESSMENTS

(Provided as a separate document)