LEVEE DISTRICT NO. 1
OF SUTTER COUNTY

STAR BEND SETBACK LEVEE AND HABITAT ENHANCEMENT PROJECT

BASIS OF DESIGN

FEBRUARY 2009

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DEVELOPING INNOVATIVE DESIGN SOLUTIONS

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1.0 INTRODUCTION

This Basis of Design Report is an update of the draft report originally included in the Lower Feather River Levee at Star Bend Feasibility Study, which was prepared by Wood Rodgers, Inc. in April 2007. This update has been prepared to incorporate new levee design criteria, hydraulics design criteria, update changes in the project description, and identify ongoing coordination efforts with the California Department of Water Resources, Central Valley Flood Protection Board (CVFPB), and the U.S. Army Corps of Engineers (USACE).

1.1 Purpose of Project

The purpose of the Star Bend Levee and Habitat Enhancement Project (Project) is to realign the right bank levee of the Feather River near River Mile 18 to provide additional flow and freeboard capacity for high flow events in the Lower Feather River, and to replace a section of levee with known seepage deficiencies. The proposed Project would also include several habitat enhancement measures. By setting back the existing levee, approximately 50 acres of new floodplain habitat would be created, allowing greater connectivity of riparian habitat between the Abbott and O'Connor Lakes Wildlife Units of the California Department of Fish and Game's Feather River Wildlife Unit.

1.2 Project Background

In 2006, the USACE reinitiated the Sutter Basin Feasibility Study to evaluate alternatives to reduce flood damage in the Sutter Basin, which encompasses the urbanizing communities of Yuba City and Live Oak in Sutter County. A setback levee at Star Bend, located approximately seven miles south of Yuba City, is included as a component of 23 of the 24 preliminary alternatives developed for the study (USACE and the California Reclamation Board 2006). The USACE and the CVFPB (the CVFPB was formerly known as the State Reclamation Board) characterize a setback levee at Star Bend as both an ecosystem restoration measure and a vital flood reduction structural measure for Levee District No. 1 of Sutter County (LD 1). The setback levee would reduce the risk of flooding on 84.5 square miles of land in the southern portion of the Sutter Basin, between the southern portions of Yuba City and the confluence of the Feather River with the Sutter Bypass. In the Sutter Basin Pre-F4 document, dated November 2006, the USACE and CVFPB state the project "would provide dual benefits of ecosystem restoration and flood damage reduction."

Concurrent with the development of the Sutter Basin Feasibility Study, local agencies identified a number of early implementation projects that are needed to correct known deficiencies, including a setback levee at Star Bend (CDWR 2008). In addition, California Governor Arnold Schwarzenegger signed legislation leading to the development of a comprehensive Central Valley Flood Protection Plan (CVFPP) (Schwarzenegger 2007). On February 6, 2008, Governor Schwarzenegger announced that his administration was expediting funds to four critical early implementation projects, including $16.33 million to the CDWR to fund the construction of a setback levee at Star Bend (Schwarzenegger 2008). On April 23, 2008, CDWR approved a funding agreement with LD 1 and noted that the setback levee: (1) should be carried out expeditiously prior to completing the CVFPP due to current conditions of the levee system; (2) would reduce risks to human lives in Yuba City; and, (3) would not impair or impede future changes to regional flood protection or the CVFPP (CDWR 2008). CDWR's determinations indicate that setting back the levee at Star Bend has independent utility outside the CVFPP or the Sutter Basin Feasibility Study processes and that implementation of the levee setback cannot wait for either planning process to be completed in another two to four years.

1.3 Project Description

The proposed setback levee would consist of a 23- to 25-foot-high earthen levee beginning near the intersection of Star Bend Road and Levee Mile (LM) 4.50, near RM 18, and continue in a southeasterly direction to the intersection of Tudor Road and LM 3.75, along the right bank of the Feather River at RM 17. Presented on Map 1 are the existing levee configuration, existing infrastructure, and the proposed setback levee alignment in the Star Bend area. The total length of the setback levee would be approximately 3,400 feet with a minimum top width of 20 feet and side slopes of 3:1 horizontal:vertical (H:V). The foundation of the levee would include a soil bentonite (SB) slurry cutoff wall placed at or near the center of the setback levee prism to a depth of up to 62 feet below existing ground surface elevation. A typical cross section for the setback levee is shown on Figure 1. At the north and south tie-in transition points between the existing and proposed levee segments, the new levee would also consist of soil cement bentonite (SCB) cutoff walls to tie into the existing levee and provide points of overlap for any future project to address seepage and underseepage north and south of the setback levee. The existing levee between River Mile 16 and 18, with the exception of an area covering a known cultural resource site, would be completely degraded and the material used for construction of the new levee or otherwise disposed of on site.

Most of the material for the construction of the setback levee may come from three primary sources: (1) the existing levee that will be degraded; (2) a 12.6-acre triangular-shaped area located between the existing levee and 350 feet northeasterly from the proposed setback levee; and (3) three borrow/spoil areas in the O'Connor Lakes Wildlife Unit, just southeast of the setback levee location. Unsuitable embankment material from the eventual decommissioning of the existing levee would be used to fill the borrow/spoil areas at the O'Connor Lakes Wildlife Unit to match the existing ground level. Non-federal activities associated with the proposed Project would include extending and rerouting irrigation pipelines from an existing pump station through the new levee; providing new flow closure devices on the waterside hinge point of the new levee; and constructing a new irrigation distribution structure 50 feet beyond the landside toe of the new levee.

Modifications to Tudor Mutual Water Company's Star Bend pumping plant, including the agricultural water distribution system, will be required to deliver water to the landside of the new setback levee alignment. These modifications include installing two new pump discharge lines from the pumping plant to the new setback levee, constructing flow closure devices, installing new pipelines over the new levee, and installing a new irrigation distribution structure 50 feet beyond the landside of the setback levee. New irrigation pipelines to connect the flow distribution structure to the existing irrigation networks on the landside of the setback levee will also be required. The invert of the irrigation pipes below the center crown of the setback levee will be above the USACE 1957 Hydraulic Design Flow Profile with a minimum of 2 feet of cover.

The proposed Project would also include several habitat enhancement measures. Once the setback levee has been constructed and the existing levee decommissioned, a minimum of 20 acres of the newly created 50-acre floodplain would be revegetated with native plant species. Once the borrow areas at the O'Connor Lakes Wildlife Unit have been filled and graded, they will be revegetated with native herbaceous plant species.

1.4 Supporting Documents

The following documents serve to support the current design of levee improvements, agricultural system relocation, and habitat enhancement design.

1. ERM (Environmental Resources Management). "*Phase I Environmental Site Assessment for the Star Bend Levee Project, Star Bend Road, Yuba City, California,*" March 2008.

2. River Partners, Inc. and Stillwater Sciences "*Habitat enhancement plan for the Feather River Levee Setback and Habitat Enhancement Project at Star Bend, Sutter County, California*," November 2008.

3. Stillwater Sciences. "*Delineation of jurisdictional waters and wetlands for the Feather River Levee Setback and Habitat Enhancement Project at Star Bend, Sutter County, California,"* 2008.

4. Stillwater Sciences. "*Survey of potential valley elderberry longhorn beetle habitat for the Feather River Levee Setback and Habitat Enhancement Project at Star Bend, Sutter County, California. Prepared for Levee District One of Sutter County, Yuba City, California*," 2008.

5. Stillwater Sciences. "*Biological assessment for the Feather River Levee Setback and Habitat Enhancement Project at Star Bend, Sutter County, California. Prepared for Levee District One of Sutter County, Yuba City, California*," 2008.

6. Wood Rodgers, Inc., "*Hydraulic and Hydrologic Analysis of Lower Feather River Setback Levee at Star Bend (Revision 1),*" November 2007.

7. MBK Engineers, Inc., Memorandum – *Hydraulic Impacts of Sutter County's Proposed Feather River West Levee Setback at Star Bend*," September 25, 2008.

8. LD1 (Levee District One of Sutter County), "*Supplemental Information to Grant application for the Feather River Levee Setback at Star Bend to the State-Federal Flood Control System Modification Program, Fiscal Year 2007-2008, Early-Implementation Projects,"* October 2007.

9. LD1 (Levee District One of Sutter County), "*Grant Application for the Feather River Levee Setback at Star Bend to the State-Federal Flood Control System Modification Program, Fiscal Year 2007-2008, Early Implementation Projects,"* May 2007.

10. Wood Rodgers, Inc. "*Draft Lower Feather River Feasibility Study. Prepared for Levee District No. 1 of Sutter County, Yuba City, California,"* April 2007.

11. EIP Associates, Inc., "*Draft Environmental Impact Report, Feather River Setback Levee Project at Star Bend*," February, 2007.

12. EIP Associates. *"Final Environmental Impact Report for the Feather River Setback Levee Project at Star Bend; SCH No. 2006052087,"* 2007.

13. Blackburn Consulting, Inc., "*Geotechnical Report for Star Bend Setback Levee, Levee District No. 1, Sutter County, California,"* October 20, 2006.

14. Blackburn Consulting, Inc. "*Addendum No. 1 to Geotechnical Report for Star Bend Setback Levee, Levee District No. 1, Sutter County, California,*" November 20, 2007.

15. Blackburn Consulting, Inc. "*Evaluation of Star Bend Setback Levee Seepage and Slope Stability with the Water Surface at the Hydraulic Top-of-Levee,*" December 12, 2008.

16. *Blackburn Consulting, Inc. "Response to Corps of Engineers Backcheck Comments 7, 10, 18, 19, 25, 28 and 34,"* January 12, 2009. These comments were submitted to Wood Rodgers and included: (1) Seepage Analysis for Borrow Area No 3, March 28, 2008; (2) Updated End-of-Construction Slope Stability; and (3) Updated Settlement Analysis.

17. River Partners, Inc., "*O'Conner Lakes Unit Riparian Restoration Plan, Feather River Wildlife Area, Sutter County, California,"* August 15, 2006.

18. U.S. Army Corps of Engineers and the Reclamation Board. "*Sutter Basin, California, General Investigation Feasibility Study: Pre-F4 Document. U.S. Army Corps of Engineers, Sacramento District and State of California, Reclamation Board Sutter County,"* 2006.

19. MBK Engineers, Inc., "*Memorandum - Star Bend Setback Levee Hydraulic Analysis,*" June 28, 2004.

20. Corps of Engineers, "*Sacramento River Flood Control Project, Phase II, Levee Reconstruction, Contract 3 Drawings,*" March *1998.*

21. USACE, *"Sacramento and San Joaquin River Basins Comprehensive Study, Technical Studies Documentation,"* December 2002.

22. von Geldern Engineering Company, "*Tudor Mutual Water Company, Service Area Map,"* May 24, 1994.

23. Edward von Geldern, Civil Engineer, "*Exhibit B, Cross Section of the Levee of Levee District No. 1 of Sutter County, Calif. Showing Proposed Pipes to be Installed for Tudor Mutual Water Company,"* August 15, 1955.

2.0 DESIGN CRITERIA

2.1 Central Valley Flood Protection Board

The CVFPB has primary jurisdiction for approval of levee design and construction within the Central Valley of California. Primary standards that control levee design and construction include:

- CVFPB Standards: California Code of Regulations (CCR), Title 23, Division 1, Article 8 (Sections 111 through 137).

- General and Special Conditions contained in: (1) CVFPB Permit No. 18191 for construction of the levee; and (2) CVFPP Permit Nos. 18437 and 18438 for construction, operation, and maintenance of irrigation facilities.

An encroachment permit through the CVFPB was applied for in March of 2007 (Application No. 18191). A permit for the levee improvements is anticipated to be received from the CVFPB following LD 1 receiving 408 Permit authorizations from the USACE. Once received, the general and special conditions contained within the permit will be made a part of the construction contract documents. Until the permit is obtained, conditions that the CFVPB has applied to similar projects will be assumed to apply to this Project and have been incorporated into the design, as appropriate.

2.2 U.S. Army Corps of Engineers

The USACE has federal jurisdiction for approving levee design and construction. Primary standards that control levee investigation, design, and construction are as follows:

- Engineer Manual EM 1110-2-1913, "*Design and Construction of Levees*," 30 April 2000.

- Sacramento District, "D*ocument REFP10L0*," April 11, 2008.

- Sacramento District, Standard Operating Procedure EDG-03, "*Geotechnical Levee Practice*,"7 July 2004.

- 2003 CESPK Levee Task Force, "*Recommendations for Seepage Design Criteria, Evaluation and Design Practices,*" 15 July 2003.

- Engineer Manual EM 1110-1-1804, "*Geotechnical Investigations,*" 1 January 2001.

- Engineer Manual EM 1110-2-1902, "*Slope Stability*," 31 October 2003.

- Engineer Technical Letter No. ETL 1110-2-569, "*Engineering and Design, Design Guidance for Levee Underseepage*," 1 May 2005.

- Engineering Technical Letter No. ETL 1110-2-571, "*Guidelines for Landscape Planting and Vegetation Management at Levees, Floodwalls, Embankment Dams, and Appurtenant Structures,*" 3 April 2008.

2.3 Federal Emergency Management Agency

The project must also comply with requirements of the Federal Emergency Management Agency (FEMA) as outlined in Section 65.10 of the National Flood Insurance Program regulations (44CFR Ch. I, Section 65.10).

2.4 State of California, Department of Water Resources

CDWR is in the process of developing levee design criteria as part of the State Plan of Flood Control as set forth in Senate Bill 5, signed into law in October of 2007. This plan is to be adopted by the CCFPB by July 1, 2012. Until this levee design criteria is finalized, the CDWR has issued the following draft document to provide interim guidance in the design of levee improvements to levees within the State Plan of Flood Control:

- DWR, "*Proposed Interim Levee Design Criteria for Urban and Urbanizing Area State-federal Project Levees,*" August 22, 2008.

3.0 PROJECT-SPECIFIC DESIGN CRITERIA

Based upon the above references and criteria, the following project-specific design criteria apply to this project:

3.1 Hydraulics Design

The design water surface elevation for the subject setback levee is the USACE 1957 Feather River Hydraulic Design Flow Profile. The 1957 Hydraulic Design Flow Profile was obtained from Mr. Ethan Thompson, hydraulic engineer, of the USACE Sacramento office on August 14, 2006, and is included in Table 1 and Table 2. The 1957 Hydraulic Design Flow Profile values provided by the USACE included in Table 1 and Table 2 were compiled for the USACE's Yuba General Reevaluation Report.

The minimum freeboard for the new setback levee will be three feet above the USACE 1957 Hydraulic Design Flow Profile. The top-of-levee elevation for the proposed setback levee will also be at least as high as the top of levees indicated in the USACE 1957 Design Profile exhibits. In all locations, the new top of levee elevation will provide freeboard in excess of 3.60 feet (3.6 feet at the north tie-in point to 4.1 feet at the south tie-in point as noted in Table 2) over the USACE 1957 Hydraulic Design Flow Profile.

It should be noted that the USACE 1957 Hydraulic Design Flow Profile for the existing and planned levee improvements is higher in elevation than the 1-in-200 AEP event. Refer to Table 2 and Figure 4.

The irrigation pipes below the crown of the setback levee will be elevated above the USACE 1957 Hydraulic Design Flow Profile, and all irrigation pipes will have a minimum of 2 feet of cover below the levee crown.

The hydraulic evaluations of the setback levee were based upon the HEC-RAS hydraulic model developed by the USACE for the report titled, "Amended Draft Lower Feather River Floodplain Mapping Study," revised February 17, 2005, and subsequent revisions by MBK Engineers, Inc (MBK). The HEC-RAS model prepared by the USACE was revised by MBK and the details are included in MBK's report titled, "Hydraulic and Hydrologic Documentation for FEMA Certification of the Three River's Levee Improvement Authority Project," prepared on March 2007.

An important assumption was made while performing the hydraulic simulation of the leveed river system. The analysis assumes that levees upstream within the Sacramento, Feather and Yuba River Systems would not fail before or after overtopping. Top-of-levee profiles were compared to the calculated 1-in-200 AEP event water surface profiles to determine low spots where levee overtopping may occur. The locations were defined in the updated MBK HEC-RAS model report of March 2007.

The unsteady flow analysis was performed for 1-in-10, 1-in-25, 1-in-50, 1-in-100, and 1-in-200 annual exceedence probability (AEP) water surfaces. The steady flow analysis was performed for each reach in the hydraulic model with a specified 1957 Design Floodplain flow rate. The specified 1957 Design Floodplain flow rate for the Project reach (Feather River between Yuba River and Bear River) is 300,000 cfs. At the downstream boundaries of the model on the Sacramento River and Yolo Bypass, the specified 1957 Design Floodplain water surface elevations were adopted from this analysis.

Three scenarios were evaluated for this analysis: an Existing Conditions Scenario, a Pre-Project Condition Scenario, and a Proposed Condition Scenario.

Existing Conditions – No Setbacks on the Feather River (between the Yuba River and Bear River)

The existing condition represents the scenario with no setbacks on the Feather River, but includes the completed setback on the Bear River with its confluence with the Feather River. Channel and levee conditions were represented with the best estimate of present conditions.

Pre-Project Conditions – With TRLIA Setback Levees

The pre-project condition represents the scenario with the proposed Three Rivers Levee Improvement Authority (TRLIA) Segment 2 Feather River Setback Levee Project; which consists of setting back the Feather River east (left bank) levee from River Mile 17.0 to 24.3, and habitat enhancement in its setback levee area. It also includes the TRLIA Setback Levee on the Bear River at the confluence of the Bear and Feather Rivers.

Proposed Conditions – With TRLIA and Star Bend Setback Levees

The proposed condition includes the TRLIA Setback Levees and Sutter County's proposed Lower Feather River Setback Levee on the right bank or west levee from River Mile 17.25 to 18.25. The set back configuration and hydraulic parameters for model cross-sections 16.5 to 18.25 were also prepared. For cross-sections 17.0 to 18.25, roughness values for the channel and overbank of .039 and 0.088, respectively, were adopted by MBK. The roughness values are consistent with the roughness characteristics of the TRLIA Setback Levee on the east side of the Feather River, represented in the cross-sections between 18.25 and 24.25.

3.2 Seepage Investigations

Maximum Underseepage Exit Gradient at Levee Landside Toe: 0.5.

Steady-State Analysis.

Hydraulic top-of-levee analysis performed to confirm levee does not fail by seepage.

3.3 Levee Cross Section

Levee Crown: Minimum 20-foot width.

Operating Road: 12-foot-width; 4-foot tapering shoulders.

Levee Side Slopes: 3 horizontal to 1 vertical (3:1).

3.4 Levee Embankment Materials

Soil Classification: SM or SC, ML, or CL

Plasticity Index: Greater than or equal to 8, less than 30.

Liquid Limit: Less than 45.

30% Passing No. 200 sieve, 100% Passing 2-inch sieve.

Compaction: 95% of maximum density per ASTM D698.

Maximum Moisture Content Range: -2% to 2% over optimum moisture content.

3.5 Slurry Cutoff Wall Construction

Width: 36-inches.

Depth: 40-62 feet.

Soil-bentonite Slurry Cutoff Wall: Constructed at the levee centerline.

Hydraulic Permeability: 5x10-7 cm/sec (maximum) as tested by ASTM D 5084.

Soil Backfill Requirements:

Sieve Size or Number	Percent (%) Passing by Dry Weight
2-inch	100
No. 4	40 to 100
No. 40	25 to 60
No. 200	20 to 40

3.6 Irrigation System Replacement

The irrigation pipes will be above USACE 1957 Hydraulic Design Flow Profile with a minimum of 2 feet of cover.

Concrete:

American Concrete Institute, Building Code Requirements for Structural Concrete (ACI 318).

Reinforced Concrete Pipe:

ASTM C76, Standard Specification for Reinforced Concrete Culvert, Storm Drain, and Sewer Pipe.

Steel Pipe:

AWWA C200, Standard for Steel Water Pipe 6 In. and Larger.

Positive Closure Devices:

AWWA C505, Standard for Metal Seated Gate Valves for Water Supply Service.

3.7 Datum and Units of Measure

Elevations contained in the design documents and construction plans for the Project are referenced to mean sea level (msl) and are based upon the 1929 National Geodetic Vertical Datum (NGVD 29). Horizontal alignments are based upon the North American Datum of 1983 (NAD 83).

The English System of units is to be used for this Project.