VEGETATION VARIANCE REQUEST
Natomas Levee Improvement Program

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April 2, 2010

(With additional information provided April 27, 2010)

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ACRONYMS AND ABBREVIATIONS

Airport	Sacramento International Airport
ARNL	American River north levee
Basin	Natomas Basin
CNDDB	California Natural Diversity Database
Common Features Project	American River Watershed Common Features Project
Common Features/Natomas Project	American River Watershed Common Features Project in Natomas
PACR	American River Watershed Common Features Project/Natomas Post-authorization Change Report
CVFPB	Central Valley Flood Protection Board
CVP	Central Valley Project
CVP/SWP Biological Opinion	June 2009 biological opinion issued by the National Marine Fisheries Service on Federal Central Valley Project and State Water Project water management operations, including flood control
dbh	diameter at breast height
Draft Guidance	Draft Policy Guidance on Variances from Vegetation Standards for Levees and Floodwalls published in the Federal Register on February 9, 2010
DST	Decision Support Tool
DWR	California Department of Water Resources
ETL	Engineering Technical Letter 1110-2-571
FPOM	fine particulate organic matter
Ford	David Ford & Associates
Framework	California Central Valley Flood System Improvement Framework adopted by the California Levees Roundtable on March 26, 2009
JSA Study	*Use of Floodplain Habitat of the Sacramento and American Rivers by Juvenile Chinook Salmon and Other Fish Species*
LCM	life cycle management
LM	levee mile
LMA	Local Maintaining Agency
LPP	locally preferred plan
MLD	most likely descendent
MOU	Memorandum of Understanding
Natomas Company	Natomas Company of California
NCC	Natomas Cross Canal
NEMDC	Natomas East Main Drainage Canal
NEPA	National Environmental Policy Act
NHC	Northwest Hydraulic Consultants
NMFS	National Marine Fisheries Service

NLIP	Natomas Levee Improvement Program
NWSE	normal (2-year) water surface elevation
Parkway	American River Parkway
PGCC	Pleasant Grove Creek Canal
Phase 4a FEIS	*Final Environmental Impact Statement for the Natomas Levee Improvement Program Phase 4a Landside Improvements Project*
Phase 4b DEIS/DEIR	*Draft Environmental Impact Statement/Draft Environmental Impact Report on the American River Watershed Common Features Project/Natomas Post-authorization Change Report/Natomas Levee Improvement Program, Phase 4b Landside Improvements Project*
PIR	problem identification report
Plan Formulation Report	Area Plan Formulation Report
RD	Reclamation District
Roundtable Communique	Media Communique issued by the California Levees Roundtable on March 26, 2009
SAFCA	Sacramento Area Flood Control Agency
SIR	Supplemental Information Report
SRA	Shaded Riverine Aquatic
SREL	Sacramento River east levee
SRFCP	Sacramento River Flood Control Project
SWP	State Water Project
USACE	U.S. Army Corps of Engineers
USFWS	U.S. Fish and Wildlife Service
variance area	proposed vegetation-management zone

EXECUTIVE SUMMARY

This request for a variance from the standard vegetation guidelines set forth in the U.S. Army Corps of Engineers' ("USACE's") Engineering Technical Letter 1110-2-571 ("ETL") is being submitted by the Sacramento Area Flood Control Agency ("SAFCA") and the Central Valley Flood Protection Board ("CVFPB") for consideration by USACE. SAFCA and CVFPB are the non-Federal sponsors of the American River Watershed Common Features Project ("Common Features Project"). This variance request identifies the locally preferred plan for managing vegetation on the 42-mile perimeter levee system protecting the Natomas Basin (or "Basin") in Sacramento and Sutter Counties. It is anticipated that a decision on this variance request will facilitate timely completion of the American River Watershed Common Features Project/Natomas Supplemental Information Report ("SIR"). The information presented herein is organized in accordance with the Draft Policy Guidance on Variances from Vegetation Standards for Levees and Floodwalls published in the Federal Register on February 9, 2010 ("Draft Guidance"). This information will be appropriately referenced and evaluated in the *Draft Environmental Impact Statement/Draft Environmental Impact Report on the American River Watershed Common Features Project/Natomas Post-authorization Change Report/Natomas Levee Improvement Program, Phase 4b Landside Improvements Project* ("Phase 4b DEIS/DEIR") currently being prepared by USACE and SAFCA.

This vegetation variance request is intended to comply with applicable provisions of the California Central Valley Flood System Improvement Framework that was adopted by the California Levees Roundtable on March 26, 2009 ("Framework"). The Framework specifically states that where, as in the case of the American River Watershed Common Features Project in Natomas ("Common Features/Natomas Project"), major modifications of existing levee sections are required, such modifications:

> "will comply with the [USACE] levee vegetation standards, but may allow vegetation to remain if these projects can demonstrate that the public safety risks posed to levee integrity have been adequately addressed and engineered into project designs. The [USACE] levee standards may evolve over time, when appropriate, to incorporate the latest developments in science and engineering."

SAFCA and CVFPB propose that existing vegetation be allowed to remain on all or portions of the waterside slopes of most of the levees protecting the Natomas Basin (or "Basin"). This request is supported by an engineering analysis demonstrating that the public safety risks posed to the integrity of these levees have been adequately addressed by the design of the Common Features/Natomas Project. The analysis reflects the best available information on the root characteristics of the affected waterside vegetation, the vulnerability of this vegetation to uprooting due to wind throw, and the potential for such uprooting to undermine the safety and integrity of the levee structure by triggering scour of the waterside levee slope.

The information on tree root characteristics and wind toppling is derived from studies of vegetation on Central Valley levees in 1989 and 1991, an ongoing study of the root characteristics of trees excavated from a sandy levee along the Loire River in France, reviews of these studies by scientists participating in the science collaborative initiated in connection with the California Levees Roundtable, and recent tree toppling data gathered from Central Valley levees as part of the science collaborative. This information suggests that (1) the root mass of the waterside vegetation is largely contained within the outer 3 to 4 feet of the waterside levee slope and (2) if tree toppling does occur, the resulting root pit is unlikely to have a depth greater than 2 to 3 feet.

The Common Features/Natomas Project has been designed to accommodate waterside vegetation and address the risk of levee instability due to tree fall and root pit scour by enlarging the footprint of the levees protecting the Natomas Basin. To demonstrate the adequacy of the project design, SAFCA retained Kleinfelder to perform a seepage and stability analysis and Northwest Hydraulic Consultants ("NHC") to evaluate scour potential on each the affected levee sections.

For each levee section, Kleinfelder began by comparing a typical cross section of the levee as designed to a hypothetically reduced (or "remnant") levee section. The remnant section was created by removing the outer 15 feet of the base of the levee at the waterside toe and extending a new waterside slope back to the levee crown at a grade of between 1.7-to-1 horizontal-to-vertical (1.7H:1V) and 3-to-1 horizontal-to-vertical (3H:1V). Each remnant levee section was evaluated to determine whether minimum USACE criteria for underseepage and rapid drawdown were met. Kleinfelder concluded that all of the remnant levee sections met these criteria. This analysis provided an initial baseline for considering the impact of scour because it showed that levee safety could be maintained even if the portion of the design levee section that contains the vast majority of the root mass of the waterside vegetation was lost.

To test the limits of Kleinfelder's analysis, NHC conducted a scour analysis to determine whether tree toppling could induce enough scour to penetrate Kleinfelder's remnant levee sections and prevent these sections from meeting the minimum underseepage and rapid drawdown criteria. NHC selected one or more sites in each of the levee sections covered by this vegetation variance request where scour potential would likely be greatest. At each site, NHC defined the geometry of the levee section, the size and location of the trees that could be subject to toppling, and the nature and grain size of local soils. Based on a literature review and discussions with experts, the likely dimensions and positions of fallen trees were identified. Local hydraulic conditions were defined based on existing data from MBK Engineers or USACE. NHC developed suitable equations for calculating the maximum depth of scour based on the identified hydraulic conditions, and modeled the maximum scour hole depth and geometry in the vicinity of a fallen tree in each levee section. These scour holes were then compared to the remnant levee sections devised by Kleinfelder to determine if the holes altered these sections and thus threatened levee stability. NHC concluded that tree fall induced scour would alter the critical dimensions of two of the remnant levee sections. Kleinfelder then modeled these two sites with the scour holes in place and determined that the remnant levees nevertheless met the minimum seepage and stability criteria.

In order to display the results of these analyses, SAFCA developed typical levee cross sectional drawings for each of the eight levee reaches covered by this variance request. These cross sectional drawings displayed the current configuration of the of the levee, the improvements proposed as part of the Common Features/Natomas Project and a "theoretical levee prism" that roughly corresponds to the minimum levee section needed to meet USACE criteria for resistance to underseepage and rapid drawdown. For seven of the reaches this theoretical levee prism has a 20-foot crown width and a 2H:1V waterside slope. The eighth reach comprising the lower portion of the Natomas East Main Drainage Canal (or "NEMDC") west levee has a 20-foot crown and a 1.7H:1V theoretical waterside slope. Each cross sectional drawing also displayed a "maximum scour envelope" reflecting NHC's calculation of the portions of the levee that would be lost due to treefall and scour assuming a maximum initial root pit depth of 3-feet.

Based on this approach, it was determined that none of the maximum scour envelopes developed by NHC penetrated the theoretical levee prisms determined to be stable by Kleinfelder. This suggested that the existing vegetation in the variance areas identified in the cross sectional drawings could be allowed to remain without posing an unacceptable public safety risk to the integrity of the levees covered by the variance request.

Nevertheless, following a round of review and comments by USACE, it was felt that an even more severe scour analysis should be performed based on a maximum initial root pit of 4-feet in depth. The new analysis showed that the resulting maximum scour envelope would still avoid the theoretical levee prism in all levee reaches and the cross sectional drawings were revised to reflect this result.

These analyses demonstrate that the risks to the safety and structural integrity of the Natomas Basin levees due to tree fall and scour have been adequately addressed by the design of the Common Features/Natomas Project. This is the essential finding required by the Framework. In addition, this vegetation variance request presents information showing that the waterside vegetation would not reduce the functionality of the Natomas levee system by reducing the flood conveyance capacity of the river and stream channels surrounding the Basin, nor would this vegetation unacceptably restrict accessibility to the affected levees for routine operation and maintenance and flood response activities. Included in this information is a description of the Life Cycle Management ("LCM") program that SAFCA has developed with Reclamation District ("RD") 1000 and that RD 1000 will implement as part of the Common Features/Natomas Project.

SAFCA and CVFPB anticipate that this vegetation variance request will be subject to additional review by USACE prior to the Alternative Formulation Briefing on the Common Features/Natomas Project scheduled for May 2010. The goal of this review process is to reach concurrence that this vegetation variance request meets the requirements of the Framework and is thus a justified element of the locally preferred plan ("LPP") to be displayed in the SIR and evaluated in the Phase 4b DEIS/EIR.

CHAPTER 1 – INTRODUCTION

1.1 Scope of Report

The non-Federal sponsors are requesting a variance that would allow existing vegetation to remain on all or a portion of the waterside slope and berm of several of the levee segments comprising the perimeter levee system protecting the Natomas Basin. Specifically, it is requested that existing vegetation be allowed to remain on the following levee sections as shown in **Plate 1**:

- The entire waterside slope of the Sacramento River east levee (or "SREL") between the Natomas Cross Canal (or "NCC") and the American River;
- The entire waterside slope of the American River north levee (or "ARNL") between the Sacramento River and the NEMDC at Northgate Boulevard;
- The entire waterside slope of the portion of the NEMDC west levee occupied by the Arden-Garden Connector between Northgate Boulevard (levee mile [LM] 0.0) and the Arden Garden Connector bridge (LM 0.3);
- The lower 1/3 of the waterside slope and berm of the NEMDC west levee between the Arden-Garden Connector bridge (LM 0.3) and the NEMDC Pumping Facility (LM 4.4);
- The lower 1/2 of the waterside slope of the portion of the NCC south levee between LM 3.5 and LM 4.38; and
- The waterside berm of the NCC south levee below the projection of the landside toe of the levee on the waterside slope between LM 0.0 and LM 3.5.

These levee sections represent approximately 30 miles of the 42-mile perimeter levee system protecting the Natomas Basin. The levee sections comprising the remaining 12 miles of the system, including the Pleasant Grove Creek Canal (or "PGCC") west levee and the NEMDC west levee north of the NEMDC Pumping Facility are vegetation free and are therefore not subject to this vegetation variance request.

1.2 Authorization for Vegetation Management Policy

Section 202(g) of the Water Resources Development Act of 1996 directs USACE to provide a coherent and coordinated policy for vegetation management for levees that allows for regional variations in levee management and resource needs:

> (g) VEGETATION MANAGEMENT GUIDELINES.—
>
> (1) REVIEW.—The Secretary shall undertake a comprehensive review of the current policy guidelines on vegetation management for levees. The review shall examine current policies in view of the varied interests in providing flood control, preserving, protecting, and enhancing natural resources, protecting the rights of Native Americans pursuant to treaty and statute, and such other factors as the Secretary considers appropriate.
>
> (2) COOPERATION AND CONSULTATION.—The review under this section shall be undertaken in cooperation with interested Federal agencies and in consultation with interested representatives of State and local governments and the public.

(3) REVISION OF GUIDELINES.—Based upon the results of the review, the Secretary shall revise…the policy guidelines so as to provide a coherent and coordinated policy for vegetation management for levees. Such revised guidelines shall address regional variations in levee management and resource needs…

1.3 Proposed Variance Policy

The Levee Vegetation ETL was issued in accordance with the above authority on April 10, 2009. It supersedes prior USACE guidance on this matter and requires all woody vegetation on or near Federal project levees to be removed with certain exceptions for planting berms and planters as specified in the ETL. In anticipation of the ETL's potential effect on levees in California's Central Valley, a number of Federal, state, and local agencies including USACE, CVFPB, and SAFCA created the California Levees Roundtable and issued a Media Communique dated March 26, 2009 ("Roundtable Communique") signaling their agreement on a framework for accommodating the ETL in efforts to improve the flood control system in the Central Valley. The Framework recognizes that USACE's national standard for levees as embodied in the ETL is an appropriately conservative national public safety standard, and is likely achievable for most of the Federally authorized levees across the country. However, as described in the Roundtable Communique, "legacy levees" built immediately adjacent to California's major riverine systems present unique challenges that will likely require regional variances or other engineered alternatives.

The Framework specifically states that where, as in the case of the Common Features/Natomas Project, major modifications of existing levee sections are required, such modifications:

> "will comply with [USACE's] levee vegetation standards, but may allow vegetation to remain if these projects can demonstrate that the public safety risks posed to levee integrity have been adequately addressed and engineered into project designs. [USACE's] levee standards may evolve over time, when appropriate, to incorporate the latest developments in science and engineering."

The relationship between the Framework and the Draft Policy Guidance is clarified in a letter dated April 2, 2010 from Steve Stockton, USACE Director of Civil Works, to Ben Carter, President of the CVFPB. The letter states:

> "Addressing the levee issues and challenges facing California is one of our priorities. Therefore, we will continue to seek opportunities to collaborate to find solutions. One opportunity is to continue to support implementation of the Central Valley Framework Agreement which recognizes that factors, other than vegetation on levees, may constitute higher flood risk to California's citizens…The Framework Agreement will continue to be the guiding document as DWR continues to develop its long-term plan to resolve vegetation issues; a plan we understand will be finalized and provided to USACE in July 2012. The draft vegetation variance process published in the Federal Register will not supersede the Framework." (emphasis added).

Consistent with this approach, this variance request focuses on the engineering standard set forth in the Framework for allowing vegetation to remain on Project area levees while relying on the Draft Guidance to provide an organizational structure for presenting the information necessary to demonstrate compliance with this standard. The Draft Guidance asks for a general description of the affected levee system including "potential human and environmental consequences" (description of population at risk, potential economic losses, and identification of critical public facilities and special environmental considerations). And identifies the kind of information that is needed to demonstrate that the levee sections where vegetation is allowed to remain will meet acceptable standards for safety, structural integrity, functionality, and accessibility. The following chapters provide this information.

CHAPTER 2 – GENERAL DESCRIPTION

2.1 Project Authority

The Natomas Basin is protected from high flows in the American and Sacramento Rivers and their tributaries by an interconnected levee system that extends for 42 miles around the perimeter of the Basin ("Natomas Levee System"). This levee system is part of the Sacramento River Flood Control Project ("SRFCP"), a comprehensive plan for controlling the flood waters of the Sacramento River and its tributaries that was authorized by the California Legislature in the Flood Control Act of 1911. The SRFCP including the Natomas Levee System was approved by Congress in the Flood Control Act of 1917 (PL 64-367).

2.2 Project Area

Located north of the confluence of the American and Sacramento Rivers, the Natomas Basin ("Project Area") includes portions of the City of Sacramento, the County of Sacramento, and the County of Sutter as shown in **Plate 2**. This area is protected by the Natomas Levee System which includes the SREL, ARNL, NEMDC west levee, PGCC west levee, and NCC south levee. The SREL protects the western flank of the Basin. This levee extends for approximately 18.6 miles along the east bank of the river from the NCC to the mouth of the American River. The ARNL protects the southern flank of the Basin. This levee occupies the north bank of Bannon Slough, an engineered drainage channel that extends for approximately 2.2 miles eastward from the Sacramento River to Northgate Boulevard. At that point, the channel turns northward and becomes the NEMDC. This canal extends for approximately 13 miles from Northgate Boulevard to Sankey Road. It intercepts flows from the tributary streams east of Natomas and diverts them around the southern end of the Basin through Bannon Slough to the Sacramento River in low flow and to the American River in flood stage. The NEMDC west levee occupies the west bank of the canal and protects the eastern flank of the Natomas Basin. The NCC south levee protects the northern flank of the Basin. This levee occupies the south bank of the NCC, an engineered drainage channel that extends for approximately 5.3 miles from the Sacramento River to the PGCC. The NCC receives flows from the tributary streams northeast of Natomas and diverts them around the northern end of the Basin to the Sacramento River.

2.3 Population at Risk

The Natomas Levee System protects approximately 53,000 acres of improved agricultural, environmental, and urban lands. About 30 percent of the Basin is occupied by developed urban uses mostly located south of Elkhorn Boulevard. The urban area contains approximately 22,200 residential, 380 commercial, and 180 industrial structures, and a population of approximately 80,000 people.

2.4 Critical Public Infrastructure and Facilities

Lands owned by Sacramento County and operated as part of Sacramento International Airport ("Airport") account for about 10 percent of the land in the Natomas Basin. Half of the Airport lands lie outside of the developed footprint of the Airport Operations Area and consist of "bufferlands" devoted to agricultural or open space use. In addition to the Airport, the Basin also contains three major public transportation facilities—Interstate 5, Interstate 80, and State Route 99/70—as well as numerous public facilities such as police stations, fire stations, libraries, schools, and community centers that serve the Basin's urban population.

Outside the urban area, approximately 30,000 acres of land in the Basin remain in some form of developed agriculture or open space use, including 4,000 acres of aquatic and upland habitat preserves that have been created as part of the Natomas Basin Habitat Conservation Plan and are under the management of The Natomas Basin Conservancy.

2.5 Potential Economic Losses

An uncontrolled flood in the Natomas Basin would cause substantial direct damage to structures and contents and, depending on the timing and circumstances of the flood, pose a serious threat of loss of life and injury. Direct flood damages were estimated based on an inventory of structures created in connection with the formation of SAFCA's Consolidated Capital Assessment District (April 2007). Structure replacement values were estimated by David Ford & Associates ("Ford") in a study prepared for SAFCA in 2008. The estimate was based on Marshall & Swift unit construction cost factors. Content values were derived using structure-to-content ratios established by USACE and the State. Based on these data, it is estimated that the structures and contents exposed to flooding have a depreciated replacement value of approximately $8.2 billion.

Ford also performed an economic and risk analysis to determine the damages that might result from an uncontrolled flood in the Natomas Basin. Exterior (river and drainage channel) and interior (floodplain) water surface elevations and flood inundation-damage relationships were developed for a range of flood events based on USACE models and analysis from the Sacramento-San Joaquin River Basins Comprehensive Study. Based on these relationships, Ford estimated that direct flood damages in a single uncontrolled flood under existing conditions could total $7.0 billion with residential structures and contents accounting for about 70 percent of this value, commercial about 20 percent, and industrial about 10 percent.

2.5.1 Special Environmental Considerations

As discussed in Chapter 4, the woody vegetation on the waterside of the Natomas Levee System provides important habitat to a large number of special-status fish and wildlife species. This habitat is thus protected under the provisions of the Federal and California Endangered Species Acts, California Department of Fish and Game Code 1602, and the Migratory Bird Treaty Act. Along the waterside of the ARNL and the lower reach of the NEMDC west levee, the woody vegetation is within the boundaries of the American River Parkway and is thus also protected under the provisions of the Federal and California Wild and Scenic Rivers Acts. Removal of this vegetation would therefore require a careful balancing of the resulting public safety benefits and environmental harms.

CHAPTER 3 – CROSS SECTIONAL DRAWINGS

This chapter provides cross sectional drawings, photos, and plates displaying vegetation and other relevant conditions that characterize the eight levee reaches covered by this variance request as shown in **Plate 3**. These levee reaches are referenced by location (SREL, ARNL, NEMDC, and NCC) and length by levee mile (LM). The cross sectional drawings reflect typical conditions at a selected index point in each levee reach. These conditions include the normal water surface elevation ("NWSE") for the Sacramento River and the American River, representing the mean daily river flow during the summer dry season (June/July/August) when river flow and stage are controlled by upstream reservoir releases for downstream urban and agricultural uses; and the ordinary high water mark ("OHWM") for all water bodies, representing the 2-year flood elevation. The drawings also display project right-of-way, the improved levee section (including a theoretical levee prism), appurtenant structures, the proposed vegetation-management zone ("variance area"), and the areas that will be vegetation-free. The theoretical levee prism depicted in each cross sectional drawing was derived by extending a "levee baseline" from the landside toe of the improved levee section and connecting this baseline to the 20-foot levee crown along a 2-to-1 horizontal-to-vertical (2H:1V) slope (or 1.7H:1V in the case of the lower NEMDC) representing the waterside slope of the prism. This slope was selected based on a determination by Kleinfelder that it would be geotechnically stable for sudden drawdown (factor of safety exceeds USACE minimum criteria of 1.1).

Each levee cross sectional drawing also displays the levee soil conditions, maximum scour potential, and foundation stratigraphy representative of the index point depicted in the drawing. For purposes of these displays, scour potential represents the "maximum extent of scour during the 200-year flood" assuming that during the flood, high winds topple a large tree generating a root pit that is 4-feet deep and 20-feet wide. This condition was modeled by NHC at several points along the waterside of each levee cross section. These calculations were generalized to show the maximum extent of scour that could occur at any point along the waterside levee slope and berm. The actual scour hole resulting from fall of a particular tree would be much smaller than the envelope shown in the cross section.

The conditions shown in the cross sectional drawings and the methodologies used to derive these conditions are further described in Chapter 5 by levee reach. **Tables 3-1** through **3-8** provide additional information on the waterside vegetation that is proposed for retention, including a description of the trees found on the waterside of the levee within 50 feet of each index point between the waterside hinge point (crown) and the river channel.

3.1 SREL LM 5.8

Index point SREL LM 5.8 is considered representative of the 12.8-mile reach of the SREL downstream of the NCC between LM 0 and LM 12.8 where the non-Federal sponsors propose to construct a raised adjacent levee section. **Plate 4** depicts the waterside vegetation at this index point. **Plates 5** and **6** display typical cross sections, levee soil conditions, maximum scour potential, and foundation stratigraphy for the raised adjacent levee design, including a cross section containing a seepage cutoff wall (**Plate 5**) and a cross section containing a seepage berm (**Plate 6**). **Plate 7** provides more detail on levee soil conditions and foundation stratigraphy. As indicated in these plates, the raised adjacent levee design will enlarge the existing levee section by approximately 40 feet. The non-Federal sponsors propose to allow vegetation to remain on the waterside slope and berm of the existing levee and on the levee crown (Garden Highway) 10 feet beyond the centerline of the existing levee.

As shown in **Table 3-1**, trees at this index point are composed of native species. As shown on **Plate 5**, trees tend to grow robustly along the upper sections of the waterside of the levee (variance area) as well as the lower sections (along the waterside "bench" west of the variance area). As shown on **Plate 4** in the upstream and downstream views of the ground level water side photos, the density of trees in this area tends to be higher on the waterside bench than in the variance area.

Table 3-1 Tree Survey Data for SREL LM 5.8			
Species	Number of Trees	Average Diameter at Breast Height (inches)	Average Crown Width (feet)
Valley Oak	11	19	26
Fremont Cottonwood	1	19	25
Box Elder	17	10	12
Willow spp.	3	19	25
Source: Data compiled by AECOM in 2010			

3.2 SREL LM 15.2

Index point SREL LM 15.2 is considered representative of the 3.7-mile reach of the SREL between LM 12.8 and LM 16.5 where the non-Federal sponsors propose to construct an adjacent levee section in an undeveloped portion of the Basin. **Plate 8** depicts the waterside vegetation at this index point. **Plates 9** and **10** display typical cross sections, levee soil conditions, maximum scour potential, and foundation stratigraphy for the adjacent levee design, including a cross section containing a seepage cutoff wall (**Plate 9**) and a cross section containing a seepage berm (**Plate 10**). **Plate 11** provides more detail on levee soil conditions and foundation stratigraphy. As indicated in these plates, the adjacent levee design will widen the existing levee section by approximately 24 feet. The non-Federal sponsors propose to allow vegetation to remain on the waterside slope and berm of the existing levee and on the levee crown (Garden Highway) 10 feet beyond the centerline of the existing levee.

As shown in **Table 3-2**, trees at this index point are composed of native species. As shown on **Plates 9** and **10**, trees tend to grow more robustly close to the waterside crown of the levee. As shown on **Plate 8**, the density of trees tends to be higher outside of the variance area than in the variance area, especially on the waterside "bench," although the diameter at breast height ("dbh") tends to be lower.

Table 3-2 Tree Survey Data for SREL LM 15.2			
Species	Number of Trees	Average Diameter at Breast Height (inches)	Average Crown Width (feet)
Valley Oak	8	18	25
Fremont Cottonwood	5	43	33
Box Elder	5	13	13
Oregon Ash	8	7	16
Alder	2	11	25
Black Willow	6	24	23
Red Willow	2	13	9
Bishop Pine	2	16	30
Source: Data compiled by AECOM in 2010			

3.3 SREL LM 17.0

Index point SREL LM 17.0 is considered representative of the 2-mile reach of the SREL between LM 16.5 and LM 18.6 where the non-Federal sponsors propose to construct an adjacent levee section in a developed portion of the Basin. **Plate 12** depicts the waterside vegetation at this index point. **Plate 13** displays a typical cross section, levee soil conditions, maximum scour potential, and foundation stratigraphy for the adjacent levee design containing a seepage cutoff wall. **Plate 14** provides more detail on levee soil conditions and foundation stratigraphy. As indicated in these plates, the adjacent levee design will widen the existing levee section by approximately 24 feet depending on the finished grade of the landside levee slope. The non-Federal sponsors propose to allow vegetation to remain on the waterside slope and berm of the existing levee and on the levee crown (Garden Highway) 10 feet beyond the centerline of the existing levee.

As shown in **Table 3-3**, trees near this index point consist of both native and ornamental species. As shown on the aerial photo on **Plate 12**, vegetation is denser in the variance area than outside of the waterside variance area. This appears to be due mainly to the planting of ornamental tree species by property owners, rather than natural volunteering of locally occurring species. Growth tends to be more robust on the waterside "bench" than on the levee slope as shown on **Plate 13**.

Table 3-3
Tree Survey Data for SREL LM 17.0

Species	Number of Trees	Average Diameter at Breast Height (inches)	Average Crown Width (feet)
Valley Oak	16	23	26
Bishop Pine	9	25	30
California Fan Palm	1	15	10
Ornamental Orange	1	16	33
Unknown Ornamental	2	5	8
Source: Data compiled by AECOM in 2010			

3.4 ARNL LM 1.1

Index point ARNL LM 1.1 is considered representative of the 2.3-mile reach of the ARNL between the Sacramento River (LM 0) and Northgate Boulevard (LM 2.3). **Plate 15** depicts the waterside vegetation and **Plate 16** displays a typical cross section, levee soil conditions, maximum scour potential, and foundation stratigraphy for the oversized levee in this reach of the Natomas levee system which was widened to the waterside in the 1950's to accommodate the Garden Highway. Trees have been added to Plate 16 from other locations in this reach (approximately 200 feet upstream) to reflect the full range of conditions in the reach. **Plate 17** provides more detail on levee soil conditions and foundation stratigraphy. The non-Federal sponsors propose to allow vegetation to remain on the waterside slope and berm of this oversized levee.

As shown in **Table 3-4**, trees at this index point are composed of native species. As shown on **Plate 15**, robustness of tree growth tends to be similar within the variance area compared to outside the variance area. Species of trees tend to be composed of both native and non-native species.

Table 3-4
Tree Survey Data for ARNL LM 1.1

Species	Number of Trees	Average Diameter at Breast Height (inches)	Average Crown Width (feet)
Valley Oak	24	9	13
Fremont Cottonwood	9	25	26
Box Elder	6	8	13
Oregon Ash	2	24	25
Red Willow	2	28	23
Source: Data compiled by AECOM in 2010			

3.5 NEMDC LM 0.0

Index point NEMDC LM 0.0 is considered representative of the 0.3-mile reach of the NEMDC west levee between Northgate Boulevard (LM 0) and the Arden Garden Connector Bridge (LM 0.3). **Plate 18** displays the waterside vegetation, and **Plate 19** displays a typical cross section, levee soil conditions and foundation stratigraphy for the oversized levee at this index point which was recently widened to accommodate the Arden-Garden Connector. **Plate 20** provides more detail on levee soil conditions and foundation stratigraphy. As indicated in these plates, the non-Federal sponsors propose to allow existing vegetation to remain on the waterside slope and berm of the levee.

As shown in **Table 3-5**, trees at this index point consist of native species. As shown on the cross section on **Plate 18**, trees tend to grow more robustly near this index point towards the crown of the levee. Tree density tends to be greater closer to the water surface. Almost all trees occur within the variance area.

Table 3-5
Tree Survey Data for NEMDC LM 0.0

Species	Number of Trees	Average Diameter at Breast Height (inches)	Average Crown Width (feet)
Valley Oak	7	16	17
Willow spp.	16	15	18
Alder spp.	1	8	18
Source: Data compiled by AECOM in 2010			

3.6 NEMDC LM 0.3

Index point NEMDC LM 0.3 is considered representative of the 4.1-mile reach of NEMDC west levee between the NEMDC Pumping Facility (LM 4.4) and the Arden Garden Connector (LM 0.3). **Plate 21** displays the waterside vegetation, and **Plate 22** displays a typical cross section, levee soil conditions, maximum scour potential, and foundation stratigraphy for the standard levee section at this index point. Trees have been added to Plate 22 from other locations near this reach (NEMDC LM 1.0) to reflect the full range of conditions near the reach. **Plate 23** provides more detail on levee soil conditions and foundation stratigraphy. To avoid the maximum scour envelope at this index point, the waterside slope of the theoretical levee prism has been steepened to 1.7H:1V. This slope has been determined to be geotechnically stable by Kleinfelder for sudden drawdown (factor of safety exceeds the minimum USACE criteria of 1.1). As indicated in these plates, the non-Federal sponsors propose to remove existing vegetation from the upper 2/3 of the waterside slope and allow it to remain on the lower 1/3 of the waterside slope and berm of this levee section and the adjacent berm.

As shown in **Table 3-6**, trees at this index point are composed of native and local species. As shown on **Plate 21**, robustness of tree growth is greater near the crown of the levee than near the water surface. Most of the vegetation occurs within the variance area, which consists of the lower 1/3 of the waterside levee surface.

Table 3-6
Tree Survey Data for NEMDC LM 0.3

Species	Number of Trees	Average Diameter at Breast Height (inches)	Average Crown Width (feet)
Valley Oak	7	18	15
Button Willow	3	11	14
Oregon Ash	3	13	15
Red Willow	2	4	5
Willow spp.	11	19	12
Source: Data compiled by AECOM in 2010			

3.7 NCC LM 0.7

Index point NCC LM 0.7 is considered representative of the 4.3-mile section of the NCC south levee extending west from the PGCC to LM 3.5. **Plate 24** shows the waterside vegetation, and **Plate 25** displays a typical cross section, levee soil conditions, maximum scour potential, and foundation stratigraphy of the standard levee section at this index point. **Plate 26** provides more detail on levee soil conditions and foundation stratigraphy. As shown in these plates, the non-Federal sponsors propose to allow existing vegetation to remain on the extended waterside slope (or berm) below the waterside levee toe.

As shown in **Table 3-7**, trees consist of native riparian species. As shown on the cross section on **Plate 24**, tree density is evenly distributed in a fairly narrow band. Trees near this index point occur mainly on the waterside berm near the NCC water surface.

Table 3-7
Tree Survey Data for NCC LM 0.7

Species	Number of Trees	Average Diameter at Breast Height (inches)	Average Crown Width (feet)
Valley Oak	16	10	7
Willow spp.	5	24	7
Source: Data compiled by AECOM in 2010			

3.8 NCC LM 3.6

Index point NCC LM 3.6 is considered representative of the 1-mile section of the NCC south levee between LM 3.5 and LM 4.38. **Plate 27** shows the waterside vegetation, and **Plate 28** displays a typical cross section, levee soil conditions, maximum scour potential, and foundation stratigraphy of the expanded levee section at this index point. **Plate 29** provides more detail on levee soil conditions and foundation stratigraphy. As shown in these plates, the non-Federal sponsors propose to allow existing vegetation to remain on the lower 1/2 of the waterside slope of this levee section.

As shown in **Table 3-8**, tree species near this index point consist of both native and non native species. As shown on **Plate 27**, growth of trees is more robust on the waterside levee slope than on the waterside berm; however, tree density is greater on the berm than on the slope.

Table 3-8
Tree Survey Data for NCC LM 3.6

Species	Number of Trees	Average Diameter at Breast Height (inches)	Average Crown Width (feet)
Fremont Cottonwood	10	30	15
Willow spp.	4	6	10
Source: Data compiled by AECOM in 2010			

CHAPTER 4 – ENVIRONMENTAL CONSIDERATIONS AND ALTERNATIVE SOLUTIONS

4.1 Affected Environmental Resources

As shown in **Plate 30**, the levees around the Natomas Basin are part of the integrated system of levees, overflow bypass channels, and dams that comprises the SRFCP. This flood control system was initially designed to improve navigation and reduce the risk of flooding so as to facilitate agricultural development of the extensive floodplains encompassed by the Sacramento Valley. Over time, the capacity of the SRFCP was greatly expanded by the construction of five major, multiple-purpose reservoirs (Shasta, Black Butte, Oroville, New Bullards Bar, and Folsom Reservoirs) containing 2.7 million acre-feet of dedicated flood space. These dams were justified in part by public safety considerations, specifically the need to provide a high level of flood protection to the historical urban settlements that grew up at the confluence of the Feather and Yuba Rivers (Yuba City and Marysville) and the American and Sacramento Rivers (Sacramento and West Sacramento).

The SRFCP and its associated reservoir storage facilities, and the agricultural and urban developments supported by these facilities, have greatly altered the physical landscape of the Sacramento Valley and contributed to the demise of what was once a vast natural floodplain containing extensive riparian and wetland landforms. **Plate 31** depicts the extent of this floodplain in the Sacramento River Basin near the end of the 19^{th} century. Along the main stem of the Sacramento River, the riparian forest averaged four to five miles in width. This area supported more fish and wildlife species than any other river ecosystem in California. Today, only about 2 percent of these historic woodlands remain.

4.1.1 Importance of Woodlands in the Project Area

Woodlands remaining on the waterside of the levees in the Project Area are comprised of predominately native tree species. The most common are valley oak (*Quercus lobata*). A rendering of the root structure of this species is displayed in **Plate 32**. Other common species are Fremont cottonwood (*Populus fremontii*), black willow (*Salix nigra*), California sycamore (*Platanus racemosa*), box elder (*Acer negundo*), black walnut (*Juglans hindsii*), red willow (*Salix laevigata*), arroyo willow (*Salix lasiolepis*), white alder (*Alnus rhombifolia*) and Oregon ash (*Fraxinus latifolia*). These trees are a remnant of the historic riparian ecosystem in the valley. Because of the wide-scale reduction in riparian woodlands over the past century, this ecosystem is now confined to a series of narrow corridors extending along the waterside margins of the Sacramento River and its tributaries. A large percentage of the river margins within the levee system are devoid of all woody vegetation due to the past half century of bank protection projects (rock riprap) placed on river banks. These corridors provide the primary, and in some regions the only, habitat link between the woodland patches that survive on the valley floor and the undeveloped, riparian woodlands of the foothill rivers and creeks surrounding the Coast Range and Sierra Mountains.

In the Project Area, waterside woodlands continue to provide important year-round and migratory habitat for more than 200 species of mammals, fish, amphibians, reptiles, and birds. The migratory fish species include Chinook salmon, steelhead trout, Delta smelt, and white and green sturgeon. The migratory bird species include Swainson's hawk and several species of neotropical songbirds, including the warbling vireo, the blue grosbeak, and the western yellow-billed cuckoo. The year-round wildlife populations include more than 135 species of native birds, native mammals (such as river otter, deer, beaver, and raccoon), and numerous reptiles and amphibians (such as Western pond turtle and Pacific tree frog).

Western riparian habitats, including those along the Sacramento River, are naturally linear systems with extensive edges. Patch isolation (lack of connectivity) may influence bird communities as much as habitat fragmentation. Small patch size and/or patch isolation may increase predation and brood parasitism rates, and limit population dispersal. For example, although a number of riparian areas in California are of sufficient size and structure to support Yellow-billed Cuckoos, individuals may not colonize these areas because of their distance from existing populations and the lack of enough potential mates in close proximity. When large, contiguous patches of riparian habitat are fragmented, the amount of edge increases, with detrimental effects on songbirds. For example, evidence from coastal riparian habitats in northern California indicates that Song Sparrows at the edge of habitat patches tend of have lower productivity than those nesting farther from the patch edge (PRBO 2000). Song Sparrows with edge territories are more accessible to many predators and may buffer the interior Song Sparrow pairs from predation pressure. Understory (the weedy, shrubby growth underneath trees) is also a crucial habitat feature for many birds. A healthy and diverse understory with lots of ground cover offers well-concealed nest and foraging sites.

Riparian trees are used for nesting, foraging, and protective cover by many bird species, including black-headed grosbeak, tree swallow, Bewick's wren, and Cooper's hawk; and are also used as roosting habitat for some bat species, such as hoary bat and California myotis. Riparian canopies provide nesting and foraging habitat for common mammals, such as western gray squirrel. Understory shrubs provide cover for mammals such as desert cottontail and ground-nesting birds such as spotted towhee that forage among the vegetation and leaf litter. Mammals such as raccoon and opossum benefit from the variety of berries, invertebrates, small mammals, and bird eggs for food. Piscivorous birds in particular–such as Kingfisher, Blue Herons, Cormorants, and Egrets–hunt, roost, and/or nest in banks, trees, and associated woody debris in the riparian corridor. A large number of songbirds (Passerines) use the riparian area heavily for nesting, foraging, roosting, and migration habitat. The complex structure of riparian habitat provides a large diversity of protected nesting substrates (e.g. cavities, tree branches, dense understory), and supports an abundance for food sources including invertebrates, seeds, and vegetation.

Wooded natural floodplains and banks of Central Valley rivers are an essential component of the Sacramento-San Joaquin River Delta ecosystem and the overall food web supporting Delta aquatic life. In particular, these floodplains serve as a major source of allochthonous biomass which contributes nutrients, fine particulate organic matter ("FPOM"), aquatic prey sources (zooplankton and invertebrates), and habitat structure (woody debris). Declining ecosystem health and fish populations of the Delta are a major concern of the Federal and state agencies that have worked together for over fifteen years under the CALFED Bay-Delta Program and Bay Delta Conservation Plan to reverse these declines by preserving and restoring the key elements that support aquatic life in the Delta, including the remnant floodplains of the Sacramento and San Joaquin Rivers and their tributaries.

4.1.2 Special Status Species in the Project Area

Many of the fish and wildlife species that occupy the Project Area are protected under applicable provisions of the Federal and California Endangered Species Acts. Details on these species and the special-status protections they have been granted are presented in the *Final Environmental Impact Statement for the Natomas Levee Improvement Program Phase 4a Landside Improvements Project* ("Phase 4a FEIS") (USACE 2010) and in the environmental documents identified in Chapter 9 which were issued in connection with earlier phases of the Natomas Levee Improvement Program ("NLIP"). These documents are available on SAFCA's website at www.safca.org/Programs_Natomas.html.

The NLIP documents indicate that the following special-status wildlife species are likely to nest in or occupy woody substrate, shrubs or trees in the riparian habitat areas on the waterside of the SREL, ARNL, and the lower reaches of the NEMDC and NCC in the Project Area:

- Valley elderberry longhorn beetle (Federal threatened),
- Cooper's hawk (California species of special concern),
- White-tailed kite (California fully protected),
- Swainson's hawk (California threatened),

- Bank swallow (California threatened), and
- Tri-colored blackbird (California species of special concern).

All of the bird species listed above are also protected under the Migratory Bird Treaty Act and Executive Order 13186, which directs all Federal agencies taking actions that have, or are likely to have, a measurable negative effect on migratory bird populations to cooperate with the U.S. Fish and Wildlife Service ("USFWS") in developing and using principles, standards, and practices that will lessen the amount of unintentional take. This cooperative effort is to be spelled out in a Memorandum of Understanding ("MOU") with USFWS that promotes the conservation of migratory bird populations.

Because riparian woodlands provide important nesting and roosting habitat for a wide variety of wildlife species (including colony-nesting bird species and special-status species such as Swainson's hawk) and serve as movement corridors for these species, they are considered sensitive habitats by Federal and state regulatory agencies. Riparian woodlands in particular are rich in biological fauna and flora, and provide valuable resources and protection for aquatic habitats. They are considered sensitive habitats subject to California Fish and Game Code Section 1602. They are identified as "rare and worthy of consideration" in natural communities recognized by the California Natural Diversity Database ("CNDDB"). These sensitive communities provide essential habitat to special-status species that are often restricted in distribution or are decreasing throughout their range. Some woodland patches within the Project Area could be categorized as Great Valley cottonwood riparian forest, which is a natural community documented in the CNDDB.

The waterside riparian corridor along the Sacramento River in Natomas is among the most contiguous and undisturbed in the Project Area and provides the most nesting habitat for bird species, especially Swainson's hawk. Monitoring conducted as part of the Natomas Basin Habitat Conservation Plan annual reporting and other independent data (The Natomas Basin Conservancy 2005–2009; AECOM 2009) indicates that the majority of Swainson's hawk and other raptor nests occur in the riparian area on the waterside of the levee, likely because it is the most contiguous and undisturbed nesting habitat, which is in contrast to the clustered tree groves on the landside of the Basin near active agricultural activities.

Guidance on identifying the riparian zones that provide important habitat to migratory birds is contained in EMRRP *Technical Notes Collection* (TN EMRRP-SI-09) issued by the U.S. Army Engineer Research and Development Center in Vicksburg, Mississippi (Fischer 2000). The guidance states that research has shown that riparian zones must meet certain minimum width and canopy continuity criteria to provide suitable habitat for most bird species. To encourage a diverse avian community, riparian corridors should be as wide and as long as possible, and be relatively free from improved roads, human settlements, and other potential impacts.

The following special-status fish species seasonally occupy or benefit directly from seasonally inundated riparian habitat on the Sacramento River and the lower reaches of the American River, NEMDC, and NCC:

- Central Valley fall/late fall run Chinook salmon (Federal species of concern, California species of special concern);
- Central Valley spring-run Chinook salmon (Federal and California threatened);
- Sacramento River winter-run Chinook salmon (Federal and California endangered);
- Central Valley steelhead (Federal threatened);
- North American Green Sturgeon (Federal threatened);
- Delta Smelt (Federal and California threatened);
- Sacramento Splittail (California species of special concern); and
- Hardhead (Federal species of concern, California species of special concern).

The condition of these fish species is addressed in the June 2009 biological opinion issued by the National Marine Fisheries Service ("NMFS") on Federal Central Valley Project ("CVP") and State Water Project ("SWP") water management operations, including flood control (referred to herein as the "CVP/SWP Biological Opinion"). The opinion finds that these operations are likely to jeopardize the continued existence of protected fish species in the Central Valley (including Central Valley steelhead, Central Valley spring-run Chinook salmon and Sacramento River winter-run Chinook salmon) in part because of the significant reduction in critical habitat in the Sacramento River Basin and Delta that has resulted from the operation of both projects.

In the Sacramento River, this critical habitat includes the river water column, river bottom, and adjacent riparian zone (limited to those areas above a streambank and on seasonally inundated floodplains that provide cover and shade to the nearshore aquatic areas) used by fry and juveniles for rearing. The lateral extent of this habitat is defined by the 2-year water surface elevation or by the bankfull elevation (defined as the level at which water begins to leave the channel and move into the floodplain).

USFWS refers to this habitat as Shaded Riverine Aquatic (or "SRA") habitat. SRA cover is defined as the near-shore aquatic area occurring at the interface between a river and adjacent woody riparian habitat. The principal attributes of this valuable cover type include sufficient water quantity and floodplain connectivity to form and maintain physical habitat conditions and support the growth and mobility of juvenile salmonids; water quality and forage supporting juvenile development; and natural cover such as shade, submerged and overhanging large woody material, log jams and beaver dams, aquatic vegetation, large rocks and boulders, side channels, and undercut banks. Both spawning areas and migratory corridors comprise rearing habitat for juveniles, which feed and grow before and during their outmigration. Non-natal, intermittent tributaries also may be used for juvenile rearing. Rearing habitat condition is strongly affected by habitat complexity, food supply, and the presence of predators of juvenile salmonids. Some complex, productive habitats with floodplains remain in the system (e.g., the lower Cosumnes River, remnants of Sacramento River reaches with setback levees [i.e., primarily located upstream of the City of Colusa]) and lower elevations of flood bypasses (i.e., Yolo and Sutter Bypasses). However, the channelized, levee confined, and rocked bank river reaches and sloughs that are common in the Sacramento-San Joaquin River system typically have low habitat complexity and low abundance of food organisms, and offer little protection from either fish or avian predators. Juvenile life stages of salmonids are dependent on the function of this habitat for successful survival and recruitment. Steelhead are more susceptible to the negative effects of degraded rearing habitat, as they rear in freshwater longer than winter-run and spring-run. Because of historic reductions in this habitat and the difficulty of replacing ongoing losses, USFWS has categorized SRA cover as Resource Category 1 indicating that this habitat is of high value for evaluation species and is unique and irreplaceable on a national basis or in the ecoregion section. The mitigation goal for habitat in Resource Category 1 is "no loss of existing habitat value."

Although generally lower in complexity and food abundance than other parts of the Sacramento River watershed, the river and stream channels in the Project Area and their adjacent riparian zones nevertheless provide part of the critical rearing habitat that sustains the salmon and steelhead populations that remain in this watershed. The importance of this habitat was underscored by a study completed in June 1999 by Jones & Stokes Associates entitled *Use of Floodplain Habitat of the Sacramento and American Rivers by Juvenile Chinook Salmon and Other Fish Species* ("JSA Study"). This study, which is attached as **Appendix A**, was initiated in February/March 1999, when seasonally high flows in the Sacramento and American Rivers caused Bannon Slough (the channel excavated to create the ARNL) and the NEMDC to backup and overflow into areas of the American River Parkway, including SAFCA's Borrow Site 18a ("Site 18a") adjacent to Northgate Boulevard and the NEMDC. This inundation allowed fish to freely use the resulting flooded habitat. The water surface level over the floodplain subsequently dropped, stranding fish in Site 18a and providing an opportunity to assess floodplain habitat use by juvenile chinook salmon and other species.

During the study, a total of 24 fish species were captured in Site 18a, 6 of which were native. The overwhelming majority of these fish were juvenile (fall-run) chinook salmon. Over 3,000 of these juveniles were captured along with a smaller number of winter- and spring-run sized Chinook salmon. Based on this capture data, the JSA Study estimated that as many as 50,000 juveniles may have been present in Site 18a at one time. These results confirmed the importance of shallow floodplain habitat in the rearing of these protected fish species prior to their migration out to the ocean.

4.1.3 Wild and Scenic Rivers Act Protections

The woody vegetation along the waterside slope of the ARNL and the waterside slope and berm of the NEMDC west levee is an integral component of the habitat highlighted in the JSA Study. All of the waterside vegetation on the ARNL and NEMDC west levee downstream of El Camino Avenue is within the boundaries of the American River Parkway (or "Parkway"). This vegetation is thus afforded added protection under the Federal and California Wild and Scenic Rivers Acts. Both acts designate the Lower American River as wild and scenic within the boundaries of the Parkway. This designation prohibits Federal and State assistance to, or construction of, water resource related projects that adversely affect the extraordinary values qualifying the river for wild and scenic status. These values include support for the anadromous fish populations that seasonally occupy the Lower American River, Bannon Slough, and the lower portion of the NEMDC.

4.2 Affected Cultural/Historic Resources

The Project Area is situated within the lands traditionally occupied by the Nisenan, or Southern Maidu. Numerous archaeological investigations have focused on the lands closest to the rivers and levees, particularly the east side of the Sacramento River. Several prehistoric occupation and burial sites, frequently seen as mounds or the disturbed remnants of mounds, have been identified on the landside of the SREL. These sites fall under the jurisdiction of the National Historic Preservation Act and thus implicate the rights of the most likely descendents ("MLD's") of the Nisenan/Southern Maidu people. Because many of the covered sites likely extend underneath the levee, these MLD rights could be affected by the manner in which woody vegetation on or near the levee is managed.

- **CA-Sac-15/H.** This site, near the Sacramento River east levee south of I-5, consists of a prehistoric occupation midden mound with a concentration of debitage, flaked stone tools, shell artifacts, faunal remains, fire-cracked rock, and baked clay objects. The mound has been heavily affected by farming and ranching activities. There is a ranch complex including a bunkhouse, garden, shed, chicken coop, water tower, garage, and driveway on the mound; historic debris on the site includes glass and broken ceramic fragments. A limited auger testing program was carried out west of the mound along the Sacramento River east levee and found no cultural materials along that transect (Bouey and Herbert 1990).

- **CA-Sac-16/H (P-34-000043).** CA-Sac-16/H is in the Airport north bufferlands south of the Airport Operations Area. This site has been variously called the Bennett Mound, Mound Ranch, Willey Mound, and S-16. It includes the remains of a prehistoric occupation mound, possibly the largest in the Sacramento Valley, but has been leveled in stages by agricultural activities. The site location corresponds to the ethnographic village of Nawrean. What remains today consists of dark midden soils in plowed fields with fragments of human remains, shell, fire-cracked rock, baked clay objects, ground stone, faunal bone, flaked stone artifacts, and debitage. A few historic artifacts, such as brick and ceramic fragments, are also on this site.

- **CA-Sac-17 (P-34-000044).** This is the location of a mound site reported by Heizer in 1934 west of Fisherman's Lake; however, none of the mound remains. In 1990, Bouey and Herbert attempted to locate any cultural remains but could not find any evidence of cultural deposits on the surface or in auger holes.

- **CA-Sac-18 (P-34-000045).** This site, landward of the Sacramento River east levee located north of San Juan Road, consists of a sparse scatter of basalt debitage, one cryptocrystalline biface fragment, a polished stone, and possible fire-cracked rock. It was originally described by Heizer as a mound 30 yards in diameter and 5 feet high; however, Heizer may have misinterpreted a natural rise in the landscape as a mound. CA-Sac-18 appears to be lacking the intensive cultural deposits that are the hallmark other nearby known mound sites (Dames & Moore 1994).

- **CA-Sac-160/H (P-34-000187).** This is a multicomponent site near the Sacramento River east levee located north of San Juan Road. It includes a prehistoric occupation mound with a farm complex situated on top. Excavations in the 1940s removed numerous burials and artifacts, including ground stone, flaked stone tools, shell beads and ornaments, fire-cracked rock, baked clay objects, stone beads, faunal remains, bone awls, bird bone tubes and whistles, obsidian drills, quartz crystals, charmstones, and historic glass trade beads, as well as historic debris related to farming and occupation of the top of the mound.

- **CA-Sac-164 (P-34-000191).** CA-Sac-164 is a very large, deeply stratified prehistoric occupation and burial mound near Sand Cove Park on the Sacramento River that has been explored a number of times using archaeological techniques; however, in spite of these efforts, the true boundaries of the site remain unknown. The site includes shell midden with abundant cultural materials including fire-cracked rock, flaked and ground stone tools, charmstones, polished bone implements, debitage, quartz crystals, bone and shell beads, baked clay objects, and plentiful faunal remains. Large fire-cracked rock features and hearths have also been noted. Because of its significant scientific value and integrity, CA-Sac-164 was nominated for listing on the National Register of Historic Places in 2001.

  The site was first recorded in 1951, after a newspaper article reported that human remains and stone tools were eroding out of the cutbank and into the Sacramento River. Observers who walked along the edge of the cutbank in summer and fall when the river was at its lowest noted that site deposits, interspersed with flood-deposited silt, extended at least 4 meters below the current-day surface. Excavations in the 1970s, 1980s, and 1990s confirmed the depth of intact and resource-bearing cultural strata at the site. Work on the landside of the Sacramento River levee indicated that downward-trending cultural strata might be found there as well, beginning well over a meter below the ground surface.

  Annual river height fluctuation, wave action resulting from boat wakes, and looting combined to cause continual erosion and collapse of the cutbank. This resulted in artifacts and remains falling onto the beach area below, where they either washed into the river or were collected by the public. To address this issue, SAFCA and USACE initiated a site stabilization program in 2005 that included placing dirt and plantings over the cutbank and creating a wave break near the river's edge of the site. This program was funded under USACE's environmental restoration authority.

4.3 Alternative Solutions

Most of the improvements proposed by the non-Federal sponsors for the Natomas levee system are being implemented by SAFCA as part of an early implementation project approved and funded in part (70 percent) by the California Department of Water Resources ("DWR") with bond funds approved by California voters as part of the Infrastructure Improvement, Smart Growth, Economic Reinvestment and Emergency Preparedness Financing Act of 2006. Under the terms of the State's early implementation program, SAFCA must demonstrate that: (1) the risk to life and property posed by the existing condition of the levee system in Natomas justifies moving quickly forward with improvements to this system; and (2) the proposed improvements will not impair or impede future changes to the regional flood protection system that might be adopted as part of the State's updated flood protection plan for the Central Valley.

4.3.1 Plan Formulation

Based on these guidelines, SAFCA developed a plan of improvements that could be quickly implemented without altering the basic design of the regional flood protection system surrounding the Natomas Basin. In addition, SAFCA's plan was designed to accommodate the vegetation management requirements of the ETL in light of the Framework set forth in the Roundtable Communique. As indicated in the Area Plan Formulation Report ("Plan Formulation Report") that SAFCA submitted as part of its early implementation program grant application (available at www.safca.org/Programs_Natomas.html), SAFCA evaluated three alternative approaches to improving the Natomas levee system:

- The "Fix-in-Place" alternative (improving the levees generally within their existing footprint);
- The "Adjacent Levee" alternative (widening the footprint of the existing levee system); and
- The "Setback Levee" alternative (constructing setback levees where possible).

The differences between these alternatives focus primarily on their treatment of the existing vegetation on the waterside slope of the SREL in light of the requirements of the ETL. The Fix-in-Place alternative separates the levee from the waterside vegetation by removing the vegetation from the levee; the Setback Levee alternative accomplishes this separation by removing the levee from the waterside vegetation; and the Adjacent Levee alternative allows the waterside vegetation to remain by creating an oversized levee that is wide enough to meet the safety, structural integrity, functionality and accessibility standards typically associated with a vegetation-free levee.

These alternatives were evaluated in the Plan Formulation Report based on the following criteria;

- **Completeness**: The extent to which the alternative provides flexibility to accommodate changing engineering standards and accounts for all necessary investments or other actions to achieve project objectives.

- **Efficiency**: The extent to which the alternative is the most cost-effective means of achieving the project objectives.

- **Effectiveness**: The extent to which the performance of the alternative contributes to achieving the project objectives.

- **Acceptability**: The extent to which the alternative minimizes effects on the environment and otherwise complies with applicable laws, regulations, and public policies.

4.3.2 Fix-in-Place Alternative

Removal of the trees on the waterside of the SREL would create serious engineering challenges and would be extremely costly. Assuming the removal process follows the guidelines in Section 5-3 of the ETL, the trunk (or stem), stump, rootball, and all roots greater than 1/2 inch in diameter would need to be removed. This would require extensive excavation of the existing levee structure to remove tens of thousands of existing waterside trees and shrubs occupying the ETL prescribed "vegetation free zone." The outer layer of the waterside slope and berm of the existing levee would be compromised, exposing the typically sandy materials encapsulated in the levee. It is likely that these materials would need to be removed from the area and the levee reconstructed with competent soil material.

Because residential development has been allowed on the waterside of the levee, much of the vegetation to be removed from the levee is located on private property. These residential developments are covered by encroachment permits and flood control easements which give the government the right to operate and maintain the levee and undertake the improvements that may be deemed necessary. However, these rights have not been extensively tested in court. Assertion of the government's rights to remove woody vegetation from the levee would likely be legally contested and it could take the government several years to be in a position to enter the residential developments so as to remove the vegetation and reconstruct the levee.

Given the extent of the woody vegetation to be removed, it is likely that substantial portions of the levee section would have to be reconstructed. This activity could damage human remains and artifacts of Native Americans associated with some of the cultural resources site described above that extend under the levee. In that event, the limited window of time available for levee excavation and reconstruction might not allow compliance with the recovery and documentation requirements of the National Historic Preservation Act.

Excavation and reconstruction of the waterside slope of the SREL to remove vegetation would also result in significant and unavoidable impacts to habitat protected under the Federal and California Endangered Species Acts and the Migratory Bird Treaty Act. According to the environmental documents prepared in connection with the NLIP (see Chapter 9), approximately 80 acres of waterside riparian vegetation would be removed as part of this alternative. These documents conclude that this loss could not be fully mitigated because there is insufficient waterside space within the lower portion of the Sacramento River system to accommodate the replacement plantings that would be required for this and other projects affected by USACE's vegetation management policy. Most of the potential riparian mitigation areas (i.e., where there is no existing riparian vegetation and SRA habitat) along rivers in the Sacramento region are narrow bands adjacent to levees that, if planted, would also be in violation of the ETL policy. Even if regulatory agencies approved a 1:1 compensation ratio (2:1 or 3:1 replacement is more common), the maximum potential mitigation area available is considerably less than 80 acres. Mitigation policy of NMFS, USFWS, and California resource regulatory agencies do not allow substantial impacts to waterside riparian and SRA habitat to be compensated by habitat creation landside of the river levees. As a result, pursuit of this alternative would likely result in a jeopardy opinion from NMFS and USFWS that could make it very difficult to proceed with levee improvement activity.

For these reasons, the Fix-in-Place alternative does not adequately address any of the plan formulation criteria.

4.3.3 Setback Levee Alternative

The SRFCP is designed to convey the vast majority of the flood waters entering the system upstream of the Natomas Basin over the Fremont Weir and through the Yolo Bypass, thereby limiting the flows entering the Sacramento River channel downstream of the weir. Accordingly, setting back the levee on the east side of the river would create an inherent risk of encouraging larger flows into the channel that could overwhelm the levee system downstream of Natomas. For this reason, the Setback Levee alternative would have to be integrated into a larger regional plan of flood protection and could not be implemented apart from the updated Central Valley Flood Protection Plan. This alternative would therefore not be eligible for early implementation.

More importantly, the path of the Setback Levee alternative along the east bank of the Sacramento River would be blocked by the Airport. The Sacramento County Airport System has made it clear that it would not welcome any change in the configuration of the Sacramento River channel that would increase the aquatic habitat near the arrival and departure corridors of its aircraft. Such landscape changes would likely be considered inconsistent with the Memorandum of Agreement Between the Federal Aviation Administration, the U.S. Air Force, the U.S. Army, the U.S. Environmental Protection Agency, the U.S. Fish and Wildlife Service and the U.S. Department of Agriculture to Address Aircraft-Wildlife Strikes which was executed in 2002 and 2003. For this reason, the existing Garden Highway levee would have to be maintained and the new setback levee would have to be designed around the Airport. Given the condition of the existing levee, its continued maintenance would not reduce the currently unacceptable risk that this levee could fail catastrophically, alter the flow split at the Fremont Weir, and overwhelm the Sacramento River channel downstream of Natomas.

Thus, the Setback Levee alternative would not address the basic objectives of the NLIP; would not qualify for early implementation; would not address the weaknesses in the existing Garden Highway, or protect the community from these weaknesses; and, because it would have a significantly larger footprint than the Fix-in-Place or Adjacent Levee alternatives, requiring substantially more real estate and borrow material to construct, the Setback Levee alternative would be much more costly than these alternatives. This alternative is thus not only incomplete, but would also be inefficient and ineffective.

4.3.4 Adjacent Levee Alternative

The adjacent levee design is feasible in all reaches of the SREL, including the reaches east of Interstate 80 where urban development has occurred near the landside toe of the levee and the reaches north of RD 1000's Pumping Plant No. 3, where the levee must be raised to meet applicable standards adopted by the California Legislature for levees protecting urban areas. Under these State standards, urban levees must have crowns that are at least 3 feet above the mean 200-year water surface elevation in the channel adjacent to the levee. To meet this standard, the non-Federal sponsors are proposing to implement a "raised adjacent levee" design in the upper 13.1 miles of the SREL. To accommodate stormwater drainage along the landside of the Garden Highway, this design includes a drainage swale between the new adjacent levee crown and the existing levee. The raised adjacent levee footprint is thus significantly larger than the footprint of the adjacent levee in the reaches where no raise is required.

The Phase 4b DEIS/DEIR includes an estimate that approximately 90 acres of landside woody vegetation will have to be relocated or removed to accommodate this expanded levee footprint, the landside berms that are proposed to address underseepage, and the maintenance area along the landside toe of the improved structure. This is a slightly greater landside impact than the Fix-in-Place alternative. However, it is apparent from the coordination that has occurred on this plan to date, that this landside loss can be fully mitigated through preservation or creation of approximately 240 acres of woodlands in corridors parallel to and set back from the landside toe of the improved structure in several reaches of the SREL. Thus, the key to the feasibility of the Adjacent Levee alternative is its ability to address levee integrity issues while avoiding the loss of approximately 80 acres of waterside vegetation that would likely generate a jeopardy opinion and potentially halt progress on flood risk reduction in the Natomas Basin. For these reasons, this plan is the most complete, efficient, effective, and acceptable alternative.

4.3.5 Improvements Undertaken to Date

In 2009, SAFCA and the State entered into an agreement to implement improvements to the NCC south levee and the upper 14.8 miles of the SREL as part of the State's early implementation program. Toward this end, the State has received permission from USACE to raise and strengthen 5.3 miles of the NCC south levee and alter approximately 8.8 miles of the SREL through construction of a raised adjacent levee section. This work will be completed in 2010. The State's request for USACE approval to alter an additional 6 miles of the SREL through construction of a raised adjacent levee section (3.7 miles) and an adjacent levee section (2.3 miles) that would commence in 2010 is currently pending.

CHAPTER 5 – ENGINEERING CONSIDERATIONS

This chapter provides background on the historic construction of the levees around the Natomas Basin, describes the structural measures proposed by the non-Federal sponsors for improving the system, and addresses the adequacy of the improvements with respect to meeting USACE criteria for levee safety, structural integrity, functionality and accessibility for maintenance, inspection, monitoring, and flood fighting.

5.1 Background

The Natomas Company of California ("Natomas Company") constructed the levees around the Natomas Basin between 1912 and 1914 using several clamshell dredges and ditchers and a suction dredge to excavate and place a total of 9.5 million cubic yards of material. The suction dredge did the work along the Sacramento River where the levee followed an alignment along high ground several hundred feet from the river channel. The dredge pumped sand from the channel bottom through a system of pipes into a trench excavated through a woodland clearing. The trench served to confine the sand and convey the excess water back to the river. The sand was configured into the design dimensions of the levee (24-foot crown with 3H:1V waterside and 2H:1V landside slopes) and then covered with a layer of the sediment excavated to create the confinement trench. Away from the Sacramento River, the Natomas Company employed long-boom clamshell dredges using buckets with a capacity of up to 6 cubic yards to construct what the Natomas Company called the "cross" levees along the NCC in the north and Bannon Slough (American River north levee) in the south and the "east" levee along the lower portion of the NEMDC. The dredges cut new drainage channels and cast new levees with the excavated material following a template similar to the levee along the Sacramento River (20-foot crown with 3H:1V waterside and 2H:1V landside slopes).

5.1.1 SREL

The SREL protects the western flank of the Natomas Basin. As shown in **Plate 1**, this levee extends for approximately 18.6 miles along the east bank of the river from the NCC to the mouth of the American River. As discussed above, this levee was constructed by suctioning sand from the bottom of the river channel and forming a new levee on high ground several hundred feet away from the channel. This sand was pumped into a receiving trench and then covered with a layer of sediment excavated from the trench. Vegetation was allowed to remain on the berm between the levee and the river, and over time new vegetation established itself on the waterside slope of the levee.

Uniquely among all of the levee systems within the SRFCP, the proximity of the Natomas Basin to the City of Sacramento and the design of the SREL, created a demand for residential development on the waterside of the SREL. The alignment of the levee severed large agricultural parcels, creating remainders between the levee and the river channel that were too small to farm but big enough to support residential development with roadway access off the top of the SREL, which became known as Garden Highway. Landowners petitioned Sacramento County to turn these remainders into legal parcels and then sought permits from the California Reclamation Board, which was the predecessor of the CVFPB, to allow residential structures to be constructed on the new parcels. The California Reclamation Board ultimately adopted special regulations to permit residential development along Garden Highway. As a result of this residential development, the vegetation on the waterside of the SREL largely exists on private property in an area covered by encroachment permits and flood control easements, which give the government the right to operate and maintain the levee and undertake the improvements that may be deemed necessary.

5.1.2 ARNL

The ARNL protects the southern flank of the Natomas Basin. This levee extends for approximately 2.3 miles along the north bank of Bannon Slough from the mouth of the American River to Northgate Boulevard as shown in **Plate 1**. As discussed above, this levee was constructed using a long-boom clamshell dredge. The dredge cut a new drainage channel (Bannon Slough) extending eastward from the Sacramento River along an alignment more than 1,500 feet north of the American River low flow channel. The material excavated from the channel was used to create the ARNL. East of what is now Northgate Boulevard, the new channel turned northward, became the NEMDC, and extended all the way to high ground south of what is today Sankey Road.

The new channel was designed to intercept flows in the tributary streams, draining the foothills east of the Natomas Basin, and divert these flows around the eastern and southern flanks of the Basin to the Sacramento River in low flow conditions and to the American River in flood conditions. Prior to reclamation, the Natomas Basin functioned as an overflow area known as the American Basin that absorbed run-off from these tributary streams and from the American and Sacramento Rivers. The Basin thus relieved pressure on the American River south levee protecting the City of Sacramento. Accordingly, in response to the Natomas Company's reclamation plan, the City insisted on an alignment of the ARNL that would give the confined portion of the American River channel adequate capacity to pass the run-off from the American River Basin and the diverted run-off from foothill basins during flood conditions. This exchange produced the area's first setback levee.

The ARNL was constructed of the soil material excavated from Bannon Slough. This material consisted of a mixture of sand, silt and clay that provided a much more consistent medium for levee construction than the sands used to construct the SREL. As a result, the ARNL had a more standard geometry with a 20-foot crown width, a 3H:1V waterside slope, and a 2H:1V landside slope. Over the years, the crown has been widened to at least 40 feet to accommodate Garden Highway and more recently to over 80 feet to accommodate the Arden-Garden Connector.

5.1.3 NEMDC West Levee

The NEMDC west levee protects the eastern flank of the Natomas Basin. This levee extends for approximately 14 miles along the west side of the NEMDC from Northgate Boulevard to Sankey Road as shown in **Plate 1**. The NEMDC was created to intercept flows in the tributary streams east of the Natomas Basin and divert them around the Basin to the Sacramento River in low flow and to the American River in flood stage. The NEMDC west levee was constructed from the material excavated from the new channel by a long-boom clamshell dredge. Like the material used to construct the ARNL, this material consisted of a mixture of sand, silt and clay that provided a much more consistent medium for levee construction than the sands used to construct the SREL. Thus like the ARNL, the NEMDC west levee had a standard geometry with a 20-foot crown width, a 3H:1V waterside slope, and a 2H:1V landside slope.

5.1.4 NCC South Levee

The NCC south levee protects the northern flank of the Natomas Basin. This levee extends for approximately 5.3 miles along the south side of the NCC from the Sacramento River to the PGCC as shown in **Plate 1**. The NCC was created to intercept flows in the tributary streams draining the watersheds in western Placer County and southern Sutter County, east of the Natomas Basin, and divert them around the Basin to the Sacramento River. The south levee was constructed from the material excavated from the NCC channel by a long-boom clamshell dredge. This material consisted of a mixture of sand, silt, and clay that provided a consistent medium for levee construction and allowed the levee to be constructed with a standard geometry with a 20-foot crown width, 3H:1V waterside slope, and 2H:1V landside slope.

5.2 Structural Measures

5.2.1 SREL

The SREL improvements proposed by the non-Federal sponsors were designed after USACE issued the levee vegetation management policies set forth in the ETL. As displayed in **Plates 4** through **14** and described in Chapter 3, these improvements consist of constructing a raised adjacent levee section between LM 0.0 and LM

12.8 to meet the State's urban levee height requirement (crown elevation must be at least 3 feet above the 200-year design water surface elevation) and an adjacent levee section between LM 12.8 and LM 18.6 where the existing levee is already high enough to meet this requirement. The raised adjacent levee section will be approximately 40 feet wider than the existing levee section, while the adjacent levee section will be approximately 20 to 24 feet wider. Depending on foundation conditions, underseepage risk will be addressed in both designs either by installing cutoff walls of various depths or by constructing seepage berms. Waterside vegetation is proposed to remain on the waterside slope and berm, and on the levee crown 10 feet beyond the centerline of the existing levee. This represents the original crown width of the levee and excludes portions of the crown where waterside widening has occurred to accommodate residential development. Based on the minimum height and width of the adjacent levee section, this design will create an outer layer of material around the geometry of a standard levee section that contains the vast majority of the root mass of the trees allowed to remain on the waterside slope.

5.2.2 ARNL

As displayed in **Plates 15** through **17** and described in Chapter 3, the ARNL improvements proposed by the non-Federal sponsors include installing seepage cutoff walls of various depths depending on foundation conditions and flattening or strengthening the landside slope of the levee. The levee does not need to be raised because the existing levee already meets the State's urban levee height requirement. Moreover, the existing levee section is oversized due to the widening the levee crown to accommodate the Garden Highway. Like the adjacent levee design for the SREL, the ARNL's over-widened crown and extended height create an outer layer of material around the geometry of a standard levee section that contains the vast majority of the root mass of the trees and other woody vegetation that would be allowed to remain on the lower 2/3 of the waterside slope.

5.2.3 NEMDC West Levee

As displayed in **Plates 18** through **23** and described in Chapter 3, the NEMDC west levee improvements proposed by the non-Federal sponsors between LM 0 and LM 4.4 include installing seepage cutoff walls at selected locations where the NEMDC intersects with the abandoned streambeds of Dry/Robla, Magpie, and Arcade Creeks and strengthening the landside slope of the levee. This portion of the levee was raised by SAFCA following the flood of 1986 and it currently meets the State's urban levee height requirement. SAFCA's improvements replicated the design geometry of this portion of the levee (20-foot-crown width, 3H:1V waterside slope, and 2H:1V landside slope) at the new design height. Following completion of these improvements, the City of Sacramento constructed the Arden Garden Connector Project connecting Arden Way in North Sacramento to the Garden Highway in Natomas by bridging the NEMDC and widening the crown of the west levee by at least 40 feet between the new bridge and Northgate Boulevard, a distance of approximately 1,500 feet. As a result, this portion of the lower NEMDC west levee is oversized in a manner similar to the section of the ARNL to which it connects.

Like the ARNL, this oversized segment contains a very wide outer layer of material around the geometry of a standard levee section that contains the vast majority of the root mass of the woody vegetation on the waterside slope. Accordingly, the non-Federal sponsors propose to preserve all of the vegetation on the waterside slope of this portion of the levee. Where the levee section is not oversized (between LM 0.3 and LM 4.4), it is proposed that existing vegetation be allowed to remain on the lower 1/3 of the waterside slope.

5.2.4 NCC South Levee

As displayed in **Plates 24** through **29** and described in Chapter 3, the NCC south levee has already been improved as part of SAFCA's early implementation project. Most of this levee section (LM 0.0 to LM 4.38) has been raised to meet the State's urban levee requirement. This portion of the levee has also been strengthened through installation of a seepage cutoff wall, and the improved levee section has been moved slightly landward. Between LM 3.5 and LM 4.38, the levee has been set back far enough to accommodate a 4-to-1 horizontal-to-vertical

(4H:1V) waterside slope and a 3H:1V landside slope. The lower 1/2 of the waterside slope of this portion of the levee is vegetated and the non-Federal sponsors propose that this existing vegetation be allowed to remain.

Between LM 0.0 and LM 3.5, the improved levee has a more standard 3H:1V waterside slope that will be extended by 0.7 mile to complete the NCC improvements in 2010. The waterside slope of this portion of the levee is largely vegetation-free; however, vegetation exists along the extended portion of the slope below the projection of the landside toe of the levee on the waterside slope. The non-Federal sponsors propose that this existing vegetation be allowed to remain.

5.3 Levee Safety

As displayed in the levee cross sections described in Chapter 3 and as shown in the valley oak rendering displayed in **Plate 32**, the trees allowed to remain on the waterside of the affected levees typically have a root structure characterized by a mass of lateral roots concentrated in the upper 3 to 4 feet of the slope with a series of vertical roots extending another 3 feet downward from the trunk. Accordingly, in the levee sections covered by this vegetation variance request, this root mass will be largely concentrated in the space between the waterside slope of the existing levee and the hypothetical waterside slope of the new or designated levee prism, or in the portion of the waterside slope that lies below the landside ground elevation. Moreover, because most of the roots have a lateral orientation, the root mass is unlikely to create pathways for seepage through the affected levee structures.

Although root architecture has not been widely studied, the pattern identified above is consistent with the findings in the *Technical Report on the Effects of Vegetation on the Structural Integrity of Sandy Levees* (August 1991), prepared by Donald H. Gray, F. Douglas Shields, and others for USACE's Waterway Experiment Station in Vicksburg, Mississippi. This report, which is attached as **Appendix B**, is referred to herein as the "WES Report." The WES Report focuses on the relationship between vegetation and the structural integrity of river levees. Field work was carried out on a portion of the Sacramento River west levee directly across from the Natomas Basin in RD 1600. This levee is very similar in composition and structure to the SREL. Thus, the observations and conclusions of this study are particularly relevant to the Common Features Project in Natomas.

The identified root pattern is also consistent with field studies reported in the Letter Report from Kleinfelder to Larry Aksland dated February 14, 1989 and the supplemental *Root Pattern Investigation* prepared by Agro Environmental Services, which is attached thereto. This report, which is attached as **Appendix C**, is referred to herein as the "Kleinfelder Report." At SAFCA's request, this report was reviewed by Dr. Alison Berry, a research professor in plant sciences at the University of California, Davis; and Dr. Chris Peterson, a research professor at the University of Georgia, Athens. These scientists are both members of the Levee Vegetation Science Team created by SAFCA and DWR to advise the California Levees Roundtable. Dr. Berry's review is included as an attachment to **Appendix C**. Dr. Peterson's review along with the preliminary results of his analysis of tree toppling data in the Central Valley is contained in **Appendix H**. The Kleinfelder Report focuses on native riparian vegetation on the Mosher Slough levee in the San Joaquin River Delta near the City of Stockton. This levee is formed more of clay than sand, and is more frequently inundated than the SREL. Nevertheless, the conclusions and observations of the study, particularly with respect to the root architecture of riparian vegetation, are in accord with the WES Report and generally reflect the more recent research being conducted by Dr. Berry.

Finally, the identified root pattern is consistent with data being developed for a dissertation on tree root structure by Caroline Zanetti. Ms. Zanetti is a doctoral student currently evaluating root structures found in trees growing on the waterside of a sandy dike on the Loire River in France. As part of this effort, she has participated in excavating and examining several trees of a similar species, size, and relationship to the dike and the river as those found in the Project Area. Her observations along with photos of some of the excavated trees are attached as **Appendix D**. As in the WES and Kleinfelder Reports, she notes that the trees in dikes along the Loire River bank produce a mass of shallow lateral roots that grow in the surface soil of the dike structure (upper 3 to 4 feet) parallel to the levee slope. These trees also produce a smaller number of vertical roots (including tap roots in the case of oak trees) that may extend up to 5 feet down.

As observed in the WES Report, this kind of root structure has the effect of reinforcing the surface layer of sandy levees such as those that were constructed along both sides of the Sacramento River. This root structure also increases the shear strength of the sandy soils comprising these levees, thus making the waterside slope and berm more resistant to erosion from river flows and wind and wave action and more resistant to slope instability due to ground shaking, toe scour, or rapid draw down. Moreover, according to the WES Report, woody vegetation on the waterside slope and berm of sandy levees does not appear to adversely affect the structural integrity of these levees by creating open voids or conduits, which might facilitate through levee seepage. Not only does the root structure not penetrate beyond the surface layer of the levee, rotted or decayed roots tend to infill with soil.

5.4 Structural Integrity

5.4.1 Levee Seepage and Stability Analysis

At SAFCA's request, Kleinfelder performed an analysis of potential seepage and stability impacts associated with the presence of vegetation along the waterside slope and base of the levees covered by this vegetation variance request. As shown in **Table 5-1**, the analysis was performed at levee cross section locations at or near seven of the eight index points identified in Chapter 3 where Kleinfelder had previously gathered data and conducted analyses as part of the Problem Identification Reports and Alternative Analyses prepared in connection with the NLIP. No analysis was performed at index point NEMDC LM 0.0 because this levee section has an 85-foot crown.

Table 5-1
Representative Cross Section Station

Kleinfelder Seepage and Stability Analysis			Variance Request
Levee Section	**Representative Site (Model)**	**Corresponding Levee Mile**	**Levee Cross Section**
SREL	320+00	LM 6.5	SREL LM 5.8
SREL	838+00	LM 16.3	SREL LM 15.2
SREL	904+50	LM 17.4	SREL LM 17.0
ARNL	47+50	LM 0.75	ARNL LM 1.1
NEMDC South	anp[1]		NEMDC LM 0.0
NEMDC South	58+00	LM 1.1	NEMDC LM 0.3
NCC	183+00	LM 0.8	NCC LM 0.7
NCC	21+00	LM 4.0	NCC LM 3.6

Note: anp = analysis not performed on this section because no remediation is planned for this section and the section had an 85-foot crown.
Source: SAFCA 2010

Kleinfelder analyzed the potential effects of vegetation presence along the waterside slope and toe of the affected levees by evaluating the performance of the levee as designed and after removal of the portion of the waterside slope believed to contain the vast majority of the root mass of the waterside vegetation. This was accomplished by removing a 15-foot section from the base of the levee (as designed) at the waterside toe and projecting a hypothetical slope back to the levee crown. The hypothetical slope was projected on a 3H:1V grade as long as the remnant crown was at least 20 feet wide, otherwise the grade was adjusted to intersect a 20-foot crown or the existing crown if it was less than 20-feet wide. This created remnant levee sections with waterside slopes that varied from 1.7H:1V to 3H:1V.

Kleinfelder then analyzed the structural integrity of the remnant levee sections by calculating underseepage gradients at the landside toe of these sections and by comparing the sudden drawdown factors of safety produced by the remnant sections and the levees as designed. The calculated underseepage gradients were below USACE criteria in all cases and although the remnant levee sections generally showed a decrease in drawdown factor of safety by comparison to the levees as designed, all of the remnant sections exceeded minimum USACE criteria for the sudden drawdown condition.

The results of the Kleinfelder analysis are set forth in the letter report entitled *Levee Seepage and Stability Analysis* attached as **Appendix E**. These results suggest that even if the outer layer of the waterside slope of the modeled levee sections, which likely contains the vast majority of the root structure of any waterside vegetation on the levee, was lost due to erosion, scour or other factors, the remaining remnant levee section would be considered stable with respect to underseepage and sudden drawdown.

To ensure that these results are applicable to all levee sections included in this vegetation variance request, Kleinfelder reviewed the soils data that was gathered for all of these sections as part of the NLIP to determine whether there are unique conditions at locations other than the selected index points where replication of the remnant levee analysis might produce different results. Based on this review, Kleinfelder concluded that the selected index points adequately represent soil conditions in their respective levee segments and thus serve as appropriate indicators of seepage and stability risk.

5.4.2 Wind Toppling and Scour Potential

To test the limits of Kleinfelder's analysis, NHC conducted a scour analysis to determine whether tree (fall) toppling could create root pits and subsequently under flood conditions could induce enough scour to penetrate Kleinfelder's remnant levee sections and prevent these sections from meeting the minimum underseepage and rapid drawdown criteria. An enlarged root pit could alter the remnant levee sections devised by Kleinfelder and potentially invalidate their seepage and stability conclusions. This analysis is set forth in **Appendix F**.

The sites selected for this analysis were based on identifying at least one large tree that might potentially erode the levee if it fell. At least one such site was located in each of the levee reaches included in the variance request. These sites are summarized in Table 5-2. They do not necessarily match the index points used to develop the typical cross sectional drawings described in Chapter 3. Rather, NHC chose "worst case" sites, where scour around a fallen tree might penetrate the levee template. Hence, the sites in Table 5-2 represent locations where a large tree existed on the waterside levee slope where local hydraulics would likely maximize scour. Further details on these sites are included in **Appendix F**.

Table 5-2
NHC-Selected Scour Sites

NHC Study Site	Soil Type	Scour Condition	Proposed Improvement
Sac 1 (LM 0.3)	Silty Sand	Large trees on lower bank	Raised adjacent levee
Sac 2 (LM 5.3)	Silty Sand	Large tree on berm at levee toe	Raised adjacent levee
Sac 3 (LM 12.0)	Silty Sand	Very large tree 20 feet from levee toe	Raised adjacent levee
Sac 4 (LM 13.3)	Silty Sand	Large tree on levee slope	Raised adjacent levee
Sac 5 (LM 14.9)	Silty Sand	Large tree on berm 15 feet from levee toe	Adjacent levee in agricultural area
Sac 6 (LM 17.4)	Silty Sand	Large tree on levee slope	Adjacent levee in urban area
NEMDC 1 (LM 1.3)	Silty Clay	Large trees at levee toe	Cut-off wall in standard levee section
NCC 1 (LM 3.7)	Silty Clay	Large trees on levee slope and berm	Raised levee with flattened waterside slope and cut-off wall
Amer 1 (LM 0.7)	Silty Sand	Large tree on levee slope	Cut-off wall in oversized levee
Amer 2 (LM 1.7)	Silty Sand	Large trees near levee toe	Cut-off wall in oversized levee

Source: SAFCA 2010

Tree Fall and Scour Analysis

The presence of a structure in flowing water, in this case the root plate and trunk of a fallen tree, changes the velocity field in several ways that lead to local scour or erosion of exposed soils. These changes include 1) increased local velocities as the flow accelerates around the upstream end of the root plate; 2) deflection of flow towards the bed; and 3) flow separation downstream of the root plate and trunk, creating a turbulent wake with vortices in the flow. All these changes to the velocity field increase the erosive forces exerted on the exposed soil in the root pit and result in scour around the structure. Breusers and Raudkivi (1991) describe the flow and scour characteristics for various structures in detail; May *et al* (2002), Melville and Coleman (2000) and TAC (2004) describe scour processes for bridges and piers.

The scour that occurs at structures is divided into "live-bed" and "clear-water" types. In the clear-water type the velocities upstream of the structure are too low to mobilize the local soil or bed material – no bed load transport occurs – and this case is typical for the fallen trees considered in **Appendix F**. Under this condition, scour will occur if the intensified flows around the structure are sufficient to mobilize the local soils. As the scour hole increases in size, the flow acceleration near the structure and the interaction of the flow with the bed become less intense, reducing the ability of the flow to transport the bed material and deposited it downstream. Eventually, the scour hole becomes so large that the flow is incapable of removing more material. This is referred to as the maximum or equilibrium scour depth for the particular flow, structure and material. The time taken to reach this maximum or equilibrium depth depends on upstream flow conditions and local soil characteristics and can be very long.

Calculating Scour Depths around Fallen Trees

There is no known procedure for calculating the maximum or equilibrium scour depth around fallen trees. After internal discussion, NHC adopted scour calculation procedures for bridge piers using parameters that reflected the general character of the root plate. This approach ignored scour associated with the trunk. As discussed in more detail in **Appendix F**, the root plate is closest to the levee and will cause scour towards the levee section and greater scour depths are expected at the root plate because of its greater vertical extent or height.

Pier scour equations are generally empirical equations based on physical modeling of scour around different pier dimensions and shapes in non-cohesive bed materials. A number of different equations have been recommended or developed by different organizations but most equations rely on predicting the depth of scour from local flow depth and pier width, then adjusting this prediction for other factors. As an example, Figure 5-1 shows the basic relationship between the ratio of scour depth (d_s) to pier width (b) and that of flow depth (y) to pier width (TAC 2004; their Figure 4-17).

Figure 5-1 (refer to curve labeled Melville 1997) shows that when the flow depth is much greater than the pier width that the maximum scour depth tends to be a constant ratio of the pier width. For very shallow depths, the maximum scour depth goes to a very small portion of the pier width, or to zero. For intermediate depth to pier width ratios, which often occur around the root plates of fallen trees on the levee slope, the maximum scour depth is a function of both pier width and flow depth. The Melville and Coleman (2000) equations are described in detail in **Appendix F**. Velocity becomes important in determining if scour will occur and the time it takes for the scour hole to reach maximum or equilibrium depth.

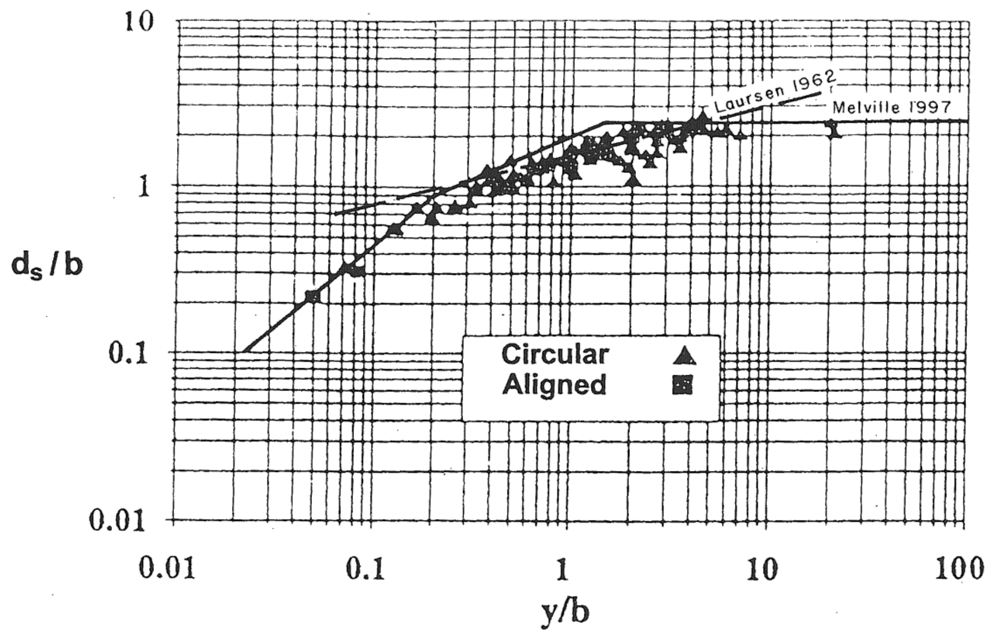

Figure 5-1: Basic Local Scour Relationship for Aligned or Circular Piers

__Applying Pier Scour Equations__

NHC applied both the FWHA HEC-18 (Richardson and Davies 2001) and the New Zealand (Melville and Coleman 2000) pier scour equations to calculate maximum scour depths. The following information was required for the calculations:

- The depth and velocity just upstream or in the vicinity of the fallen tree
- The width, length, and height of the root plate of the fallen tree
- The angle of the root plate relative to flow direction (called "skew")
- The median size and characteristics of the soils exposed in the root pits. The soils were assumed to be erodible silty sands except at the NCC and NEMDC sites (Table 5-2). Appendix F describes field investigations and assumptions.
- An estimate of the correction factor for pier shape (assumed to be 1.1)
- The correction factor for clear-water scour (assumed to be 1.1)
- The duration of the design flood when the scour occurs

Appendix F provides details on how the above variables were estimated and how scour depths were calculated from the two pier equations. Initial analysis indicated that the Melville and Coleman equation predicted greater maximum scour depths than the FWHA equations at all the study sites and their equation was adopted to calculate all the subsequent maximum scour depths.

Addressing Uncertainty and Worst Case Conditions

There is some uncertainty in all the variables used for the pier scour equations at each site. In order to ensure that worst case conditions or the greatest maximum scour depths were calculated NHC adopted the assumptions described below to incorporate "worst case" hydraulic conditions and root plate dimensions.

Although great effort was put into choosing conservative yet representative flow and root plate characteristics, it is recognized that there is some uncertainty involved in determining all of these variables. A Monte Carlo approach was used to account for uncertainty in these input variables: root plate geometry, orientation to flow, flow velocity and flow depth. In this approach, the input variables are assigned a range of values centered on the expected value for a given variable. A repetitive numerical process randomly selected the input variables from these ranges and computed a scour depth for each random set of input variables. The final outcome of this approach is a distribution of scour depths centered on the expected scour depth with a variance representative of the uncertainty in the various inputs to the scour depth equations. **Appendix F** provides a more detailed discussion of this approach.

Along the Sacramento and American Rivers, both depths and velocities increase with discharge, so the most extreme case for scour is at the most extreme discharge; for this analysis, the 200-year flood was adopted. The NEMDC and the NCC are backwatered during the 200-year flood; depths are greatest then, but velocities are near zero. In these two canals, the worst case for scour occurs at intermediate conditions as is demonstrated in **Appendix F**. In its calculations NHC adopted velocities appropriate for this intermediate condition but assumed depths that are equivalent to those during the 200-year flood. Given that flow depth dominates the calculated scour, this is a very conservative assumption for maximum scour calculations.

Determining Root Plate Dimensions

The majority of the trees on the waterside of the levees in the Project Area are winter deciduous. As such, these trees are less subject to wind force leverage during the flood season. On the other hand, flood conditions could weaken the stability of tree root structures through erosion soil saturation. In any event, as discussed in the 1989 Kleinfelder Report (Appendix C) and in Dr. Chris Peterson's review of this report (**Appendix H**), if one of these trees is toppled by high winds, the uprooted plate is likely to be relatively shallow (2 to 3 feet). Dr. Peterson notes that "my own experience after observing literally thousands of uprooted trees in eastern U.S. forests, is that a majority of root pits are indeed less than 2-feet deep, and probably 95% or more of root pits are less than 3-feet deep. I don't think I have seen a single root pit more than 4-feet deep…More specific to trees on California levees, initial findings from the California Levee Research Program's 'windthrow' study, of which I am the lead investigator, support the above conclusions. In this study, over 50 trees, most on levee slopes, were winched down to document their wind-firmness and the size of root pits for the ones that uprooted. Of those that uprooted, none created root pits greater than 3-feet deep, and most were less than 2-feet deep."

In light of these findings, NHC initially assumed a typical root plate thickness of 3 feet and a width and length of 15 feet. As described in **Appendix F** the width of the root plate was varied from 2 to 3.5 feet and the height and length were varied from 12 to 15 feet in the Monte Carlo. The simulated scour analysis associated with these root plate dimensions is referred herein as "Trial 1". Following a round of review and comment on the results of this analysis, a second simulated scour analysis was performed assuming a typical root plate thickness of 4 feet and a width and length of 20 feet. As described in **Appendix F** the width, length and depth of the root plate were not varied in the subsequent Monte Carlo simulation but the hydraulic conditions were varied. This second simulation is referred to herein as "Trial 2".

NHC notes that the 4-foot thick root plate with a length and width of 20 feet may not actually occur. The wind forces required to blow down a tree and topple or lift such a weight may seldom be reached (see **Appendix H**). Consequently, the Trial 2 calculations provide very conservative scour depths.

Results of Scour Calculations

Table 5-3 summarizes the maximum scour depths calculated from the Melville and Coleman (2002) equations for each study site for the three trials described above. The maximum scour depths were adjusted for flow duration as described in **Appendix F**.

Table 5-3
Maximum 200-Year Scour Depths (feet)

NHC Study Site	Trial 1	Trial 2
SREL 1 (LM 0.3)	11.8	17.9
SREL 2 (LM 5.3)	11.6	16.5
SREL 3 (LM 12.0)	11.7	16.5
SREL 4 (LM 13.5)	2.4	2.8
SREL 5 (LM 14.9)	11.7	16.6
SREL 6 (LM 17.4)	0.1	0.1
ARNL 1 (LM 0.7)	3.9	7.4
ARNL 2 (LM 1.7)	11.7	17.4
NEMDC 1 (LM 1.3)	7.3	9.8
NCC 1 (LM 3.6)	9.6	13.3

An eroded section, or a scour hole, was drawn around each fallen tree root plate assuming 2:1 side slopes and other assumptions described in **Appendix F**. The selected trees, the assumed root pits, and the subsequent eroded areas are shown on drawings for each study site in **Appendix F**. The drawings also show 1:3 and 1:2 theoretical waterside slopes for the existing levee and for the proposed improvements for reference.

Sources of Conservatism in the Scour Analyses

The scour depths cited in Table 5-3 are conservative and likely overestimate the actual scour that is likely to occur. The elements of conservatism that are incorporated into the calculations include:

- It was assumed that the root plate was similar to a pier when calculating scour even though the root plate will not extend to maximum scour depth at a constant diameter. It is believed that drag and buoyancy may move the tree from the site before scour reaches the maximum calculated depth.

- Scour was calculated from depth-averaged velocities taken from 2-D model grid cells that are much larger than the individual trees. These velocities do not fully account for the effect of structures or other large trees on local velocities and they are an average over a large area so they do not predict the velocities near the levee face well. The velocities adopted for analysis are expected to exceed actual values that occur at the study sites.

- NHC assumed erodible silty sands to depth along the Sacramento River and did not account for erosion resistance from roots, other vegetation, erosion-resistant layers, etc. All of these would reduce the maximum scour depth reached during the 200-year flood.

- NHC calculated maximum scour depths from two common sets of equations. Both equations predict maximum scour depth from envelope curves based on laboratory studies and are known to overestimate the observed scour under field conditions by up to 100% (May *et al* 2002). NHC adopted the greater of the two sets of estimates for calculating the eroded section.

- The eroded section that develops from the maximum scour hole assumed 2:1 side slopes based on the ASCE Manual No 110 on Sedimentation Engineering (Garcia 2006). Other advice suggested that these side slopes are conservative and that steeper slopes may develop, resulting in less erosion than predicted.

Interpreting Levee Stability

The preliminary interpretation of levee stability under tree fall scour at the study sites was based on comparing the interpreted Trial 1 scour hole to the remnant levee section defined by Kleinfelder in **Appendix E**. The maximum scour depths calculated for Trial 1 penetrated the remnant levee section along the upper SREL reach and the lower NCC reach. Kleinfelder then re-calculated the stability of levee waterside slope under sudden drawdown with the scour holes in place (**Appendix E**). Based on this re-analysis, they concluded that factors of safety at the levee sections exceed the minimum USACE criterion of 1.1 and all the levee sections remained stable under the worst case maximum scour depths for Trial 1. Subsequently, Kleinfelder analyzed the Trial 2 eroded sections following their earlier procedures described above. The results of this analysis also indicated that all the levee sections remained stable under drawdown. Table 5-4 provides a summary of Kleinfelder's Trial 1 and Trial 2 analyses and a removal of the 15-foot section from the base of the levee as described in section 5.4.1.

Scour Depths at the Representative Cross Sections

In order to display the results of these analyses, NHC calculated a "maximum scour envelope" for display in the cross sectional drawings for each of the eight levee reaches described in Chapter 3. Maximum scour depths for each cross section were calculated following the procedures described above for the local site conditions and incorporating the Trial 2 assumptions regarding root plate dimensions. Based on these calculated depths, maximum scour envelopes for each cross section were calculated as follows:

- At the elevation of the 200-year water surface, the scour depth was assumed to be zero.

- Root pits below the 200-year water surface elevation were extended to 15 feet of slope distance uphill from the position of large trees located on the levee slope.

- The maximum scour depth at the waterside toe of the levee or the waterside edge of the variance area was plotted on the cross section based on the values shown in Table 5-5 and a line was extended horizontally from this elevation towards the waterside bank. A line was also projected from this point to join existing ground at or near the 200-year water surface elevation or the landside edge of the variance area while encompassing root pits on the levee slope below this elevation. In cases where the levee shape varied significantly from a basic levee shape, additional scour depth calculations were made to adjust the envelope.

- In order to account for the presence of trees at or near the 200-year water surface elevation (or the landside edge of the variance area), the maximum scour envelope was adjusted to reflect the 4-foot depth of the root pit for these trees.

Table 5-4 Summary of Analysis of Tree-Fall Scour and Erosion						
Reach	**Levee Section**	**Kleinfelder Representative Model Station**	**Type of Analysis/Concern in area of analysis**	**Scour Depth**	**Seepage Gradient at Levee Toe**	**Sudden Draw-down Factor of Safety**
NCC	NCC LM 0.7[1]	183+00	15-foot levee section removal zone		<0.10	1.35
	NCC LM 3.6[1]	21+00	15-foot levee section removal zone		0.46	1.56
	NCC LM 3.7[2]	21+00	15-foot by 3-foot Root Plate	9.6	a.n.p.	1.19
			20-foot by 4-foot Root Plate	13.3	a.n.p.	1.11
SREL	SREL LM 5.8[1]	320+00	15-foot levee section removal zone		<0.10	1.86
	SREL LM 15.2[1]	838+00	15-foot levee section removal zone		0.20	1.35
	SREL LM 17.0[1]	904+50	15-foot levee section removal zone		0.10	2.50
	SREL LM 0.3[2]	27+00	15-foot by 3-foot Root Plate	11.8	a.n.p.	1.34
			20-foot by 4-foot Root Plate	17.9	a.n.p.	1.11
	SREL LM 5.3[2]	287+00	15-foot by 3-foot Root Plate	11.6	a.n.p.	1.27
			20-foot by 4-foot Root Plate	16.8	a.n.p.	1.11
	SREL LM 12.0[2]	640+00	15-foot by 3-foot Root Plate	11.7	a.n.p.	2.23
			20-foot by 4-foot Root Plate	16.5	a.n.p.	1.35
	SREL LM 14.9[2]	789+00	15-foot by 3-foot Root Plate	11.7	a.n.p.	1.58
			20-foot by 4-foot Root Plate	16.6	a.n.p.	1.33
	SREL LM 17.4[2]	838+00	Tree Fall within Upper 1/3 of Slope		a.n.p.	1.31
ARNL	ARNL LM 1.1[1]	47+98	15-foot levee section removal zone		<0.10	1.42
	ARNL LM 0.7[2]	47+98	Tree Fall within Upper 1/3 of Slope		a.n.p.	1.17
	ARNL LM 1.7[2]	96+65	15-foot by 3-foot Root Plate	11.7	a.n.p.	1.15
			20-foot by 4-foot Root Plate	17.4	a.n.p.	1.50
NEMDC	NEMDC LM 0.3[1]	58+00	15-foot vegetation zone		0.29	1.42
	NEMDC LM 1.3[2]	58+00	15-foot by 3-foot Root Plate	7.3	a.n.p.	1.29
			20-foot by 4-foot Root Plate	9.8	a.n.p.	1.17
			Scour Envelope		a.n.p.	1.18
USACE Criteria					0.80	1.1

Notes: 1. Provided by AECOM
2. Provided by NHC (as detailed in Appendix F)
3. Seepage gradients provided by Kleinfelder (as detailed in Appendix E)
a.n.p = analysis not performed
Source: AECOM 2010, Kleinfelder 2010, NHC 2010

Table 5-5 200-Year Maximum Scour Depths (ft) on the Representative Sections								
Site	**SREL LM 5.8**	**SREL LM 15.2**	**SREL LM 17.0**	**ARNL LM 1.1**	**NEMDC LM 0.0**	**NEMDC LM 0.3**	**NCC LM 0.7**	**NCC LM 3.6**
Near the toe of the levee or edge of the Variance Area	17	16.4	0.3	13	15.0	12.0	11.4	12.7

Source:NHC 2010 (as detailed in Appendix F)

5.5 Functionality

For purposes of this variance request, "functionality" is related to maintaining the conveyance capacity of the flood control channels in which the waterside vegetation is proposed to remain. Conceptually, the proposed variance should not cause any change in channel capacity because no new vegetation plantings are proposed for the upper 2/3 of the waterside slope of the affected levees. In addition, hydraulic modeling conducted for SAFCA by MBK Engineers indicates that channel roughness is not a significant factor in determining water surface elevations in the Sacramento and American River channels because these channels are several hundred feet wide and vegetation roughness on the channel margins represents a very small fraction of the overall wetted perimeter. Channel roughness is not a significant determinant of flood stages in the NCC either. Here, the location of the waterside vegetation near the low flow channel and the backwater condition produced in this channel by high flows in the Sacramento River mitigate the roughness effect. Roughness is more of a concern along the lower NEMDC; however, the design of the NEMDC west levee improvements (installation of cutoff walls) will not contribute to this concern, and the non-Federal sponsors are committed to properly managing the vegetation that is allowed to remain on the waterside slope of the levee (see Chapter 8).

5.6 Accessibility

All woody vegetation will be removed from the landside toe, levee slope, and levee crown of the ARNL, NEMDC west levee, and NCC south levee; and from the landside toe, levee slope, and widened levee crown of the SREL (extending 10 feet beyond the centerline of the existing levee on the waterside). This will improve accessibility for maintenance, inspection, monitoring, and flood fighting. Along the SREL, the levee crown will contain the existing Garden Highway and a separate levee maintenance road that will facilitate rapid daytime or nighttime deployment of vehicles and personnel. The 50-foot easement area along the landside toe will provide additional capacity. As discussed in Chapter 8, RD 1000, CVFPB, and SAFCA are taking actions that will ensure unimpaired access to and visibility of the waterside slope of the levee for routine maintenance and inspection, flood monitoring, and flood fighting activities.

Along the ARNL, the vegetation-free zone on the over-widened levee crown, landside levee slope, and landside easement areas will provide unimpaired access to and visibility of these areas under all conditions and at all times for these purposes. The levee crown will contain the existing Garden Highway, which is wide enough to accommodate rapid daytime or nighttime deployment of vehicles and personnel. The maintenance road in the easement area along the landside toe will provide additional capacity. The waterside slope and berm of the existing levee will be accessible from the Garden Highway for inspection under routine non-flood conditions and under flood alert conditions.

Along the lower NEMDC west levee, all woody vegetation will be removed from the easement area along the landside toe of the lower NEMDC west levee. This will improve accessibility for maintenance, inspection, monitoring, and flood fighting. The vegetation-free zone along the landside slope, levee crown, and the upper portion of the waterside slope upstream of the Aden-Garden Connector will provide unimpaired access to and visibility of these areas under all conditions and at all times for routine maintenance and flood fighting purposes. The levee crown upstream of El Camino Avenue will contain the Ueda Bike Trail, which is wide enough to accommodate rapid daytime or nighttime deployment of vehicles and personnel. The waterside slope and berm of the oversized portion of the levee between the Arden Garden Connector and Northgate Boulevard will be accessible from this roadway for inspection under routine non-flood conditions and monitoring during flood alert conditions.

Along the upper NCC south levee, there will be no woody vegetation in the 50-foot landside easement area that has been established as part of the non-Federal plan of improvements, or on the landside slope, levee crown, or waterside slope above the landside ground elevation. This vegetation-free zone will provide adequate accessibility for maintenance, inspection, monitoring, and flood fighting in this segment of the levee. Along the lower NCC south levee, there will be no woody vegetation in the 50-foot landside easement area, landside slope, or levee crown. The over-widened easement area and levee crown will readily accommodate two-way traffic and provide room for staging flood-fighting activities during high water events.

CHAPTER 6 – INSPECTION REPORTS

Appendix G contains the most current DWR inspection reports for all segments of the Natomas perimeter levee system. These reports have been issued pursuant to an understanding with USACE on the mutual responsibilities of the parties with respect to levee inspection. The reports include:

- Fall 2009 Levee Maintenance Deficiency Summary Report by Local Maintaining Agency ("LMA") and by unit;
- Levee Inspection Report by Mile for each unit with unit cover sheets and LMA cover sheet;
- 2009 Channel Summary Report;
- 2009 Structure Summary Report; and
- 2009 Pumping Plant Summary Report.

CHAPTER 7 – LEVEE PERFORMANCE HISTORY

This chapter summarizes the performance history of each of the four levee segments affected by this variance request.

7.1 SREL

The flood of 1986 exposed significant deficiencies in the sandy levees along the Sacramento River channel. Many days of high flow in the river saturated the sandy interior of the levee section, causing the encapsulating material on the landside slope to slough in several Garden Highway locations, nearly triggering a catastrophic levee failure. Thereafter, between 1990 and 1993, the levee strengthened through the installation of stability berms along the landside toe of the SREL for approximately 12 miles from the NCC to Powerline Road. From there to the American River confluence, seepage cutoff walls were installed through the levee and its foundation to a depth of up to 30 feet.

These repairs functioned well during the flood of 1997. However, subsequent analysis of foundation conditions, including at locations occupied by RD 1000 pumping facilities and drainage canals, revealed unacceptable vulnerability to underseepage. At RD 1000's Pumping Plant No. 2 near RM 75, this vulnerability was considered particularly unacceptable. Accordingly, in 2006, SAFCA, RD 1000, and CVFPB initiated an emergency repair project at this site. As part of this project, several hundred feet of the levee were excavated to allow removal of an impaired discharge pipe, the levee was reconstructed, and the pumping facility was set back from the levee to allow a portion of the drainage canal to be filled and to accommodate the footprint of the new raised adjacent levee at this location.

7.2 ARNL

The ARNL has experienced many high water events in the 95 years since its completion, including in 1928, 1951, 1956, 1964, 1986, and 1997. Kleinfelder reviewed the performance history of the levee in February 2006 as part of a problem identification report ("PIR") prepared for SAFCA. The PIR referenced historic documents from the State Department of Water Resources (1967) and a map issued by RD 1000 and RD 1400 (1938) showing areas affected by high water conditions in the Sacramento River during spring 1938. This event subjected the ARNL to high water for its entire length; however, it is unclear from DWR's and RDs' maps whether the seepage observed on the north side of the levee at several locations east of what is now Interstate 5 resulted from levee or foundation seepage, or from interior canal overflows.

The PIR notes that during the 1986 flood a slip was observed near the levee crown at Station 78+00. After the flood, Wahler Associates was retained by USACE to evaluate the performance of the ARNL. Despite anecdotal reports of "notorious" leakage at several locations along the levee, the Wahler Report identified no problem sites. Finally, the PIR indicates that in 1995, seepage and pin boils were observed near Station 88+00. No other indications of distress were identified in the PIR.

7.3 NEMDC

The lower NEMDC west levee has experienced many high water events in the 95 years since its completion, including in 1928, 1951, 1956, 1964, 1986, and 1997. Kleinfelder reviewed the performance history of the levee in June 2009 as part of a PIR prepared for SAFCA. The report notes that of all of these flood events, the 1986 flood was the most significant. High flows in the American River (up 134,000 cfs) combined with high flows in the tributary streams discharging to the NEMDC produced record high water stages in the lower NEMDC channel. High water marks measured south of Dry/Robla Creek are equivalent to the elevation of the current 100-year flow being used for levee design purposes.

After the flood, Wahler Associates was retained by USACE to evaluate the performance of the lower NEMDC west levee during the flood. The Wahler Report indicates that there was evidence of seepage through the levee, and foundation and internal erosion (or piping) of sandy materials through the levee by the presence of sand boils and deposits at the landside toe of the levee in the general vicinity of the abandoned Arcade Creek streambed. A depression, or possible slump, was observed at about the midpoint of the waterside slope directly opposite the landside toe sand deposit, possibly indicating internal erosion. Despite anecdotal reports of “notorious” leakage at other locations along the lower NEMDC west levee particularly downstream of Arcade Creek, the Wahler Report identified no other problem sites.

7.4 NCC

Kleinfelder reviewed the historic performance of the NCC south levee as part of a PIR prepared for SAFCA in March 2006. Historical documents and maps were reviewed to evaluate the past performance of the NCC south levee, including maps produced by DWR in 1967 and the Natomas Company in 1938. These maps indicate that as many as 6,810 acres on the landside of the NCC south levee were inundated during a high water event in May 1938. It is not clear from the maps, however, whether the conditions observed in these areas were produced by seepage through or under the levee, or by collected surface water at that location.

In addition to the observations recorded on the maps described above, Kleinfelder also noted that:

- During high water in 1997, a small pencil boil was observed near the confluence of the NCC south levee and the SREL.
- According to USACE (2002), a slide that occurred “approximately 3,500 feet southwest of Highway 99” was repaired in 1993.
- According to USACE, a slide also occurred in 1986, approximately 2,000 feet west of Highway 99, and longitudinal cracks indicative of slope instability were observed in the levee crown approximately 400 feet southwest of the highway. No clearly defined slide planes were observed, and the slide did not involve the crown. Investigators concluded that seepage forces resulting from spring flooding may have initiated the slide movement; however, the 1987 Wahler Report stated that these soil conditions were not encountered during their 1987 field investigation, and concluded that Wahler Associates was unable to explain the instability that led to the slide. A repair was performed in 1987 by Borcalli, Ensign & Buckley, encompassing approximately 300 linear feet of levee slope.

No documentation of other problems was found for this reach of the levee system.

CHAPTER 8 – VEGETATION MAINTENANCE PLAN

By agreement with CVFPB, the trees and other woody vegetation allowed to remain in the variance areas of the levee reaches covered by this variance request will be monitored and maintained by SAFCA and RD 1000 pursuant to a life cycle management ("LCM") program cooperatively developed by SAFCA and RD 1000. This program is described in *Draft Life Cycle Management of Levee Vegetation* (SAFCA 2009), which is available at www.safca.org. As applied to Project area levee reaches, the LCM program will have the following components.

8.1 Vegetation Management

8.1.1 Vegetation Allowed to Remain in the Variance Area

The LCM program anticipates use of a Decision Support Tool ("DST") to monitor the vegetation allowed to remain in the variance area and provide a framework for determining how such vegetation should be managed and maintained and under what conditions it should be trimmed or removed. The DST concept is based on a three-tiered approach that will be carried out on an annual basis:

- **Tier 1 – GIS-Based Monitoring Tool.** This tier will be an office-based GIS tool that will be used to collect and monitor relevant field information on the location and condition of the trees in the variance area with the aim of identifying trees that may be deteriorating and becoming unstable or infirm due to age, disease or other factors.

- **Tier 2 – Field-Based Evaluation Tool.** This tier will be a field-based tool used by trained levee maintenance crew members to provide the relevant field information that will be monitored using the Tier 1 GIS-based tool. The purpose of Tier 2 will be to identify trees that should be assessed further by a trained specialist or arborist in Tier 3. Table 8-1 provides an example of the type of field information that would be used to prioritize vegetation management activities. **Tier 3 – Field-Based Tree Assessment Tool.** This tier will be a field-based tool used by a qualified arborist or environmental specialist to assess unstable or infirm trees to determine if they should be removed, trimmed or otherwise treated to address their infirmity. Table 8-2 displays a Tree Assessment Checklist that would be used to track "problem" trees and inform management decisions.

Incorporation of the DST into annual maintenance activities will ensure that trees and other woody vegetation in the variance area that could prevent adequate access and/or visibility of waterside levee slopes, impair the stability of levee structures, or reduce the conveyance capacity of Project Area channels are quickly identified and monitored so that appropriate action can be taken to trim or remove this vegetation. Where removal of mature trees is required, this will be accomplished by cutting, stump grinding and backfilling the resulting root pit unless field conditions require more extensive root excavation.

8.1.2 New Vegetation

No new vegetation which has the potential to generate branches that are greater than 4 inches in diameter will be allowed to be planted or become established on the upper 2/3 of the waterside slope of any of the levees covered by this variance request. Nor will any such vegetation be allowed to planted or become established in any portion of the vegetation-free zone on the landside of the levee, an area which will be planted and maintained in native grasses. Affected waterside slope areas will be identified in the field through staking or other appropriate marking. New growth will be annually trimmed or removed through mowing, spraying, or other appropriate management actions.

8.1.3 Repair of Damage

CVFPB, through SAFCA and RD 1000, will be responsible for immediately repairing any damage to the waterside slope of any of the levees covered by the variance request that is caused by vegetation allowed to remain under the variance, including any damage due to erosion, scour, or other mechanisms. This responsibility will be set forth in the operation and maintenance manual for the Common Features/Natomas Project which CVFPB will agree to implement as part of the Project Partnership Agreement between CVFPB and USACE that will be executed following approval of the Project by Congress. Pursuant to this agreement, CVFPB will defend and indemnify the Federal Government for all damages arising from the construction, operation, maintenance, repair, replacement, and rehabilitation of the levees improved as part of the Common Features/Natomas Project, except for damages due to the fault or negligence of the Federal Government or its contractors. SAFCA and RD 1000 will enter into a matching agreement with CVFPB through which these local agencies will agree to defend and indemnify the State and carry out the CVFPB's commitments to the Federal Government. The operation and maintenance manual will also set forth the levee vegetation management responsibilities outlined in Sections 8.1.1 and 8.1.2 above.

8.2 Access to the Waterside Slope of the SREL

Managing the vegetation on the waterside slope of the SREL and conducting other necessary maintenance monitoring and flood fighting responsibilities presents particular challenges because of the residential development that has been allowed on the waterside of the levee. To carry out these responsibilities, on a long term basis, RD 1000 and CVFPB personnel must be able to inspect the waterside slope of the levee from Garden Highway. This will require that existing hedges and other vegetation that presently prevent roadside visibility of the slope be appropriately trimmed or otherwise relocated or removed. This condition must be achieved by the time the Common Features/Natomas Project is completed.

In the meantime, RD 1000 and CVFPB personnel must be able to safely park patrol vehicles at periodic locations along the Garden Highway so as to perform foot patrols during both non-flood season and high water events. These inspectors must also be able to safely walk along the Garden Highway to perform inspections of the waterside levee slope and adjacent areas. Finally, RD 1000 and CVFPB personnel must be able to access affected properties during non-flood season inspections, as well as during high water events to monitor the levee for signs of distress.

RD 1000 and CVFPB will evaluate existing opportunities for safely parking vehicles. Where inadequate parking opportunities exist, they will work with the landowners to develop safe locations at a reasonable spacing. This may include trimming or modifying existing vegetation along the Garden Highway so that vehicles may be safely parked, or to setback driveway gates to provide room for a vehicle to safely pull out of the roadway.

Table 8-1 Field-based Evaluation		
Criteria	**Potential Scoring Scheme**	**Comments**
Visibility-related Criteria		
Toe-waterside	Yes, no	Is the toe easily visible
Waterside slope	Yes, no	Is the slope easily visible
Crest	Yes, no	Is the crest easily visible
Slope mowed	Yes, no	In many cases the top 20' waterside is mowed
Significant tree branches closer to the ground than 5 feet	Yes, no	Low hanging branches may obstruct visibility
Accessibility-related Criteria		
Crown	Yes, no	Is the crown easily accessible for vehicular traffic
Toe-waterside	Yes, no	Is the toe easily accessible (from the crown, or from a toe road if provided)
Density of trees/vegetation	Low, medium, high	Categories need to be defined
Weak overhanging limbs	Yes, no	Limbs overhanging the levee crest could be damaged in high winds, preventing access for flood fighting
Proximity of tree to crest	<5 feet, 5-10 feet, 10-20 feet	
Windthrow-Related Criteria		
Height of tree	Height categories required in 5 or 10 foot increments	Vertical extent of canopy height to calculate sail size may be important and could be conducted in field
Visually large sail size	Yes, no	Standard guidance would be provided for common tree species to define "large."
Location of trees	Near crown, near toe, mid-slope	Trees near crown or on steep slopes may be more prone to windthrow
Tree substantially taller than other trees	Yes, no	Exposed trees more vulnerable to windthrow Standard guidance would be provided to define "substantially taller."
Erosion at base of tree	Yes, no	
Overall health of tree	Good, fair, poor	Are there dead limbs, hollows, is tree leaning/unstable, etc.
Tree leaning	Degree of leaning from vertical	
Tree pruned or canopy modified	Yes - symmetrically or asymmetrically	Asymmetrical pruning or canopy modification can exacerbate windthrow potential
Slope Stability-related Criteria		
Location of trees	Near crown, near toe, mid-slope	Location of tree on levee can greatly affect potential impacts to levee
Erosion at base of trees	Yes, no	
Signs of slumping	Yes, no	
Distribution and general type of vegetation	Trees, low canopy brush, bushy woody vegetation	Vegetation with different root strengths, susceptibility to windthrowing, and slope surcharge
Rigidity of waterside vegetation	N/A, willows, rigid trunks	Flexible vegetation capable of bending over in a flood and providing surface armoring
Burrowing Animal-related Criteria		
Burrows at base of tree	Yes, no	Creating potential instability
Burrows exposing roots	Yes, no	Creating erosion and tree stability risk
Tree is in a frequently inundated zone	Yes, no	Frequent inundation favored by beaver
Conditions hinder inspection	Yes, no	
Attraction for burrowing animals	Yes, no	Fruit/nut trees within a distance (to be determined) of levee centerline

Table 8-2 Tree Assessment Checklist		
Tree Genus/Species:_____________________________________		Date:__________________
Location: Inspector: _______________		GPS Coordinates: N:____________________ W:____________________
1. OVERALL TREE DESCRIPTION		
Tree Height (feet)		
Canopy Spread Diameter (feet)		
Diameter at Breast Height (DBH) (inches)		
Live Crown Ratio (%) (Height of leafy canopy/Total height of tree X 100)		
Multiple Main Trunks Present?	Circle one: Yes No	
Taper: (Good or Poor; poor has a pole-like trunk)	Circle one: Good Poor	
Tree Alone or in a Group	Circle one: Alone In a Group	
2. AGE CLASS		
Age Class	Circle one: 1 = Young 2 = Mature 3 =Overmature, senescent	
3. BASAL DECAY (at base of trunk and root crown)		
Decay Indicators		
Peeling bark/bare areas on trunk or major roots	Circle one: Present Absent	
Soft, punky wood	Circle one: Present Absent	

Table 8-2
Tree Assessment Checklist

Cavity size (if present)	Circle one: No Decay 1 = <6" diameter 2 = 6-12” diameter 3 = >12" diameter
Decay location	Circle one: No Decay Trunk only Roots only Both Trunk and Roots
Summary score for basal decay identified above	Circle one: 1 = none 2 = low 3 = moderate 4 = advanced 5 = severe, trunk and roots
4. TREE DEFECTS	
Stability Indicators	
Tree base on slope:	Circle one: 1 = no /moderate slope 2 = 3:1 slope 3 = 2:1 slope
Leaning trunk, degrees (º) from vertical	Circle one: 1 = less than 10º lean 2 = 10º to 20º lean 3 = 20º to 30º lean 4 = more than 30º lean
Downslope erosion/exposed roots	Circle one: 1 = low 2 = moderate 3 = severe
Upslope soil cracking/heaving/ uprooting	Circle one: 1 = low 2 = moderate 3 = severe
Contributing Tree Structural Problem:	
Asymmetric weight distribution of crown: onesidedness	Circle one: 1 = low 2 = moderate 3 = severe
Asymmetric weight distribution of crown: top-heavy	Circle one: 1 = low 2 = moderate 3 = severe
Asymmetric weight distribution of crown: Overhanging large branches	Circle one: 1 = low 2 = moderate 3 = severe

Table 8-2 Tree Assessment Checklist	
Cracks/splits on trunk (1, 2, 3)	Circle one: 1 = low 2 = moderate 3 = severe
Root crown (root flare) visible?	Circle one: 1 = fully visible 2 = partly visible 3 = not visible
Tree Management History	
Major tree pruning	Circle one: 1 = none or minimal 2 = moderate 3 = severe
Major root cutting near trunk base (slurry walls, utilities, trenches, roads, sidewalks)	Circle one: 1 = none or minimal 2 = moderate 3 = severe
5. SITE FACTORS	
Fill soil? (Y, N)	Circle one: Yes No
Soil texture (sandy, loamy, clay)	
Soil compaction (penetrometer reading)	Enter reading: _______________
Water table (high, low)	Circle one: High Low
Prevailing wind direction:	Enter Direction: In winter ____ In summer ____

Table 8-2
Tree Assessment Checklist

Part 2. Calculating Failure Potential

(Windthrow; root or trunk break/failure; major slope erosion due to tree)

Add scores for A+B+C within section 5. Then multiply 3*4*5, to obtain a value for failure potential. Other sections (1, 2, 6) are not assigned numerical values in this draft version. Field testing and further research are needed first. However, these sections can be used qualitatively to distinguish among tree ratings with similar scores.

1. SPECIES FACTOR

2. TREE DESCRIPTION

3. AGE CLASS (1, 2, 3) _____

4. DECAY (1, 2, 3, 4 or 5) _____

5. TREE DEFECTS (A+B+C) ___

A. Stability Indicators

___Tree on slope (1, 2 or 3)

___Leaning trunk (1, 2, 3 or 4)

___Downslope erosion (1, 2, 3)

___Upslope soil heaving (1, 2, 3)

Table 8-2 **Tree Assessment Checklist**
B. Other Structural Problems ___ ___Crown weight asymmetry (1, 2, 3) ___Damaged tree (cracks, splits, breakage) (1, 2, 3) ___Root flare abnormality (1, 2, 3)   C. Tree Management History ___ ___Major pruning (1, 2, 3) ___Major root cutting (1, 2, 3)   6. SITE FACTORS ___ Fill soil ___ Soil texture ___Compaction ___Water table ___Wind direction   TOTAL SCORE (multiply sections 3*4*5) _______

CHAPTER 9 – NEPA DOCUMENTATION

The improvements proposed by the non-Federal sponsors for all the levee segments discussed above, including removal of landside levee vegetation and limited removal of waterside levee vegetation have been described and evaluated in a series of National Environmental Policy Act ("NEPA") documents issued in connection with the Common Features Project. These NEPA documents include:

- *Final Environmental Impact Statement for 408 Permission and 404 Permit to the Sacramento Area Flood Control Agency for the Natomas Levee Improvement Project, Sacramento, CA* (USACE 2008), which presents a programmatic overview of the NLIP and covers project construction along the NCC south levee and the upper 4.3 miles of the SREL in Sutter County;

- *Final Environmental Impact Statement on the Natomas Levee Improvement Program Phase 3 Landside Improvements Project* (USACE 2009), which covers project construction along 4.5 miles of the SREL mostly north of Interstate 5 and the Lower NEMDC west levee in Sacramento County and the PGCC west levee in Sutter County;

- *Final Environmental Impact Statement on the Natomas Levee Improvement Program Phase 4a Landside Improvements Project* (USACE 2010), which covers project construction along 6.0 miles of the SREL south of Interstate 5 in Sacramento County; and

- *Draft Environmental Impact Statement/Draft Environmental Impact Report on the Natomas Levee Improvement Program Phase 4b Landside Improvements Project* (USACE and SAFCA in prep.), which covers project construction along 3.2 miles of the SREL, 2.2 miles of the ARNL, and portions of the NEMDC west levee in Sacramento County.

As indicated by this list, USACE has pursued a tiered approach to evaluate the effects of the NLIP (also referred to herein as the Common Features Project). A programmatic overview of the project was provided in the 2008 document. Each successive document has incorporated by reference the information presented in the prior document(s). In accordance with the Draft Guidance, it is anticipated that the Natomas Basin-wide variance request will be referenced in the description of the Phase 4b Project and the impacts of the vegetation and encroachment removals described herein will be evaluated as part of the Phase 4b DEIS/DEIR, either through incorporation of prior analyses or through evaluation of impacts not previously addressed. To facilitate this interaction, the Phase 4b Administrative DEIS/DEIR will be circulated with this variance request.

CHAPTER 10 – REFERENCE

AECOM. 2009. Unpublished data regarding raptor nest locations. Sacramento, CA.

Bouey, P. D., and R. Herbert. 1990. *Intensive Cultural Resources Survey and National Register Evaluation: Sacramento Urban Area Flood Control Project*. Report on file, North Central Information Center, California State University, Sacramento, CA.

Breusers, H., Raudkivi, A. 1991. Scouring. International Association for Hydraulic Research Hydraulic Structures Design Manual: Hydraulic Design Considerations. A.A. Balkema, Rotterdam.

Dames & Moore. 1994. *Archaeological Inventory Report, Natomas Locality, Cultural Resources Inventory and Evaluation, American River Watershed Investigation, El Dorado, Placer, Sacramento, and Sutter Counties, California*. Report on file, North Central Information Center, California State University, Sacramento, CA.

Fischer. 2000. EMRRP *Technical Notes Collection* (TN EMRRP-SI-09). Issued by the U.S. Army Engineer Research and Development Center. Vicksburg, Mississippi.

Garcia, M.H. (ed). 2008. Sedimentation Engineering: Processes, Measurements, Modeling and Practice. ASCE Manuals and Reports on Engineering Practice 110. Reston VA. 1,132 p.

May, R., Ackers J., Kirby, A. 2002. Manual on scour at bridges and other hydraulic structures. Construction Industry Research and Information Association (CIRIA). London. 225 pp.

Melville, B.W., Coleman, S. 2000. Bridge scour. Water Resources Publications, Colorado.

Point Reyes Bird Observatory (PRBO). August 2000. The Riparian Bird Conservation Plan: A Strategy for Reversing the Decline of Riparian Associated Birds in California. Stinson Beach, CA.

SAFCA. *See* Sacramento Area Flood Control Agency.

Sacramento Area Flood Control Agency. 2009 (February 27). *Draft Life Cycle Management of Levee Vegetation*.

The Natomas Basin Conservancy. 2005–2009. GIS data regarding Swainson's hawks nest locations in the Natomas Basin. Sacramento, CA.

Transport Association of Canada (TAC). 2004. Guide to Bridge Hydraulics: Second Edition. Thomas Telford, London. 181 p.

USACE. *See* U.S. Army Corps of Engineers.

USACE and SAFCA. *See* U.S. Army Corps of Engineers and Sacramento Area Flood Control Agency.

U.S. Army Corps of Engineers. 2008 (November). *Final Environmental Impact Statement for 408 Permission and 404 Permit to Sacramento Area Flood Control Agency for the Natomas Levee Improvement Project, Sacramento, CA*. Prepared by EDAW (now AECOM), Sacramento, CA.

———. 2009 (August). *Final Environmental Impact Statement on the Natomas Levee Improvement Program Phase 3 Landside Improvements Project*. Prepared by AECOM, Sacramento, CA.

———. 2010 (February). *Final Environmental Impact Statement on the Natomas Levee Improvement Program Phase 4a Landside Improvements Project.* Prepared by AECOM, Sacramento, CA.

U.S. Army Corps of Engineers and Sacramento Area Flood Control Agency. In prep. *Draft Environmental Impact Statement/Draft Environmental Impact Report on the Natomas Levee Improvement Program Phase 4b Landside Improvements Project.* Prepared by AECOM, Sacramento, CA.