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of Engineers**
Hydrologic Engineering Center

Documentation and Demonstration of a Process for Risk Analysis of Proposed Modifications to the Sacramento River Flood Control Project (SRFCP) Levees

June 2009

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14. ABSTRACT
The US Army Corps of Engineers (USACE), South Pacific Division (CESPD), has requested assistance from the Hydrologic Engineering Center (CEIWR-HEC) on a study of the Sacramento River Flood Control Project (SRFCP) levees. The SRFCP is a large system that includes regulated and unregulated inflows, watercourse, bypasses, hydraulic structures, and tidal influences. The request relates to the determination of possible system impacts due to a non-Federal project and the documentation required for compliance with 33 USC 408 permitting process. The impact analysis requires a comprehensive approach that considers system-wide assessment of potential transfer of risk in terms of system performance. This report provides the methods and steps to use current probabilistic analysis tools in a system-wide context to assess performance from modifications to project levee.

15. SUBJECT TERMS
South Pacific Division, HEC, Sacramento River Flood Control Project, SRFCP, levees, USACE, CESPD, CESPK, Hydrologic Engineering Center, study, HEC-RAS, HEC-FDA, system-wide, hydraulic structures, regulated, unregulated flows, inflows, inflow-outflow transform, risk analysis, flood hazard, uncertainty, hydrology, hydraulics, levee performance, guidance, EM 1110-2-1619, overtopping, flood damage, hydraulic impacts, impacts, deterministic, analysis, method, policy, ER 1105-2-101, planning, reduction, comprehensive, 408 permits, modification of a Federal project

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Abbreviations

AEP - Annual Exceedance Probability

CEIWR-HEC - U.S. Army Corps of Engineers, Institute for Water Resources, Hydrologic Engineeing Center

CESPD - U.S. Army Corps of Engineers, South Pacific Division

CESPK - U.S. Army Corps of Engineers, Sacramento District

CNP - Conditional Non-Exceedance Probability

CVFCB - Central Valley Flood Protection

CVFPP - Central Valley Flood Protection Plan

DWR - State of California, Department of Water Resources

EC - Engineer Circular

EIP - Early Implementation Projects

EM - Engineer Manual

ER - Engineer Regulation

EYR - Equivalent Years of Record

FEMA - US Department of Homeland Security, Federal Emergency Management Agency

GRR - General Re-Evaluation Report

GPS - Global Positioning System

HEC – Hydrologic Engineering Center

HEC-FDA - Flood Damage Reduction Analysis

HEC-RAS - River Analysis System

IACWD – Interagency Advisory Committee on Water Data

IPR - Intermediate Progress Review

IWR - Institute for Water Resources

LM - Levee Mile

NEMDC - Natomas East Main Drainage Canal

RTK – Real-Time Kinematic

SJRFCS - San Joaquin River Flood Control System

SRFCP - Sacramento River Flood Control Projects

UNET - One-Dimensional Unsteady Flow through a Full Network and Open Channels

USACE – U.S. Army Corps of Engineers

USGS – U.S. Department of Interior, U.S. Geological Survey

WEST - WEST Consultants, Inc.

WS - water surface

Acknowledgements

A process was defined to apply risk analysis methodologies to identify potential system-wide hydraulic impacts resulting from alterations and modifications to the Sacramento River Flood Control Project (SRFCP). The process was applied to illustrate the evaluation of potential system-wide impacts associated with several Early Implementation Projects (EIP) proposed for the SRFCP. This effort demonstrates that existing risk analysis tools can be applied in a systems context to reveal responses of one region of a system from perturbations to another region. Results from the risk analysis methods were compared against results derived from deterministic analysis methods for illustrative purposes. The example application illustrates the complexities and effort required in conducting a risk analysis. This process was documented in this report entitled "Documentation and Demonstration of a Process for Risk Analysis of Proposed Modifications to Sacramento River Flood Control Project Levees". HEC involvement in this effort is under the guidance of Christopher N. Dunn, Director, Hydrologic Engineering Center, and Michael K. Deering, Chief, Water Resource Systems Division, Hydrologic Engineering Center.

A second, but no less important reason for this exercise, was to understand more fully what is required to advance the current methods and tools for risk management assessments. Because of this second objective, Actions for Change Theme 2 (Risk Informed Decision Making) provided a large portion of the funding for this effort. Actions for Change Theme 2 emphasizes integrated risk management and requires the USACE to use risk and reliability concepts in planning, design, construction, operations and major maintenance and to improve its review of completed works program by including an assessment component with the goal of ensuring safe, reliable, and resilient infrastructure. Thus, a major goal of this Action is to develop methods, tools, and guidance for performing and using risk and reliability assessments that match the complexity and frequency of the assessments. Appreciation is extended to Dr. David Moser, National Lead for Theme 2, for his support and funding of this project.

Conception, development and implementation of this process was a team effort. The impetus behind the effort was provided by the Commander of the South Pacific Division, General John R. McMahon. The initial design and concepts of the methodology were performed by Messrs. Christopher Dunn and Michael Deering. Execution of the methodology and procedures, and the conduct of impact analysis were performed by WEST Consultants, Inc. Project oversight and product review was provided by South Pacific Division and Sacramento District staff. Appreciation is given to the State of California Department of Water Resources and their Consultants and to the Sacramento Area Flood Control Agency and their Consultants for project coordination, product review and local insights to the system and proposed system modifications. And lastly, special appreciation is given to Penni Baker for her diligence and focus in reviewing and editing to produce this final report.

Executive Summary

Risk analysis is defined as an analysis of flood hazard and consequence based on the uncertainty of contributing factors related to the hydrology, hydraulics, economics, and levee performance. The U.S. Army Corps of Engineers (USACE) guidance related to risk analysis is documented in EM 1110-2-1619, "*Risk-Based Analysis for Flood Damage Reduction Studies*" (USACE, 1996). The current study is limited to the evaluation of risk associated with levee performance related to overtopping. It is not a comprehensive example of risk analysis for flood damage consequences.

A process was defined per USACE guidance to apply risk analysis methodologies to identify potential system-wide hydraulic impacts resulting from alterations and modifications to the levees of the Sacramento River Flood Control Project (SRFCP). The process was applied to illustrate the evaluation of potential system-wide impacts associated with four Early Implementation Projects (EIP) proposed for the SRFCP. Results from the risk analysis methods were also compared against results derived from deterministic analysis methods. The example application also illustrates the complexities and effort required in conducting a risk analysis. The results of the analysis are for illustrative purposes only; the study was not conducted for permitting of the involved EIPs.

USACE policy, stated in ER 1105-2-101, "*Risk Analysis for Flood Damage Reduction Studies*" (USACE, 2006a), requires the use of risk analysis and its results in planning flood risk management studies. The goal of the policy is a comprehensive approach in which the key variables, parameters, and components of flood risk management studies are subject to probabilistic analysis. The benefit of the proposed process for the evaluation of proposed modifications to the SRFCP is an increased understanding of the risk inherent in proposed modification alternatives. Risk analysis will quantify assurance in the available flood protection and provide confidence that a proposed modification project is appropriate. It is noted that USACE policy for use of risk analysis is not recent. It was first issued in March 1996 and more recently updated in January 2006. The current work is intended to provide additional detailed guidance for risk analysis efforts.

The work effort for this study was coordinated by the Hydrologic Engineering Center (HEC) at the request of the South Pacific Division (CESPD) of the U.S. Army Corps of Engineers (USACE). State and local flood control agencies and their representatives were invited to participate in four Intermediate Progress Review (IPR) meetings (18 September 2008, 30 September 2008, 20 October 2008, and 10 December 2008) conducted for this study. Their input to the project is greatly appreciated, along with their review and comment on the draft report for this project.

The SRFCP is a large system that includes regulated and unregulated inflows, watercourses, bypasses, hydraulic structures, and tidal influences. Identification and management of potential hydraulic impacts resulting from modifications to the system requires a comprehensive approach that considers all hydraulic interactions of the system elements. The hydraulic modeling results of the study clearly demonstrate the need for system-wide assessment of potential hydraulic impacts. Due to influences on the timing and magnitude of flow, potential hydraulic impacts can exist at extended distances from proposed modifications to the system, including potential impacts on different watercourses.

Results of the hydraulic analysis also demonstrated that results for individual EIPs are different than those when multiple EIPs are considered. Cumulative changes in both water surface elevations and risk analysis results were demonstrated. The importance of considering potential cumulative impacts to the SRFCP is illustrated by the fact that the analysis results for individual EIPs were found to be less than the potential cumulative impacts for combinations of these same EIPs.

The specific steps for conducting risk analysis are very similar to those for deterministic analysis. While "definition of uncertainty" is required for the risk analysis process, the traditional deterministic analysis process requires conducting a "sensitivity analysis". Fundamentally, these analysis steps have the same purpose. Whereas the definition of uncertainty is used in risk analysis to define a function for describing the range of risk, the sensitivity analysis information describes risk as a discrete result. Similarly, "risk analysis" estimates how risk and associated consequences (flooding, economic damage, life safety) vary over the full range of potential flooding probabilities, while "consequence evaluation" is conducted to deterministically define expected consequences for specific flood events.

Various assumptions were required to conduct the analysis. Most notable, is the applicability of the available hydrology for the study area and the criteria used to define when and how a levee will fail. Modifications to these assumptions will affect the potential hydraulic impact assessment. However, for the purpose of defining a process for identifying potential hydraulic impacts to facilitate Section 408 permitting, the employed assumptions are reasonable. Similar assumptions will be required of those conducting risk analyses for Section 408 permits. Employed assumptions will need to be documented and justified by the permit applicants. It is also recognized that as better data and tools become available, the employed assumptions may be eliminated and the proposed risk analysis process can be improved. Since many assumptions are inherently deterministic, adjustment of the employed assumptions can be expected to influence the results of both risk analysis and deterministic analysis approaches.

A comparison was made with the results from the risk analysis and deterministic analysis procedures. The comparisons indicate general consistency between the two methods, the probability of overtopping defined by deterministic methods is the same as the median Annual Exceedance Probability (AEP) defined by risk analysis, and increases in water surface elevations defined by the deterministic process are reflected as a reduction in assurance (also referred to as Conditional Non-Exceedance Probability, CNP) by risk analysis. Although it was observed for most of the EIPs that more locations of increased water surface elevations were identified in the deterministic analysis compared to decreases in assurance (CNP) identified by the risk analysis. This condition is attributed to the small magnitude of the involved change in water surface elevation and the corresponding values associated with the stage-discharge relationship. It is further noted that small changes in risk analysis results may not be significant, although the concept of significance is still being discussed.

The work for this study was based on an unsteady flow HEC-RAS (Hydrologic Engineering Center's River Analysis System, 2008) model developed by the USACE Sacramento District (CESPK) as part of their work for the American River Common Features General Re-Evaluation

Report (GRR) study. The HEC-RAS model was developed from the UNET (Hydrologic Engineering Center's One-Dimensional Unsteady Flow through a Full Network of Open Channels, 2001) model prepared as part of the Comprehensive Study of the Sacramento and San Joaquin River Basins (CESPK, 2002). The model consists of plans for seven events ranging from the 0.50 to 0.002 exceedance probability floods. It should be noted that the model has not undergone public review and it is still in development by CESPK.

Based on an examination of the labor hours expended for this study, it was identified that approximately thirty-eight percent of the work effort was attributed to conducting the risk analysis. About eight percent of the work effort was attributable solely to the deterministic analysis and fifty-four percent of the work effort was common to both approaches. Thus, the risk analysis required an increase of forty-eight percent in the level of work effort compared to the deterministic analysis. It is noted that the amount of work effort required is generally unique to every project and dependent on the objectives of the study, the size and complexity of the study area, experience of the modelers, and the availability of existing data and information. It is recognized that for a large, complex system such as the SRFCP, the development of hydrology and hydraulic models are very significant work efforts, but required for either risk analysis or deterministic analysis methods. For the current study, both hydrology and hydraulic models were available. Therefore, for future studies where the hydrologic and hydraulic models have not been built the percentage of time spent on risk analysis will decrease significantly. Furthermore, it is recognized that risk analysis process is still developing and some effort will be required for additional development of the process versus application of the process for future risk analysis efforts. However, it is likely that the level of effort for future studies will reduce over time as risk analysis processes become more routinely employed.

Steps for completing the risk analysis process are summarized in Appendix A, and example calculations for developing the various relationships used in the process are provided in Appendix B. The Hydrologic Engineering Center's Flood Damage Reduction Analysis, HEC-FDA (HEC, 2008) input data for the various EIP scenarios evaluated are provided in Appendix C. A discussion related to the sensitivity of various HEC-FDA input data is provided in Appendix D. Finally, comments on the final draft of this report are provided in Appendix E.

Conclusions and recommendations of the study include:

- Accurate evaluation of potential project specific and cumulative hydraulic impacts requires consistency in the hydraulic models employed. To avoid discrepancies, it is recommended that a single HEC-RAS hydraulic model of the baseline condition be developed and maintained for the SRFCP. The baseline model could then be modified to simulate and evaluate the proposed condition. As modifications are constructed, the proposed condition model would then become the current condition model.

- Appropriate index locations should be selected for evaluation of potential hydraulic impacts for each proposed SRFCP modification. To ensure that system-wide impacts are properly evaluated, a set of designated index locations should be defined by the stakeholders responsible for SRFCP. Areas where there are high potential for flood risk, economic damage and life safety consequences should be considered in the selection of index points. Complex stage-discharge relations in tidally influenced locations may limit the utility of index locations in those areas. In addition to the designated index locations,

locations within the vicinity of the proposed modifications and where the maximum change in the water surface elevations would occur for the proposed condition should also be included in the evaluation of the proposed modifications.

- It is recognized that a variety of factors can influence levee failure, including overtopping, scour, hydraulic loading, rapid drawdown, seepage and piping, and earthquakes, among others. Future risk analysis may need to include these failure modes in the definition of levee fragility and associated uncertainty. Development of appropriate risk-based fragility relations will require additional research.

  The example process application was based on the hydrology developed by the Comprehensive Study for the Sacramento River Mainstem at Latitude of Sacramento Centering. This single centering is localized near the downstream end of the watershed. The discharge-frequency relationship for this centering is relative only to the selected centering and other locations within the watershed would have different discharge-frequency relationships. To ensure that the centering does not adversely bias the identification of potential hydraulic impacts, it is recommended that future evaluations consider a minimum of two centerings, one being the same as that considered for the current study and the other being defined by the location of the proposed modifications.

  It was assumed for the current study that the discharge-exceedance probability for the unregulated conditions at the various handoff locations represented the median relationship and the uncertainty in the relationship can be estimated using the direct analytical approach documented in "*Guidelines for Determining Flood Flow Frequency*", Bulletin 17B (USGS, 1982) and in EM 1110-2-1415, "*Hydrologic Frequency Analysis*" (USACE, 1993). The uncertainty of regulated inflows should be derived from a sensitivity analysis of reservoir inflows and routings with variations to the outlet works and spillway ratings, outlet works operation, shape and volume of inflow hydrograph, assumed initial release conditions, and safety issues. Since such an analysis was not conducted for the Comprehensive Study, or for the present study, the total uncertainty at the handoff locations was estimated using a procedure that equates the Equivalent Years of Record (EYR) to the combined uncertainty of the unregulated and regulated flow conditions. It is recommended that the hydrology for the system be re-evaluated and a sensitivity analysis be conducted to define the uncertainty in the regulated discharge-exceedance probability relationship at all of the handoff locations. The State of California, Department of Water Resources (DWR) has commissioned the Sacramento District (CESPK) of the U.S. Army Corps of Engineers (USACE) to update estimates of the flow frequency throughout the Sacramento River basin. The study will have results that are similar to the Comprehensive Study results, and uncertainty about the regulated flow frequency curves will not be identified.

- The evaluation of the Feather River EIPs did not consider the possible re-operation of the Oroville and Bullard's Bar reservoirs to offset the potential increases in flow caused by these projects. Future evaluations of EIPs proposed for the Feather River system should consider this issue.

- Overall, the HEC-FDA program is easy to utilize. However, it was noted that data entry and result extraction could be made more efficient via cut and paste options or similar. Data import/export and enhanced printing issues/capabilities will be addressed in upcoming versions of HEC-FDA.

- Potential impacts were determined from comparison of analysis results for baseline and proposed conditions. The potential impacts defined from deterministic analysis results are changes in water surface elevation and freeboard that are defined in units of length such as feet. Due to the common use of length units in everyday affairs, the significance of differences expressed in units of length are generally well understood. In contrast, the potential impacts defined from risk analysis results are changes in probabilities. In general, the significance of differences in probabilities, particularly small differences in probabilities, are difficult to conceptualize. Consequently, a need exists for development of guidance or criteria to define the significance of risk analysis results.

Chapter 1

Introduction

The SRFCP consists of a comprehensive system of levees, weirs, gates, pumping plants, leveed bypass floodways, and overbank floodway areas. It includes approximately 1,300 miles of levees that provide protection to about 800,000 acres of agricultural lands; the cities of Colusa, Gridley, Live Oak, Yuba City, Marysville, Sacramento, West Sacramento, Courtland, Isleton, Rio Vista and numerous smaller communities; transcontinental railroads; feeder railroads; airport facilities; and many Federal, State and County highways. Billions of dollars in flood damages have been prevented since the project was completed. The project was designed for specific flow conditions with specific freeboard, and it was not designed to convey flow to the top of levee. The authorized project design level of protection was recognized but not used as the base condition (or any other condition) as will be discussed in this report (see Section 1.3.4).

During major flood events, upstream reservoirs in the Sacramento, Feather and American River basins intercept and store initial surges of runoff and provide a means of regulating flood flow releases to downstream leveed streams, enlarged channels, and bypass floodways. In order to achieve the full benefits of the reservoirs, specific downstream channel capacities must be maintained. Reservoir operation is coordinated not only among various storage projects but also with downstream channel and floodway carrying capacities.

Recently, the State of California passed two bond measures that provide approximately five billion dollars over the next ten years for improvements to help manage flood risk. Much of this money will be spent in the Central Valley for improvements on the State-Federal levee system. As a result of recent legislation, the State of California is now also initiating a new plan to improve integrated flood management in the Central Valley. This plan, known as the Central Valley Flood Protection Plan (CVFPP), will provide a system-wide approach for managing floods within the Sacramento and San Joaquin River valleys. State law mandates that the CVFPP be completed and adopted by the State by 1 July 2012. 33 United State Code (U.S.C.) Section 408 requires that USACE provide approval of alterations and modifications to the SRFCP and the San Joaquin River Flood Control System (SJRFCS) before such alterations and modifications may be made by the State. Authority to approve certain alterations and modifications has been delegated to the USACE Sacramento District Engineer pursuant to 33 C.F.R. 208.10. Before the State and local agencies can proceed with these modifications, CESPK must approve them under the Section 408 permitting process to assure that such projects will not result in significant, unmitigated impacts to the flood protection system. Evaluating potential system-wide hydraulic impacts will be a major element of the Section 408 permit review and approval process. USACE plans to complete this process using risk analysis methodologies in the permit request documentation.

It is USACE policy, ER 1105-2-101 (USACE, 2006a), to utilize risk analysis and its results in planning and designing of flood risk management projects. The goal of the policy is a comprehensive approach in which the key variables, parameters, and components of a flood risk management study are subject to probabilistic analysis. The benefit of the proposed process for the evaluation of proposed modifications to the SRFCP is an increased understanding of the risk inherent in the proposed modification alternatives. Risk analysis is expected to provide both more certainty in understanding of the available flood protection and confidence that a proposed modification project is appropriate. It is noted that the USACE policy for use of risk analysis is not recent. It was first issued in March 1996 and more recently updated in January 2006. The current work is intended to provide additional detailed guidance for risk analysis efforts.

HEC was tasked by CESPD to help define and conduct a process for applying risk analysis methodologies to identify potential system-wide hydraulic impacts resulting from alterations and modifications to the SRFCP. HEC contracted with WEST Consultants, Inc. (WEST), 2601 – 25th Street, SE, Suite 450, Salem, OR 97306, to assist in defining this process. Risk analysis is defined as an analysis of flood hazard and consequence based on the uncertainty of contributing factors related to the hydrology, hydraulics, economics, and levee performance. The current study is limited to the evaluation of risk associated with levee performance related to overtopping. It is also not a comprehensive example of risk analysis for flood consequences such as flood damages. The risk analysis process was defined using the guidance provided in EM 1110-2-1619 (USACE, 1996) and the policies established in ER 1105-2-101 (USACE, 2006a). A map of the SRFCP is shown in Figure 1. As an example, the process was applied to several EIPs proposed for the SRFCP to illustrate the evaluation of potential system-wide impacts. Results from the risk analysis methods were also compared against results derived from deterministic analysis methods. The analysis process and results of the example impact evaluation are documented in this report.

The work effort for this study was coordinated by the HEC at the request of CESPD. State and local flood control agencies and their representatives were invited to participate in four Intermediate Progress Review (IPR) meetings (18 September 2008, 30 September 2008, 20 October 2008, and 10 December 2008) conducted for this study. Their input to the project is greatly appreciated, along with their review and comment on the draft report for this project.

1.1 Purpose

The objective of the study is to define a process for evaluating system-wide hydraulic impacts of proposed modifications to the levees of the SRFCP utilizing risk analysis methods that follows USACE policy as outlined in ER 1105-2-101 (USACE, 2006a), and to demonstrate the process with an evaluation of four proposed EIPs. The study is being conducted to define a process and demonstrate it. The results of the study are not intended to provide a definitive assessment for any particular project or site. Example applications of the developed analysis process were made to four EIPs to illustrate and contrast the results of risk and deterministic analysis methods. The hydraulic information developed under this effort is not intended for use in any specific Section 408 permit request or for any other purpose but to demonstrate the two analytical methods. The examples also illustrate the complexities and effort required in conducting a risk analysis.

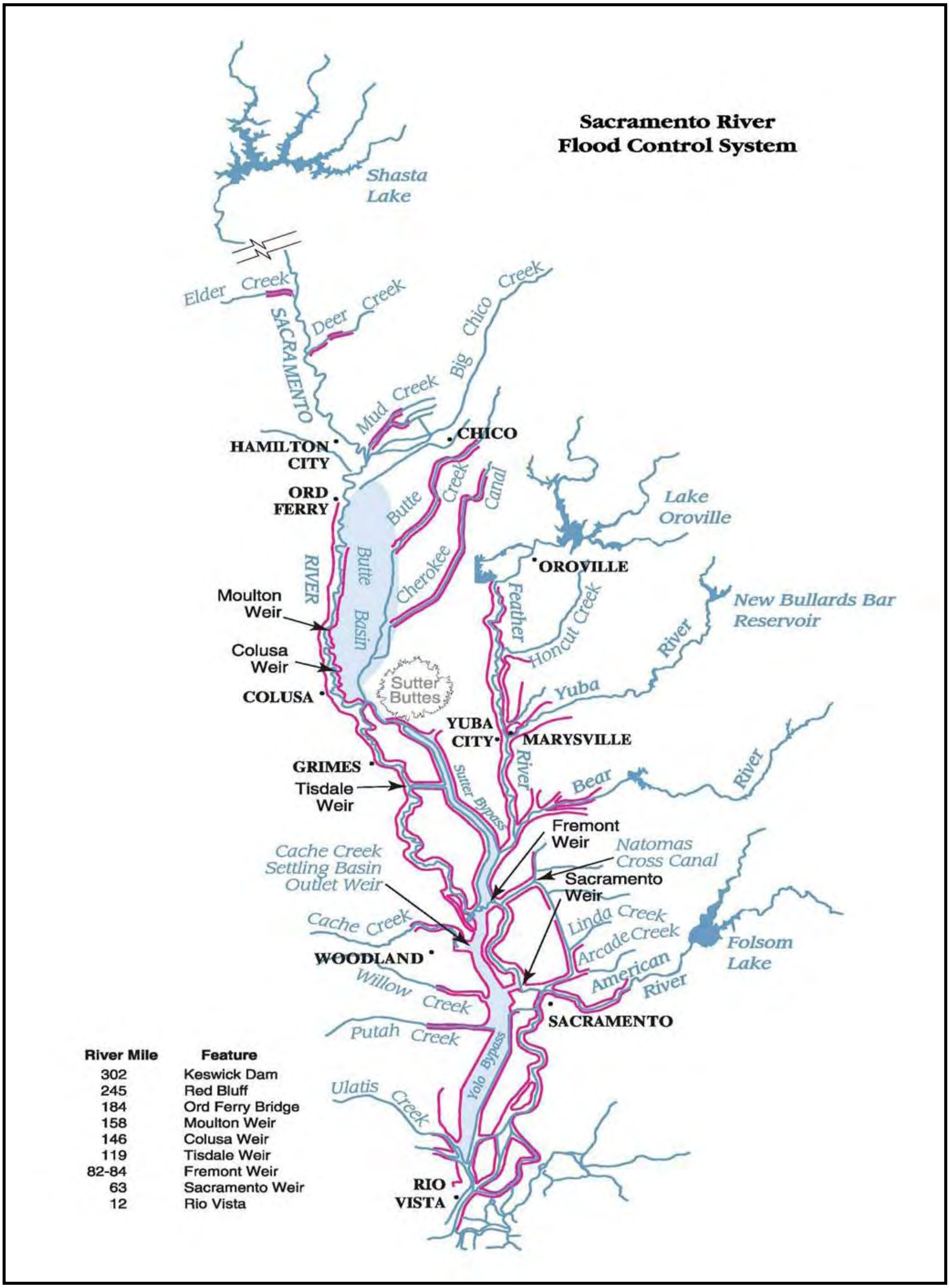


Figure 1. Map of Sacramento River Flood Control Project (SRFCP)

1.2 Study Area

The Sacramento River basin covers a 27,000 square mile area that is about 240 miles long and up to 150 miles wide. It is bounded by the Sierra Nevada Mountains on the east, the Coast Range Mountains on the west, the Cascade and Trinity Mountains on the north, and the Delta-Central Sierra area on the south. Major tributaries of the Sacramento River in the study area include the Feather and American Rivers and their tributaries, which enter the Sacramento River from the east. Numerous other smaller creeks flow into the Sacramento River from the east and west.

The study area covers the lower reach of the Sacramento River from Colusa at the upstream end, to the Sacramento-San Joaquin Delta at the downstream end. The study area also includes major tributaries (Feather, Bear, Yuba, and American Rivers), several of the smaller tributaries (Putah and Cache Creeks), and various interconnecting waterways.

1.3 Study Tasks

The scope of work for the project included the following tasks which are detailed in the following sections.

1.3.1 Coordination

Coordination efforts included the following: (1) kick-off meeting, (2) IPR meetings, and (3) presentation of Draft Final Report.

1.3.2 Data Collection and Review

Collection and review of various data, including the following:

- Hydrologic data
- Hydraulic data
- EIPs
- Area maps and visual information
- Study reports

1.3.3 Development of Potential System-Wide Hydraulic Impact Analysis Process

A risk analysis process was developed to identify potential system-wide hydraulic impacts resulting from proposed modifications to the SRFCP.

1.3.4 Evaluate Existing Baseline Performance of the SRFCP Levees

Selected aspects of the existing baseline performance of the SRFCP levees were evaluated using both deterministic and risk analysis approaches. The existing condition shall be known heretofore as the "baseline condition" and is the condition against which all potential modifications are compared. The baseline condition is defined as the 1957 design top of levee profile, including any subsequent authorized modifications to that profile, which ever is higher. The deterministic method was completed to determine the water surface elevations and available freeboard for the 0.02, 0.01, 0.005, and 0.002 exceedance probability flood events. The risk analysis was completed to define the existing median and expected AEP and assurance (CNP) for the 0.10, 0.04, 0.02, 0.01, 0.005, and 0.002 exceedance probability flood events. Two additional frequencies (0.999 and 0.0001) were considered for HEC-FDA input. The data required to perform both approaches were obtained from the same hydraulic model, and the same level of effort would be required in developing the model for either approach.

1.3.5 Modification of HEC-RAS Models - Four EIPs

Application of the developed risk analysis process was illustrated considering proposed modifications to the SCRFP. The baseline condition HEC-RAS model for the SRFCP was modified to reflect the following EIPs:

- Bear River EIP
- Feather River No. 1 (East Levee Segments 1-3) EIP
- Feather River No. 2 (Star Bend) EIP
- Natomas EIP

Description of each EIP is provided in Section 3.1.1 of this report. The combination of these EIP projects was also considered to demonstrate the variability of potential system-wide hydraulic impacts. Therefore, a total of eight scenarios were modeled with HEC-RAS assuming that the above EIPs are constructed in the order listed:

1. Baseline condition (see Section 1.3.4)
2. Bear River EIP
3. Feather River No. 1 (Segments 1 – 3) EIP
4. Bear River EIP + Feather River No. 1 EIP
5. Bear River EIP + Feather River No. 1 EIP + Feather River No. 2 EIP
6. Bear River EIP + Feather River No. 1 EIP + Feather River No. 2 EIP + Natomas EIP
7. Natomas EIP
8. Bear River EIP + Feather River No. 1 EIP + Feather River No. 1 EIP + Natomas EIP

1.3.6 Re-Evaluate Performance of the SRFCP Levees with EIPs Inplace

The performance of the SRFCP with the EIP projects inplace was evaluated using both deterministic and risk analysis approaches. It is noted that the development of a hydraulic model is necessary in completing either approach and would require the same level of effort.

- **Deterministic Approach.** The HEC-RAS hydraulic model results for each scenario were used to estimate the water surface elevations and available freeboard at all index locations.

- **Risk Analysis Approach.** For each scenario, the risk analysis was completed using the HEC-FDA program (HEC, 2008) to evaluate the median and expected AEP and assurance (CNP) for the 0.10, 0.04, 0.02, 0.01, 0.005, and 0.002 exceedance probability flood events at all index locations. Input to the HEC-FDA model is provided by output from the HEC-RAS model. The risk analysis results were prepared for all index locations.

The data required to perform both approaches were obtained from the same hydraulic model. The same level of effort for developing the hydraulic model would be required in either approach.

1.3.7 Potential Impact Evaluation

Based on the deterministic and risk analysis results, the potential impacts of each analysis scenario were defined. The potential impacts were documented in terms of the increases to water surface elevation and reductions in available freeboard over baseline condition for the deterministic process and changes in AEP and assurance (CNP) for the risk analysis process. Further, the results of the various scenarios were examined and compared to define and illustrate numerical differences in the system-wide assessment of modeled water surface elevations for each analysis approach.

1.3.8 Report

The data used, methods employed and assumptions made are documented in this report. It also contrasts the results of deterministic analysis and risk analysis procedures to potential hydraulic impact assessment.

1.3.9 Technical Review

A technical review of study methods and results was performed continuously throughout the study. The technical review included:

- Peer/Functional Review
- USACE Review

1.4 Report Organization

This report is organized into four chapters. Chapter1 provides introductory and background information. Chapter 2 outlines the data and analytical methods used to accomplish each study task. Chapter 3 presents a demonstration of hydraulic impact assessment for the four EIPs proposed to reduce flood risk within the SRFCP. The potential hydraulic impact assessment considers both deterministic and risk analysis approaches for evaluating potential hydraulic impacts on a system-wide basis. Chapter 4 presents conclusions and recommendations of the study. Detailed steps for completing the risk analysis assessment are summarized in Appendix A and example calculations for developing the various relationships used in the process are provided in Appendix B. The HEC-FDA (HEC, 2008) input data for the various EIP scenarios evaluated are provided in Appendix C. A discussion related to the sensitivity of various HEC-FDA input data is provided in Appendix D. Finally, comments on the final draft of this report are provided in Appendix E.

1.5 Deterministic Assumptions for Risk Analysis Process

The risk analysis process developed for this study required various deterministic assumptions, as is customary for all numerical modeling studies, because of the limitations of various data and available tools for performing a risk analysis evaluation. A summary of the required assumptions is provided in Table 1. Five of the eleven assumptions identified in Table 1 were utilized in both the deterministic and risk analyses. Similar assumptions will be required by those conducting risk analyses for Section 408 permits. Employed assumptions need to be documented and justified by the permit applicants.

Table 1. Deterministic Assumptions for Risk Analysis Process.

Number	Item	Assumption	Comment
1*	Hydrology	The hydrology utilized for this study is based on the "*Sacramento and San Joaquin River Basins Comprehensive Study*" (CESPK, 2002).	Some of the deterministic assumptions of the Comprehensive Study hydrology include: (1) the distribution of flow within the system (Sacramento River Mainstem at Latitude Sacramento Centering), (2) initial reservoir conditions, (3) floodplain routing, and (4) synthetic flood hydrographs.
2*	Breach Criteria	The analysis completed for this study included the potential effects of levee failure from overtopping. The levee failure criterion was set to an overtopping depth of one foot for a duration of three hours.	This criterion was assumed in defining the various relationships required for the risk analysis. A sensitivity analysis of this criterion was conducted for determining the uncertainty in these relationships.
3*	Breach Dimensions	The dimension of a breach was assumed to have a bottom width of 300 feet and 1Horizontal (1H) to 1Vertical (1V) side slopes	A sensitivity analysis of the breach dimensions was conducted for defining the uncertainty in the relationships used in the risk analysis.
4	Uncertainty of Flow at Index Locations	The uncertainty of flow at the index locations was determined using the order statistics method and EYR based on USACE guidance. The method accounts for the uncertainty of unregulated and regulated flow conditions. The standard deviation for the regulated flow conditions was estimated assuming that the 95% confidence boundaries are defined as ±10% of the median value.	Ideally, the uncertainty of regulated inflows should be derived from a sensitivity analysis of reservoir inflows and routings with variations to the outlet works and spillway ratings, outlet works operation, shape and volume of inflow hydrograph, assumed initial release conditions, and safety issues.
5	Uncertainty of Flow at Handoff Locations	The uncertainties from handoff and local inflow locations had to be transferred to each of the index locations. This was accomplished by a discharge weighted average of the EYR for each of the various sources contributing to each index location.	
6	Inflow Discharge-Exceedance Probability Relationship	The inflow discharge-exceedance probability relationship at each index location was developed by using the maximum value of the summation of the individual hydrographs that can contribute flow to the index location for	The extrapolation of the inflow discharge-exceedance probability relationship was performed to improve the uncertainty estimate for the non-analytical exceedance relationship.

*****The assumption was utilized for both the risk and deterministic analyses.

Table 1. Deterministic Assumptions for Risk Analysis Process (continued).

Number	Item	Assumption	Comment
7*	Downstream Boundary	different flood events. The relationship was defined using data with an exceedance probability between 0.50 and 0.002, and the discharges for the exceedance probabilities of 0.999 and 0.001 were extrapolated from the defined relationship. Downstream boundaries in the hydraulic model are based on the stage hydrograph measured during the 1997 event adjusted using the results of frequency analysis on the tidal data located near each of the boundary locations.	
8	Outflow Discharge-Exceedance Probability Relationship	The outflow discharge-exceedance probability relationship was revised to ensure that it increases with decreasing exceedance probabilities.	Revisions were made to the relationship. The first and most common approach involved using a discharge slightly greater than the discharge for the next larger exceedance probability flood or on occasion a discharge slightly less than the discharge for the next smaller exceedance probability flood. The second approach involved interpolation using the bounding exceedance probability floods (for example, the discharge for the 0.005 exceedance probability was interpolated using the discharges for the 0.01 and 0.002 exceedance probabilities). Similar to the inflow discharge relationship, the outflow discharges for the exceedance probabilities of 0.999 and 0.001 were extrapolated from the defined relationship.
9	Stage-Outflow Discharge Relationship	The stage-exceedance probability relationship (and stage-outflow discharge relationship) was revised to ensure that it increases with decreasing exceedance probabilities and it extends above the top of levee elevation.	Revisions were made to the relationship. The most common revision involved extending the relationship to be above the top of levee. As a result of upstream levee failures, it was found there were several locations where the slope of the stage-discharge relationship leveled off and the water surface elevation for the 0.002 exceedance probability flood event is below the top of levee. For this situation, the stage-discharge was extrapolated out to the 0.001 exceedance probability flood and then increased to be two feet above the top of levee. The second revision involved interpolation between bounding floods when there was a slight decrease in the stage.
10	Stage Uncertainty	Recommendations provided in EM 1110-2-1619 (USACE, 1996) were utilized to define the minimum standard deviation of error in stage.	This assumption was considered to account for potential uncertainties associated with the topographic data.
11*	Top of Levee Elevation	Top of levee elevations were obtained from the HEC-RAS model provided by CESPK.	The data in the model was obtained from the USACE National Levee Database.

Note: ***The assumption was utilized for both the risk and deterministic analyses.

Chapter 2

Analytical Methods

In this Chapter, a process is described to define potential system-wide hydraulic impacts to levees using risk analysis. Traditionally, a deterministic approach has been used to design and evaluate the potential impacts of flood risk management projects. Deterministic evaluation generally involves comparison of top of levee elevation to a calculated water surface elevation for a specific design flood and an assumed freeboard. Risk analysis of potential hydraulic impacts to a flood risk management project considers the uncertainty associated with the calculated water surface elevation and the related consequence to flood risk.

A summary of the general steps for risk analysis and deterministic analysis procedures to evaluate potential system-wide hydraulic impacts is presented in Table 2. As seen from the table, the analysis steps for risk analysis and deterministic analysis approaches are generally the same. A concise description of each risk analysis step is made in the following paragraphs and a detailed description of applying the risk analysis process is provided in Appendix A.

2.1 Define Analysis Conditions

Basic information on proposed project modifications must be defined in order to allow comparison to the baseline condition (see Section 1.3.4) for potential transfer of risk. The details and extent of the existing or baseline and proposed conditions should be defined to understand the scope of the proposed action, potential hydrologic and hydraulic effects, and requirements for hydraulic modeling and impact evaluation.

2.2 Identify Analysis Criteria

The specific criteria by which the proposed project modifications will be evaluated must be identified. Most fundamental is the identification of applicable law, guidance and policies, such as:

- 33 United State Code (U.S.C.) Section 408: "*Taking Possession of, Use of, or Injury to Harbor or River Improvements*" (http://vlex.com/vid/19224276)
- 33 Code of Federal Regulation (C.F.R.) 208.10, "*Local Flood Protection Works; Maintenance and Operation of Structures and Facilities*" (http://edocket.access.gpo.gov/cfr_2002/julqtr/pdf/33cfr208.10.pdf)
- 44 C.F.R. 65.10, "*Mapping of Areas Protected by Levee Systems*" (http://edocket.access.gpo.gov/cfr_2002/octqtr/pdf/44cfr65.10.pdf)
- ER 1105-2-100, "*Planning – Planning Guidance Notebook*", April 2002 (http://140.194.76.129/publications/eng-regs/er1105-2-100/toc.htm)

Table 2. Outline of Risk and Deterministic Potential System-Wide Hydraulic Impact Analysis Procedures

Step	Risk Analysis Task Description		Deterministic Analysis Task Description	
	Task	**Description**	**Task**	**Description**
1	Define Analysis Conditions	• Identify baseline condition • Identify proposed analysis conditions • Identify involved watercourses, hydrologic regulation, hydraulic controls and boundary conditions. • Identify locations throughout the study area where impact evaluation is required	Define Study Area	• Identify baseline condition • Identify proposed analysis conditions • Identify involved watercourses, hydrologic regulation, hydraulic controls and boundary conditions. • Identify locations throughout the study area where impact evaluation is required
2	Identify Analysis Criteria	• Agency policy and guidance • Desired level of flood protection • Define criteria for levee failure • Definition of impact	Identify Analysis Criteria	• Agency policy and guidance • Desired level of flood protection • Required freeboard • Define criteria for levee failure • Definition of impact
3	Data Collection	• Topographic data • Hydrologic data • Previous studied • Aerial photography • Hydraulic roughness estimates • Flow and stage measurement records • Levee data • Geotechnical information • Hydraulic structure data	Data Collection	• Topographic data • Hydrologic data • Previous studied • Aerial photography • Hydraulic roughness estimates • Flow and stage measurement records • Levee data • Geotechnical information • Hydraulic structure data
4	Hydrology	• Hydrology throughout system for range of analysis conditions.	Hydrology	• Hydrology throughout system for range of analysis conditions.
5	Hydraulic Model Development	• Develop hydraulic model of system	Hydraulic Model Development	• Develop hydraulic model of system
6	Levee Failures	• Incorporate levee breach option into hydraulic model at potential levee failure locations.	Levee Failures	• Incorporate levee breach option into hydraulic model at potential levee failure locations.
7	Calibration/Verification of Baseline Hydraulic Model	• Calibrate hydraulic model to available flow and stage measurements and observation data	Calibration/Verification	• Calibrate hydraulic model to available flow and stage measurements and observation data
8	Develop Hydraulic Models For Proposed Conditions	• Baseline condition • Proposed conditions	Develop Hydraulic Models For Proposed Conditions	• Baseline condition • Proposed conditions
9	Evaluate Proposed Hydraulic Conditions	• Evaluate baseline condition • Evaluate each proposed condition	Evaluate Proposed Hydraulic Conditions	• Evaluate baseline condition • Evaluate each proposed condition
10	Definition of Uncertainty	• Define hydrologic uncertainty • Define hydraulic uncertainty • Define operational uncertainty		
			Sensitivity Analysis	• Evaluate sensitivity of hydraulic model results over the range of possible model parameters
11	Risk Analysis	• Evaluate baseline condition • Evaluate each proposed condition		
			Impact Evaluation	• Evaluate baseline condition • Evaluate each proposed condition

12	Identification of Potential Impacts	• Comparison of proposed conditions to baseline condition
		  o Annual Exceedance Probability
		  o Conditional Non-Exceedance Probability
		• Evaluation and response to potential impacts
			Identification of Potential Impacts	• Comparison of proposed conditions to baseline condition
				  o Water surface elevations
				  o Freeboard
				• Evaluation and response to potential impacts

- ER 1105-2-101, "*Risk Analysis for Flood Damage Reduction Studies"*, January 2006 (http://140.194.76.129/publications/eng-regs/er1105-2-101/toc.htm)
- EM 1110-2-1619, "*Risk-Based Analysis for Flood Damage Reduction Studies"*, August 1996. (http://140.194.76.129/publications/eng-manuals/em1110-2-1619/toc.htm)

Additionally, in recognition of the fact that levee failures can occur within the SRFCP and such failures can have significant impact on discharge and water surface elevations within the study area, minimum criteria for occurrence of levee failure must be defined.

2.3 Data Collection

A wide range of existing data and information should be collected and reviewed.

2.4 Hydrology

Hydrology for flood events ranging from the 0.5 to 0.002 exceedance probabilities must be developed for the system. Hydrology development may consider various storm centerings. Multiple centerings could be considered, with one located near the downstream end of the watershed and the other located near the proposed modifications.

2.5 Hydraulic Model Development

A comprehensive hydraulic model of the SRFCP is required to define potential system-wide hydraulic impacts. It is recognized that various hydraulic models of the SRFCP or portions of it have been produced at different times for various purposes. A model that incorporates the most recent and comprehensive information should be utilized. Currently, an unsteady HEC-RAS model of the SRFCP developed by CESPK is recognized as the best available hydraulic model of the SRFCP. Additional information about this model is presented in Section 3.1.5 of this report.

2.6 Levee Overtopping and Failures

It is recognized that levee overtopping and failures can influence the water surface elevations and hydraulic capacity of the SRFCP. To evaluate these influences, expected locations of levee overtopping and failure should be identified and evaluated based on hydraulic modeling. Currently, minimum criteria for the occurrences of levee failure must be set as a deterministic assumption. In the future, as an improved understanding of the physics of failure mechanisms or probabilistic prediction methods become available, the deterministic assumptions for defining expected levee failure may be replaced.

2.7 Calibration/Verification of Baseline Hydraulic Model

To ensure its utility as a predictive tool, the hydraulic model must be calibrated and verified against available measurements and observation data.

2.8 Develop Hydraulic Models for Proposed Conditions

Hydraulic models for proposed SRFCP conditions are required to define the associated hydraulic conditions. The baseline condition (see Section 1.3.4) hydraulic model should be modified to reflect the proposed conditions.

2.9 Evaluation of Proposed Hydraulic Conditions

The hydraulic models for proposed conditions should be evaluated to define the associated hydraulic conditions.

2.10 Definition of Uncertainty

Three general types of uncertainty should be considered in evaluating potential hydraulic impacts, 1) hydrologic uncertainty, 2) hydraulic uncertainty, and 3) operational uncertainty. Hydrologic uncertainty can be defined using the hydrology developed under the Comprehensive Study (CESPK, 2002). Hydraulic uncertainty is defined based on an assessment of the quality of involved topographic data and an evaluation of the variation of stage over the potential range of hydraulic model input parameters such as discharge coefficients, hydraulic roughness and breaching parameters. Operational uncertainty reflects levee system performance, flood fight activities, and reservoir operations. For full evaluation of risk, one must consider the consequence associated with the flood impact area including economic losses, impact to lives, potential damages to the environment and the associated uncertainties of each. For this study and documentation heretofore, risk refers to the engineering performance of the baseline and modified conditions and does include the consequence component of a full risk analysis.

2.11 Risk Analysis

The performance of the baseline and proposed SRFCP levee modifications can be evaluated based on the results of the hydraulic models and associated uncertainty characterization. The HEC-FDA model (HEC, 2008) can be used to evaluate the median and expected AEP and assurance (CNP) over the range of flood events.

2.12 Identification of Potential Impacts

Potential impacts are identified by comparing analysis results for baseline and proposed conditions. After potential impacts are defined, their significance must be assessed. The criteria used for assessing significance are specific to the objectives of the investigation (e.g., U.S. Department of Homeland Security, Federal Emergency Management Agency (FEMA) levee certification, Section 408 permits, and planning studies). Significance was not defined as part of this study.

Chapter 3

Demonstration of Risk and Deterministic Analysis Procedures

To demonstrate the application of the risk and deterministic analysis procedures for identification and evaluation of potential hydraulic impacts associated with proposed SRFCP levee modifications, the risk and deterministic analysis procedures were applied to four EIPs. Various assumptions were made to facilitate the process demonstration. The employed assumptions may not be valid for an actual project evaluation. Accordingly, the results of the demonstration are not intended as credible information about the potential impacts of the involved EIPs. Details of the process application are presented and key assumptions are identified. The risk analysis process first is presented in Section 3.1 and the deterministic analysis process is presented in Section 3.2 for comparison purposes. As previously stated, the risk analysis process is similar to the deterministic analysis process. Example calculations for developing the relationships in the risk analysis process are provided in Appendix B.

3.1 Demonstration of Risk Analysis Process

The analysis was completed using the HEC-FDA (HEC, 2008) software developed by HEC. The program performs Monte Carlo numerical sampling of the discharge-exceedance probability, inflow-outflow transform, stage-discharge, and stage-damage relationships and their respective uncertainty distributions. However, since this study is only considering engineering performance (AEP, CNP) and not the consequence component of risk, the stage-damage relationship need not to be "real" (i.e., the stage-damage relationships need only be an ascending set of values with stages in the same range as the stage-discharge relationship; this is sometimes referred to as a "dummy" stage-damage relationship). The various analysis steps previously described in Table 2 and the application of the HEC-FDA model are described below. The HEC-FDA input data for the various EIP scenarios are provided in Appendix C.

3.1.1 Analysis Conditions

The study area was defined based on the extent of the available hydraulic model for the system. It generally includes the major tributaries (Feather, Bear, Yuba, and American Rivers), several of the smaller tributaries (Putah and Cache), and various interconnecting waterways.

The analysis was completed for the following EIPs:

- **Bear River Levee Setback.** This EIP consists of setting back the north levee for Bear River between Levee Mile (LM) 0 to 2.3 and constructing a slurry wall to eliminate underseepage and freeboard deficiencies within the reach of the proposed modifications.

- **Feather River Levee Repair and Setback No. 1.** This EIP consist of Segments 1 through 3 and involves repair to the east levee of Feather River between LM 13.3 and LM 17.2 and between LM 23.4 and LM 26.1 and levee setback (up to 2,500 feet at maximum point) and repair of the east levee of the Feather River between LM 17.2 and 23.4. The repair includes a slurry wall, restoring freeboard (three to five feet depending on where you are in the system) to design conditions, and erosion protection measures. This EIP is intended to eliminate underseepage and re-establish the design freeboard within the reach of the proposed modifications. The evaluation of this EIP did not account for potential re-operation of the Oroville and Bullard's Bar reservoirs to offset any changes in flow caused by the EIP.

- **Feather River Levee Repair and Setback No. 2.** This EIP is referred to as "Lower Feather River Setback Levee at Star Bend", and it involves setting back the levee approximately 1,200 feet at the maximum point, repair to the west levee of the Feather River between LM 16.0 and LM 19.0. The repair includes a slurry wall, restoring freeboard to design conditions, and erosion protection measures. The EIP is intended to eliminate underseepage and re-establish the design freeboard within the reach of the proposed modifications. The evaluation of this EIP did not account for potential re-operation of the Oroville and Bullard's Bar reservoirs to offset any changes in flow caused by the EIP.

- **Natomas EIP.** This EIP consisted of the proposed modifications to the Sacramento River East Levee (Phases 1 and 2), Natomas Cross Canal (Phase 1, 1B, and 2), and Natomas East Main Drainage Canal (NEMDC) West Levee Phase 1 and 2. All of the modifications include a slurry wall, added levee height, and erosion protection measures to eliminate underseepage and freeboard deficiencies within the reach of the proposed modifications.

The combination of the EIPs was also considered to evaluate the potential for cumulative impacts. Therefore, a total of eight scenarios were considered for the analysis:

1. Baseline condition (see Section 1.3.4)
2. Bear River EIP
3. Feather River No. 1 (Segments 1 - 3) EIP
4. Bear River EIP + Feather River No. 1 EIP
5. Feather River No. 2 (Star Bend) EIP
6. Bear River EIP + Feather River No. 1 EIP + Feather River No. 2 EIP
7. Natomas EIP
8. Bear River EIP + Feather River No. 1 EIP + Feather River No. 2 EIP + Natomas EIP

Locations of interest along the SRFCP were defined as "index locations" at which example application of both the deterministic and risk analysis procedures was made. A total of twenty-two index locations were selected throughout the system. The index locations were selected based on the information provided in the Comprehensive Study (CESPK, 2002) or in the "*Draft Interim Risk and Uncertainty Procedure*" prepared by DWR and the Central Valley Flood Protection Board (CVFCB). The index locations are both upstream and downstream of the proposed EIPs. The index locations are shown in Figure 2, and information about the index locations is provided in Table 3.

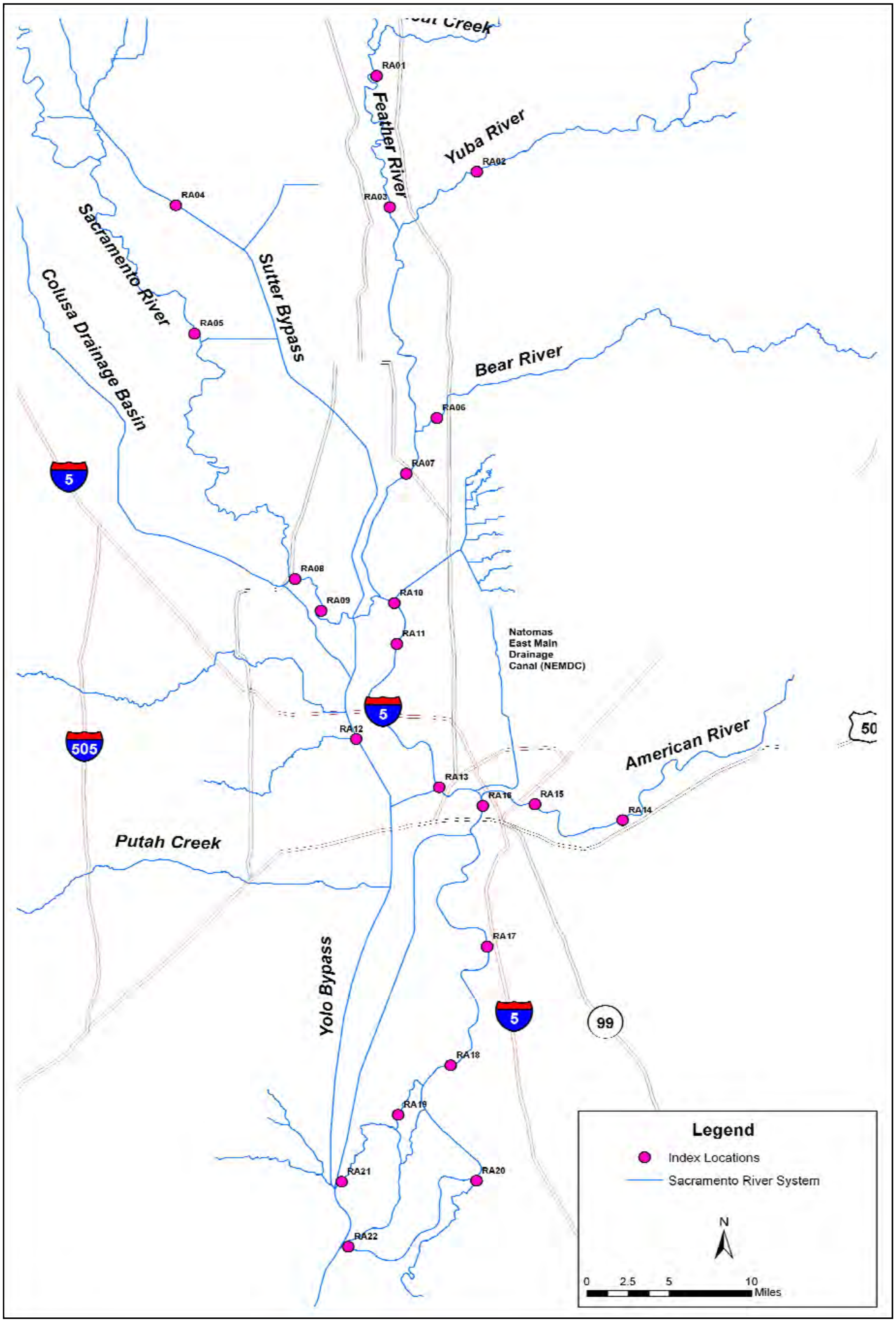


Figure 2. Map of Index Locations

Table 3. Information about Index Locations.

Index Location	System	River Mile (RM)	Bank	Source	Comprehensive Study ID	Top of Levee Elevation[a]
RA01	Feather River	42.24	Left	Corps	SAC23	89.39
RA02	Yuba River	7.00	Right	Corps	SAC18	90.58
RA03	Feather River	29.00	Right	Corps	SAC25	83.23
RA04	Sutter Bypass	88.79	Right	Corps	SAC32	59.15
RA05	Sacramento River	119.75	Right	Corps	SAC29	54.5
RA06	Bear River	1.75	Right	Corps	SAC28	56.33
RA07	Feather River	9.00	Right	Corps-DWR	SAC24	56.55
RA08	Sacramento River	90.00	Right	Corps-DWR	SAC13	40.65
RA09	Sacramento River	86.50	Left	Corps	SAC34	41.13
RA10	Sacramento River	79.21	Left	DWR		41.79
RA11	Sacramento River	76.25	Left	Corps	SAC36	40.91
RA12	Yolo Bypass	48.84	Right	Corps	SAC16	34.45
RA13	Sacramento River	63.82	Right	DWR		35.66
RA14	American River	11.00	Left	Corps	SAC40	58.38
RA15	American River	3.75	Right	Corps	SAC37	44.49
RA16	Sacramento River	59.75	Right	Corps-DWR	SAC38	36.25
RA17	Sacramento River	46.50	Right	Corps-DWR	SAC41	29.64
RA18	Sacramento River	36.50	Left	Corps	SAC47	23.09
RA19	Sutter Slough	25.23	Right	Corps	SAC42	21.45
RA20	Georgiana Slough	12.36	Left	Corps	SAC	19.31
RA21	Miner Slough	19.11	Right	Corps	SAC56	18.20
RA22	Sacramento River	14.75	Right	Corps	SAC50	22.04

[a] Top of levee elevation was obtained from the HEC-RAS model provided by CESPK, and the data in the model was obtained from the USACE National Levee Database. The data from this source is based on field survey using Real Time Kinematic (RTK) GPS equipment, which can have an accuracy of ±0.1 feet.

The information described above was also utilized for the deterministic analysis process presented later in this report (see Section 3.2).

3.1.2 Identify Analysis Criteria

The risk analysis approach is based on the guidance in EM 1110-2-1619 (USACE, 1996) and the policies established in ER 1105-2-101 (USACE, 2006a).

The analysis considered the potential for levee failure when levees were overtopped for a specific depth and duration. Maintenance of authorized hydraulic capacity of existing levees is consistent with Section 408 review of proposed SRFCP modifications. The specific criteria for levee failure utilized in the analysis are discussed in Section 3.1.6 of this report.

The potential impacts defined from the proposed risk analysis process are strictly related to the changes in the AEP and assurance (CNP). The significance of the identified potential impacts is not assessed.

The policy developed by USACE and approved by FEMA (USACE, 1996) for levee certification requires that it must have at least a 90 percent assurance (CNP) of providing protection from overtopping by the 0.01 exceedance probability flood (base flood). This minimum assurance (CNP) is required for all reaches of the levee system. If the levee elevation is less than three feet above the expected (fifty percent) base flood stage, then the levee can only be certified if the assurance (CNP) is 95 percent or greater. At each index location, the 90 percent assurance (CNP) was estimated from the HEC-FDA results.

The information presented above was not utilized for the deterministic analysis process. Potential impacts were defined as increases in water surface elevations for the deterministic analysis process.

3.1.3 Data Collection

Relevant data and information collected and reviewed include:

- **Hydrologic Data.** The hydrology utilized for this study was provided by CESPK in various HEC-DSS files. It is understood that the source of the hydrology data is the Comprehensive Study (CESPK, 2002) and the hydrographs reflect the Sacramento River Mainstem at Latitude of Sacramento Centering.

- **Hydraulic Data**. The HEC-RAS model (*SacBasin.prj* with a date of 8 August 2008) for the baseline condition was also provided by CESPK at the beginning of the study.

- **EIPs**. An HEC-RAS model for the Bear River and Feather River EIPs were provided by CESPK. A complete model was provided for the Bear River EIP, while only a geometry file (*Feather_setback.g04*) was provided for the Feather River EIP.

- **Area Maps and Visual Information.** Microstation® and ArcView® files prepared for the Comprehensive Study (CESPK, 2002) were provided by CESPK. Information in these files was used to develop various figures in this report.

- **Study Reports.** The following reports were collected and reviewed:
    a. "*Comprehensive Study of the Sacramento and San Joaquin River Basins*" (CESPK, 2002).
    b. "*Draft Supplemental Report for the Design Water Surface Profile for the Natomas Levee Improvement Program*" (MBK Engineers, 2008)
    c. "*Draft Interim Risk and Uncertainty Procedure, Evaluating Potential Hydraulic Impacts Associated with the State of California's Early Implementation Projects that Modify State-Federal Project Levees in Central Valley*" (DWR & CVFCB, 2008)

The information presented above was also necessary for the deterministic analysis process (see Section 3.2).

3.1.4 Hydrology

The hydrology utilized for this study was provided by CESPK. It is based on the Sacramento and San Joaquin River Basins Comprehensive Study (CESPK, 2002). The study evaluated the distribution of flow within the system using nineteen historic storm events. The defined flow distribution and frequency at various locations was referred to as storm centering. The flow distribution associated with the Sacramento River Mainstem at Latitude Sacramento Centering was adopted. This single centering is localized near the downstream end of the watershed, and the discharge-frequency relationship for this centering is relative only to the selected centering. Other locations within the watershed would have a completely different discharge-frequency relationship. Unregulated frequency curves for various durations (3-, 5-, 7- 10-, 15-, and 30-days) were developed at various target locations from a daily flow time series derived from gage data and daily change in storage from upstream reservoirs. The values on these frequency curves represent the average flow anticipated over a specific time interval. The curves were used to determine the total flood volumes for durations of 5-, 10-, 15-, 20-, 25-, and 30-days. Six incremental five-day volumes determined from the various durations were arranged to create synthetic flood hydrographs for seven flood frequencies. An HEC-5 (Hydrologic Engineering Center's Simulation of Flood Control and Conservation Systems) reservoir operation analysis was conducted to translate the unregulated flood inflow hydrographs into regulated hydrographs below the reservoirs. These locations are "handoff locations" to the system hydraulic model. The various handoff locations are shown in Figure 3.

It should be noted that two of the locations (upstream end of Sacramento River and Sutter Bypass) are based on the results from the UNET (HEC, 2001) model developed as part the Comprehensive Study (CESPK, 2002). The inflow at these two locations is based on upstream levee overtopping without levee failure. Also, the hydrology for the American River is based on conditions without the modifications associated with the Folsom Dam Joint Federal Project. Finally, the hydrology utilized for the current study is considered to be conservative since the river routings utilized for defining the unregulated and regulated frequency relationships are based on indefinitely large channels with no loss or attenuation of flows in the overbank areas.

The hydrographs defined in the hydraulic model were provided in various HEC-DSS files. The peak discharge for various flood events are summarized in Table 4.

DWR has commissioned CESPK to update estimates of the flow frequency throughout the Sacramento River basin. The study will have results that are similar to the Comprehensive Study (CESPK, 2002) results, and uncertainty about the regulated flow frequency curves will not be identified.

The information presented above was also necessary for the deterministic analysis process (see Section 3.2).

3.1.5 Baseline Hydraulic Model

The work for this study was based on an unsteady flow HEC-RAS model developed by SPK as part of their work for the American River Common Features GRR study. The HEC-RAS model was developed from the UNET model prepared as part of the Comprehensive Study of the

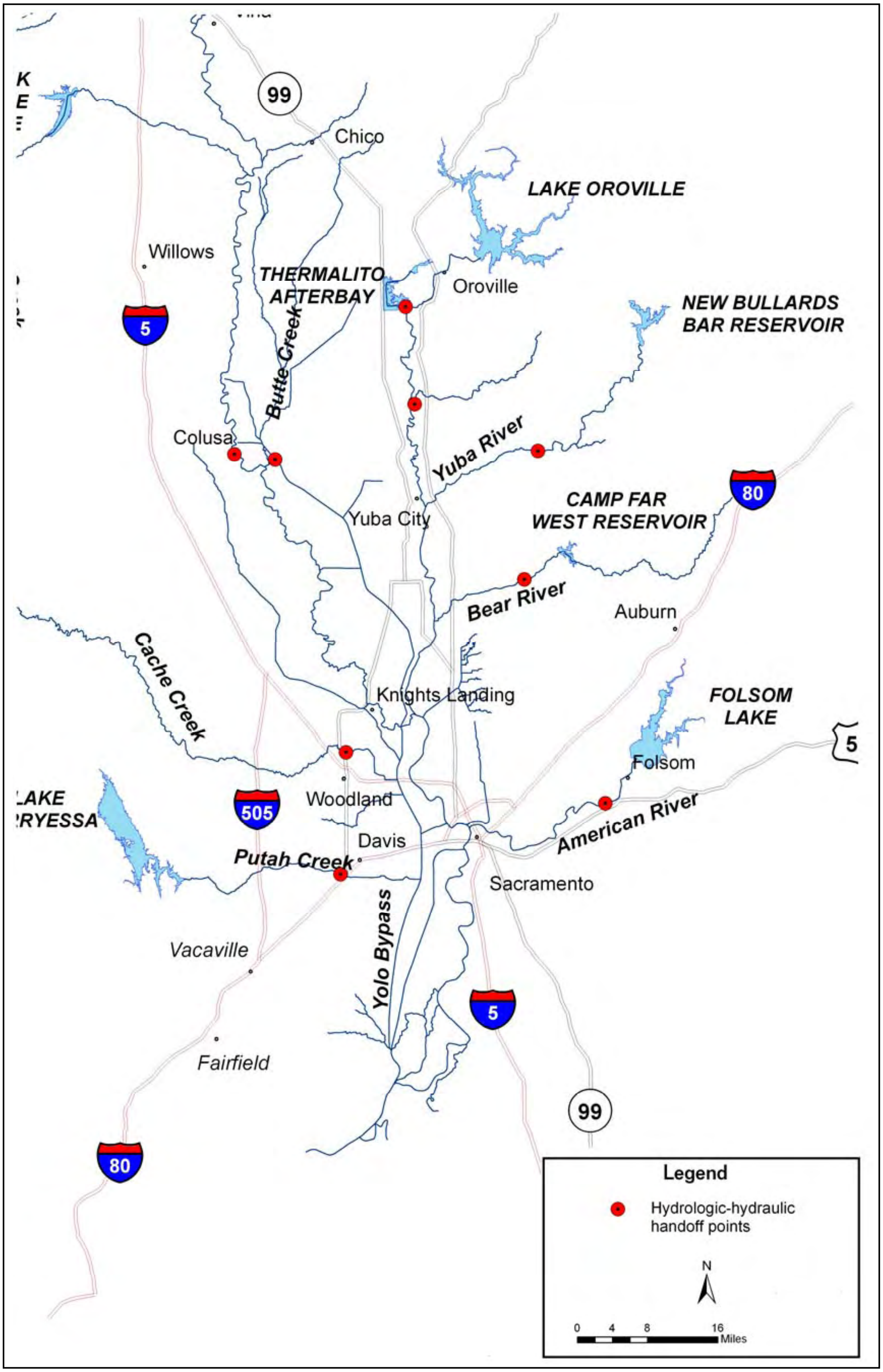


Figure 3. Map of Handoff Locations

Table 4. Peak Discharges used in Hydraulic Model.

River	Reach	River Station (Miles)	Model Type	Peak Discharge, cfs: 0.50 Exceedance Probability Flood	0.10 Exceedance Probability Flood	0.04 Exceedance Probability Flood	0.02 Exceedance Probability Flood	0.01 Exceedance Probability Flood	0.005 Exceedance Probability Flood	0.002 Exceedance Probability Flood
American River	Reach 1	22.0000	Unsteady	23,069	27,866	72,175	72,175	117,894	422,728	643,924
Bear River	Upper	12.5000	Unsteady	26,290	26,290	35,828	43,049	49,201	54,664	61,972
Best Slough	main	1.2500	Unsteady	822	822	822	822	822	822	822
Cache Creek	Main	8.2723	Unsteady	11,501	25,181	31,734	36,296	43,249	49,796	59,026
Cache Slough	RM24.0 to US	25.1548	Steady	100	100	100	100	100	100	100
Dry Creek	Main	7.5900	Unsteady	13,455	13,455	13,455	13,455	13,455	13,455	13,455
Feather River	Upper	71.4500	Unsteady	60,000	100,000	150,000	150,000	150,000	150,000	292,115
Haas Slough	Reach 1	2.8300	Steady	100	100	100	100	100	100	100
Jack Slough	main	7.5000	Unsteady	6,776	6,776	6,776	6,776	6,776	6,776	6,776
KLRC	Reach 1	6.2500	Steady	100	100	100	100	100	100	100
Lindsey Slough	Reach 1	25.4763	Steady	100	100	100	100	100	100	100
NEMDC	Reach 1	15.0520	Steady	100	100	100	100	100	100	100
NEMDC	Reach 1	3.4100	Unsteady	1,474	1,474	2,889	3,654	4,209	4,789	5,322
Putah Creek	Upper Reach	8.3370	Unsteady	100	2,932	6,015	7,803	10,418	13,994	18,730
Sac Bypass	Reach 1	1.6800	Steady	100	100	100	100	100	100	100
Sacramento DWS	Reach 1	43.7460	Steady	100	100	100	100	100	100	100
Sacramento River	Colusa-Feather	143.2400	Unsteady	43,759	48,205	49,949	52,702	55,472	59,337	67,920
Sutter Bypass	ButteSI-Wads	94.4500	Unsteady	57,522	102,216	126,369	155,273	184,494	228,632	327,399
Tisdale Bypass	Tisdale	4.3600	Steady	100	100	100	100	100	100	100
Wadsworth Canal	Wadsworth	4.2900	Steady	1,500	1,500	1,500	1,500	1,500	1,500	1,500
Willow Slough	Reach 1	8.1500	Steady	1,000	1,000	1,000	1,000	1,000	1,000	1,000
Yolo Bypass	Reach 59	57.1500	Steady	1,000	1,000	1,000	1,000	1,000	1,000	1,000
Yuba OB	Patrol	2.2600	Steady	100	100	100	100	100	100	100
Yuba OB	upper	4.8700	Steady	500	500	500	500	500	500	500
Yuba OB	low spill	1.4300	Steady	1,000	1,000	1,000	1,000	1,000	1,000	1,000
Yuba R	upper	13.8400	Unsteady	20,000	60,442	91,653	117,659	123,623	170,398	244,238
Lateral Inflows										
NEMDC	Reach 1	6.8740	Steady	1,000	1,000	1,000	1,000	1,000	1,000	1,000
NEMDC	Reach 1	6.4250	Unsteady	2,721	2,721	5,819	7,831	9,129	10,465	11,707
NEMDC	Reach 1	4.9530	Steady	617	617	617	617	617	617	617
NEMDC	Reach 1	3.4100	Unsteady	1,474	1,474	2,889	3,654	4,209	4,789	5,322
Yuba OB	low	0.7400	Steady	-1,600	-1,600	-1,600	-1,600	-1,600	-1,600	-1,600
Yuba R	upper	13.5900	Unsteady	5,991	12,476	16,464	19,578	22,104	24,439	27,382
Yuba R	upper	13.3400	Unsteady	2,684	5,908	7,799	9,276	10,414	11,449	12,897
Storage Area Inflows										
Yankee Creek	Yankee	--	Unsteady	2,792	2,792	2,792	2,792	2,792	2,792	2,792
Reeds Creek	Reeds Cr	--	Unsteady	7,347	7,347	7,347	7,347	7,347	7,347	7,347
Natomas Cross Canal	Cross Canal	--	Unsteady	7,375	7,375	15,969	21,590	25,091	32,143	7,375
Honcut Creek	Robinson	--	Unsteady	13,587	13,587	20,696	25,444	31,250	46,499	13,587

Note: The hydrology for the American River considered for this study is based on the conditions without the modifications associated with the Folsom Dam Joint Federal Project.

Sacramento and San Joaquin River Basins (CESPK, 2002). The model consists of plans for seven flood frequency events ranging from the 0.50 to 0.002 exceedance probability floods. The model covers the lower reach of the Sacramento River, from Colusa at the upstream end to the upper portion of the Sacramento-San Joaquin Delta at the downstream end. The study area also includes major tributaries (Feather, Bear, Yuba, and American Rivers), several of the smaller tributaries (Putah and Cache), and various interconnecting waterways. The model boundaries are shown in Figure 4. The upstream boundaries consist of an unsteady flow hydrograph; the internal boundaries consist of either a steady or unsteady flow hydrograph or gate control structure, and the downstream boundaries consist of an unsteady stage hydrograph. The peak discharges for the inflow hydrographs are summarized in Table 4. The downstream boundaries are based on the stage hydrograph measured during the 1997 flood event and adjusted using the results of frequency analysis on the tidal data located near each of the boundary locations.

The model is highly complex and includes about seventy reaches, 3,500 cross sections, 135 storage areas, 415 lateral structures, 180 storage connection features, and seventy bridge structures. The Manning's n-values for the main channel range from 0.035 to 0.06 and 0.035 to 0.30 for the overbank areas. The weir coefficients of the lateral weir structures range from 1.4 to 3.0. There is also one diversion structure with forty-eight gates that is located on the right bank of the Sacramento River about 2,700 feet upstream of the Highway 80 Bridge. This information was also necessary for the deterministic analysis process (see Section 3.2).

3.1.6 Levee Failures

Levee overtopping and failures can significantly influence the water surface elevations and discharges within the SRFCP. To evaluate these influences, expected locations of levee overtopping and failure were evaluated.

Levees are simulated in the model using lateral structures. Since many of the levees are overtopped by large floods, the levee breach tool available in HEC-RAS was used to determine when a levee would breach. A parametric definition of the breach size and time of formation is required for this tool. In a model that contains levee breaches like the SRFCP model does, this can be perhaps the most uncertain of all of the model parameters. Relatively little is known about the mechanics of breach formation in a levee. Furthermore, the structural adequacy of the levees is not fully known. Some levees may breach prior to overtopping, while some may be able to withstand a certain amount of erosive force before failure is initiated.

For the purpose of this demonstration, a single set of breach parameters and breach dimensions were used for each breach location in defining the median discharge-exceedance probability and stage-discharge relationships for the risk analysis. The failure criterion was set to an overtopping of one foot for a duration of three hours. Anytime that criterion was met, a 300 foot wide breach with 1Horizontal (1H) to 1Vertical (1V) side slopes was formed at the lowest spot over a duration of 3.3 hours. Based on this criterion for the baseline hydraulic model: one breach formed for the 0.01 exceedance probability flood; sixteen breaches formed for the 0.005 exceedance probability flood; and, thirty breaches formed for the 0.002 exceedance probability flood.

A sensitivity analysis of the levee breach parameters was conducted to define the uncertainties in the relationships required for the risk analysis. For the purpose of this demonstration, the lower

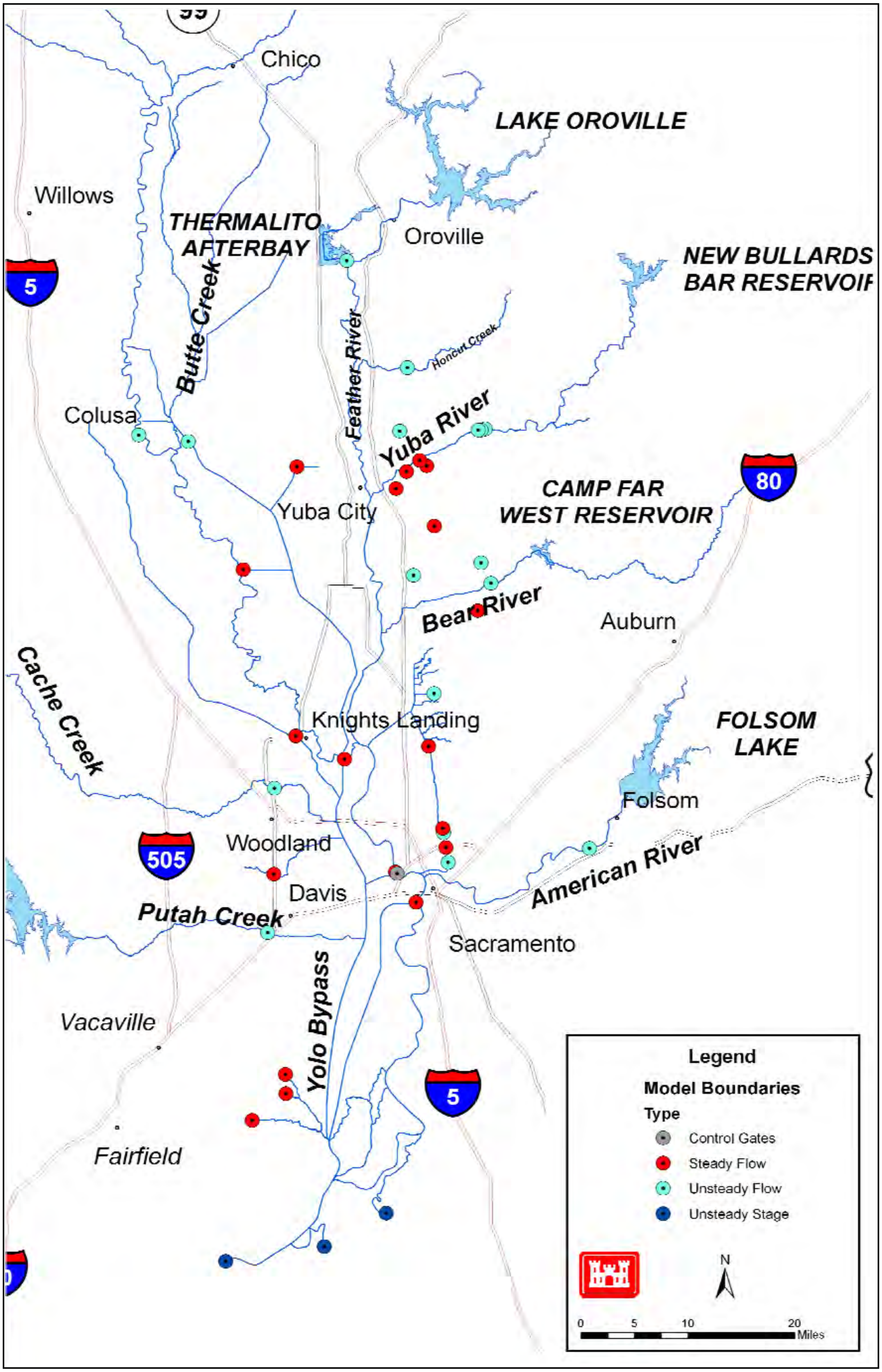


Figure 4. HEC-RAS Model Boundaries

bound of the breach dimensions was set to be 100 feet and assumed to develop over a duration of 1.1 hours. The upper bound was set to be 500 feet and assumed to develop over a duration of 5.5 hours.

The results of a hydraulic model with no levee failures were evaluated to determine the number of potential levee failure locations for a range of overtopping depths and durations. The results of the evaluation are summarized in Table 5. In general, the number of potential levee failure locations was found to be more influenced by the overtopping depth than the duration. Therefore, to allow more levee breaches, the lower bound of the failure criterion was selected to be an overtopping depth of 0.5 feet for a duration of three hours, and the upper bound was selected to be an overtopping depth of 1.5 feet for a duration of three hours. The sensitivity analysis of the levee breach parameters resulted in no changes to the standard deviation of the flow and stage for events greater than the 0.01 exceedance probability and larger standard deviation of the flow and stage for events less than the 0.01 exceedance probability.

Table 5. Total Number of Potential Levee Breaches for Various Overtopping Depths and Durations.

Overtopping Depth (ft)	0.01 Exceedance Probability					0.005 Exceedance Probability					0.002 Exceedance Probability				
	Duration (hrs)					Duration (hrs)					Duration (hrs)				
	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
0.0	11	11	11	10	10	36	36	35	35	34	73	73	73	73	73
0.5	5	5	5	5	4	28	27	26	24	23	63	63	62	62	62
1.0	2	2	2	2	2	18	18	18	17	15	47	47	47	47	44
1.5	0	0	0	0	0	12	10	10	9	7	29	29	29	29	29
2.0	0	0	0	0	0	6	6	5	5	3	23	23	23	23	23

Note: The above values are based on an evaluation of HEC-RAS model results assuming no levee failures, only depth and duration of overtopping.

As a result of involved levee enhancements, all of the EIP scenarios will influence the number of potential levee breaches. However, the Natomas EIP and the combination of the Bear River-Feather River No. 1-Feather River No. 2 (Star Bend)-Natomas EIP are the only two conditions that resulted in additional levee breaches to occur. This information was also utilized for the deterministic analysis process (see Section 3.2).

The hydraulic routing of inflows into the system to locations down system, including flows spilling over levees or flows leaving through levee breaches is captured in HEC-FDA using the inflow-outflow transformation relationship. The uncertainties are determined via sensitivity analysis as described above and represented in HEC-FDA as maximum and minimum outflows about the expected or median outflow. The inflow-outflow transformation relationship is an important representation of how flows move from up-system to down-system, how flows leave the leveed system into inundation areas and how modifications to the system can affect the flows delivered to any given index location. Inflow-outflow transformation is discussed later in Section 3.1.9.

3.1.7 Calibration/Verification of Baseline Hydraulic Model

The typical approach for hydraulic model development is to consider all uncertainty parameters and adjust those parameters to meet calibration objectives for measured flow and stage data within the system. Although the parameters theoretically change for varying flow conditions, they are typically held constant once calibration has been completed. Ideally, verification of the calibrated model is then completed for another set of measured data.

It is extremely important that the baseline hydraulic model be calibrated to available and reliable measured data (high water marks and/or gage), prior to introducing proposed conditions. High water marks are generally used for calibration of maximum stages whereas gage data can be used to calibrate the full range of stages during a recorded flood event. Typically, roughness values (Manning's n values) are adjusted for reach-wide calibration to stage; discharge coefficients, ineffective flow area definitions, and boundary conditions are adjusted for more localized calibration. Whenever possible, models should be calibrated to stage data as opposed to flow data because of the uncertainties associated with flow determination.

For this study, it was assumed that the hydraulic model provided by CESPK was appropriately calibrated and verified. This information was also necessary for the deterministic analysis process (see Section 3.2).

3.1.8 Development of Hydraulic Models for Proposed Conditions

HEC-RAS models were developed for each of the seven scenarios related to the EIPs:

1. Bear River EIP
2. Feather River No. 1 EIP
3. Combined Bear River and Feather River No.1 EIPs
4. Feather River No. 2 (Star Bend) EIP
5. Combined Bear River, Feather River No. 1, and Feather River No. 2 EIPs
6. Natomas EIP
7. Combination of all the EIPs.

The models were developed using the baseline condition model and the models of the EIP provided by CESPK. No revisions were made to the flow data defined for the baseline model. The models were generally developed in a four step process. First, a new model was developed from the original baseline model. Second, a new geometry file was defined by making a copy of the original baseline geometry file. Third, the geometry features associated with the EIP were incorporated into the new geometry file. Finally, the plans for the various flood events were revised to utilize the new geometry file reflecting the proposed EIP. For the combined Bear and Feather River EIPs, the above steps were completed starting with the Bear River EIP model in lieu of the baseline model. This information was also necessary for the deterministic analysis process (see Section 3.2).

3.1.9 Evaluation of Proposed Hydraulic Conditions for Risk Analysis

All of the models were run using HEC-RAS (HEC, 2008). The model results at the index locations were copied into an Excel® spreadsheet for each model scenario. The results were then utilized to develop the various relationships required as input for the HEC-FDA program, which include: (1) discharge versus exceedance probability relationship at the index locations, (2) stage versus discharge relationship at the index locations, (3) inflow versus outflow relationship, (4) levee information, and (5) economic data.

To construct the inflow-outflow transform relationship, two discharge-exceedance probability relationships are considered at each index location. The first relationship is related to the hydrology at the handoff locations. It is referred to as the inflow discharge in the remainder of this report. The inflow discharge-exceedance probability relationship was developed based on the maximum value of the summation of the individual hydrographs that contribute flow to the index location for different flood events. The general procedure is reflected in Figure 5. The relationship was defined using data with an exceedance probability between 0.50 and 0.002. The inflow discharge for the exceedance probabilities of 0.999 and 0.001 were extrapolated from the defined relationship. The HEC-FDA program requires that discharges increase with decreasing

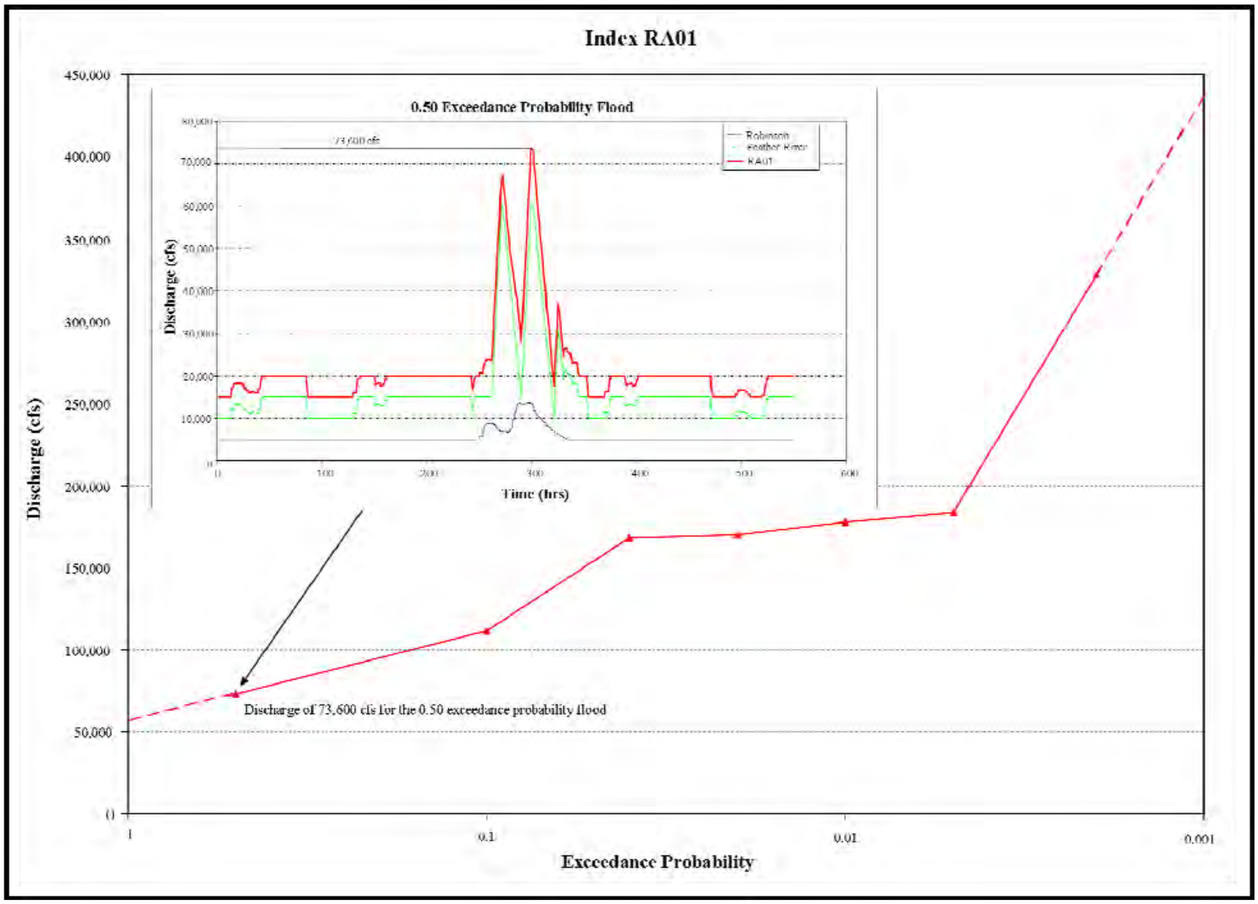


Figure 5. Graphical Representation for the Determination of the Inflow Discharge-Exceedance Probability Relationship

exceedance probabilities. This was not the case for three index locations. Index locations RA01 and RA03 required minor adjustments to the discharge for the 0.05 exceedance probability flood, and Index Location RA06 required minor adjustment to the 0.5 exceedance probability flood. A summary of the adjustments made to this relationship is provided in Table 6.

The second relationship is related to the routing of the inflow throughout the system, and it is the outflow (routed) discharge delivered to a point of interest accounting for the flows leaving the

Table 6. Summary of Adjustments Made to the Relationships Input into HEC-FDA.

Index Location	Inflow Discharge Relationship		Outflow (Routed) Discharge Relationship		Stage-Outflow Discharge Relationship	
	Adjusted	Comment	Adjusted	Comment	Adjusted	Comment
RA01	Yes	Adjustments only to the 0.05 exceedance probability event	Yes	First approach (horizontal with slight increase in flow)	Yes	Interpolation for the 0.02 exceedance probability flood
RA02	No	-	No	-	No	-
RA03	Yes	Adjustments only to the 0.05 exceedance probability event	Yes	Second approach (interpolation)	No	-
RA04	No	-	No	-	No	-
RA05	No	-	No	-	No	Relationship was extended to be above the top of levee
RA06	Yes	Adjustments only to the 0.50 exceedance probability event	Yes	First approach (horizontal with slight increase in flow)	No	-
RA07	No	-	No	-	No	Relationship was extended to be above the top of levee
RA08	No	-	Yes	First approach (horizontal with slight increase in flow)	No	-
RA09	No	-	Yes	First approach (horizontal with slight increase in flow)	No	Relationship was extended to be above the top of levee
RA10	No	-	No	-	No	Relationship was extended to be above the top of levee
RA11	No	-	No	-	No	Relationship was extended to be above the top of levee
RA12	No	-	No	-	No	Relationship was extended to be above the top of levee
RA13	No	-	Yes	Second approach (interpolation)	Yes	Interpolation for the 0.10 exceedance probability flood
RA14	No	-	No	-	No	-
RA15	No	-	Yes	First approach (horizontal with slight increase in flow)	No	Relationship was extended to be above the top of levee
RA16	No	-	No	-	No	-
RA17	No	-	Yes	First approach (horizontal with slight increase in flow)	No	Relationship was extended to be above the top of levee
RA18	No	-	Yes	First approach (horizontal with slight increase in flow)	No	-
RA19	No	-	Yes	First approach (horizontal with slight increase in flow)	No	Relationship was extended to be above the top of levee
RA20	No	-	Yes	First approach (horizontal with slight increase in flow)	Yes	Interpolation for the 0.005 exceedance probability flood/Relationship was extended to be above the top of levee
RA21	No	-	Yes	First approach (horizontal with slight increase in flow)	Yes	Interpolation for the0.005 exceedance probability flood
RA22	No	-	Yes	First approach (horizontal with slight increase in flow)	Yes	Interpolation for the 0.005 exceedance probability flood

leveed system due to overtopping and/or as breaches occur. This outflow was determined directly from the HEC-RAS results. As with the previous relationship, outflow discharges must increase with decreasing exceedance probabilities. Two approaches for adjusting the outflow discharge-exceedance relationship were utilized. The first and most common approach involved using a discharge slightly greater than the discharge for the next larger exceedance probability flood or on occasion a discharge slightly less than the discharge for the next smaller exceedance probability flood. An example adjustment is illustrated in Figure 6.

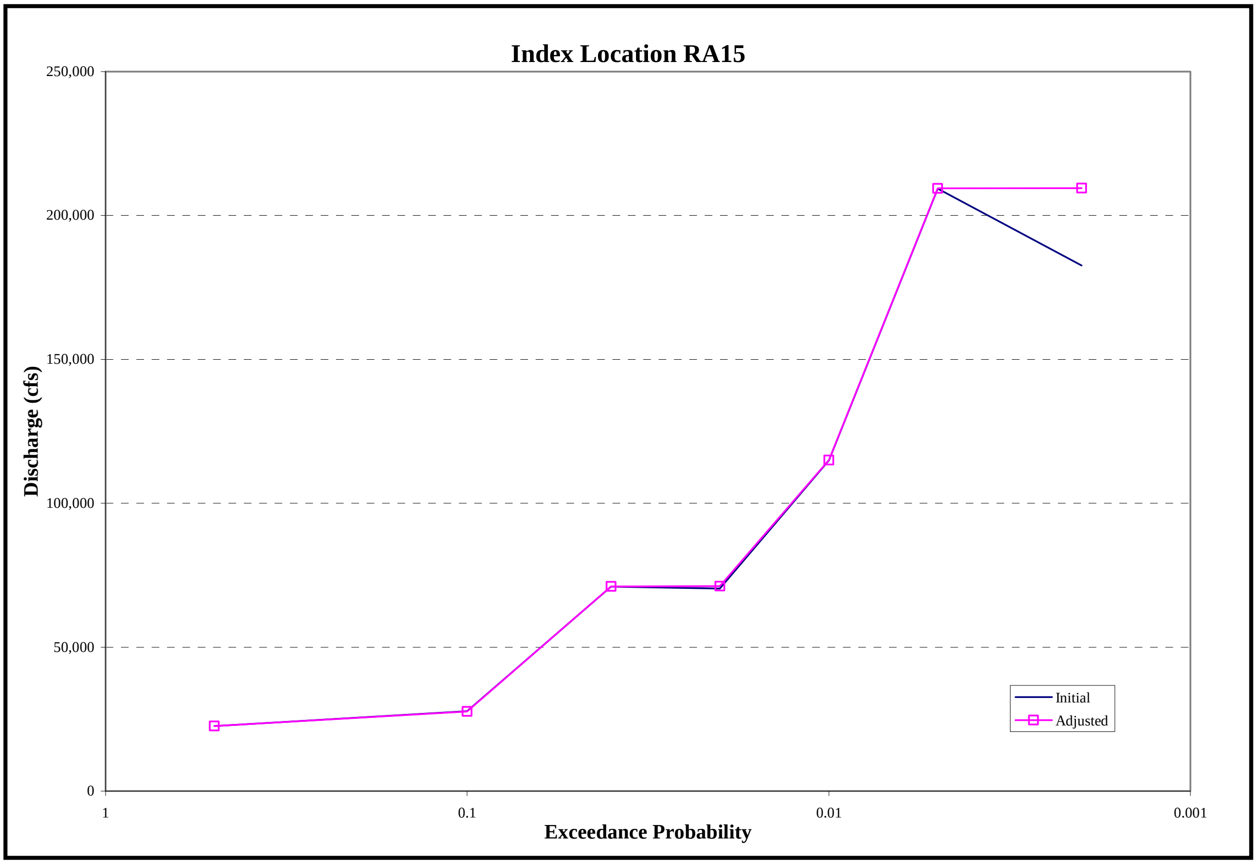


Figure 6. Example of Adjustments Made to the Outflow (routed) Discharge-Exceedance Probability Relationship

The second approach involved interpolation using the bounding exceedance probability floods (for example, the discharge for the 0.005 exceedance probability was interpolated using the discharges for the 0.01 and 0.002 exceedance probabilities). Similar to the inflow discharge relationship, the outflow discharges for the exceedance probabilities of 0.999 and 0.001 were extrapolated from the defined relationship. A summary of the adjustments made to this relationship is also provided in Table 6.

Together, the combined inflows at the handoff locations and the routed outflows are paired by frequency into an inflow-outflow transform relationship as mentioned earlier in this section. The inflow-outflow relationship was also extended by linear extrapolation to include the maximum inflow discharge that could be sampled from the inflow discharge versus exceedance probability relationship (i.e., upper bound of the relationship, which was obtained from the HEC-FDA program).

The stage-outflow discharge relationship at each index location was determined directly from the HEC-RAS results. The outflow discharge is associated with the maximum stage from the hydraulic simulation. HEC-FDA requires that this relationship increase with decreasing exceedance probabilities and that the relationship extend above the top of levee elevation. When the first criterion was not met, the stage-outflow discharge relationship was adjusted by interpolation using results from the bounding floods. As a result of upstream levee failures, it was found there were several locations where the slope of the stage-outflow discharge relationship leveled off and the water surface elevation for the 0.002 exceedance probability flood is below the top of levee. For this situation, the stage-outflow discharge was extrapolated out to the 0.001 exceedance probability flood and then increased to be two feet above the top of levee. Two feet is arbitrary but allows for testing for the extreme flows against top of levee including uncertainty in flow and stage. This situation is demonstrated in Figure 7, which shows an example of the revisions with the x-axis being exceedance probability in lieu of discharge that is associated with the exceedance probability. A summary of these adjustments is provided in Table 6.

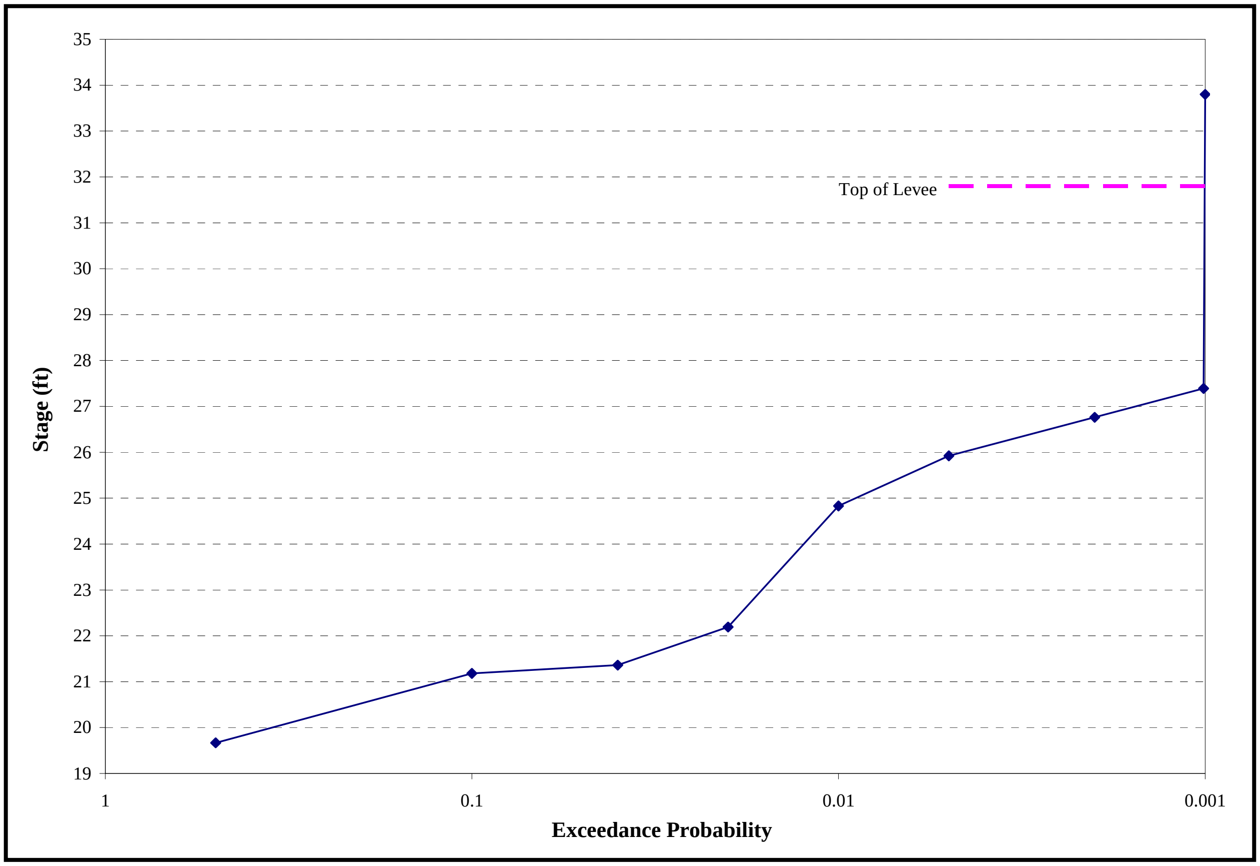


Figure 7. Example of Adjustments Made to the Stage-Exceedance Probability Relationship

For future studies, an alternate method for generating the stage-outflow discharge relationship, one that is more appropriate and one that does not require adjustments as cited above, is to route each set of hydrographs (for each frequency) down the system assuming infinitely high levees. This alternate method produces a "true" rating function and allows for flows leaving the channels to be accounted for in the inflow-outflow transform function and not in the rating function (see Step 9.1e in Appendix A).

The stage for all of the index locations not tidally influenced was defined as the thalweg elevation for the discharge of zero, while the stage for all tidally influenced locations was defined using the 0.999 chance exceedance water level for the tide gage most appropriate for the index location. The 0.999 chance exceedance water level was estimated to be 4.26 feet for the Threemile Slough gage, 4.38 feet for the Georgiana Slough, and 4.14 feet for the Sacramento at Collinsville gage.

The target stage utilized in the risk analysis is based on the top of levee elevation, which is provided in Table 3. Top of levee elevation was obtained from the baseline HEC-RAS model, and it is based on the data available from the USACE National Levee Database, which was obtained from field survey using Real Time Kinematic (RTK) GPS equipment that can have accuracy of ±0.1 feet. If desired, the analysis can be completed using another target stage, such as the authorized project design level.

HEC-FDA also requires that economic data (stage-damage) be defined, even if the user is only interested in evaluating the project performance. To accommodate this input requirement, an artificial set of data was defined and utilized for this study (see Section 3.1 for additional discussion and Appendix D, Section D.1 for sensitivity on this input). The stage-damage relationship was developed by assuming that the relationship increases linearly at a slope of $100,000 of damage per a stage increase of one to two feet. All of the required input was manually entered into HEC-FDA program.

The information presented above was not required for the deterministic analysis process (see Section 3.2). The information needed for the deterministic process involved only the top of levee elevation and calculated water surface elevations at the various index locations.

3.1.10 Evaluation of Proposed Hydraulic Conditions for Risk Analysis

There are generally three types of uncertainty that need to be considered in conducting the risk analysis process. Due to limitations of the data and available tools, assumptions were required in estimating the uncertainties. The assumptions are summarized in Table 1 (see Chapter 1). It is noted that some of the involved assumptions are not supported with research or technical references and are based on professional judgment. It is also recognized that as noted in Table 1 (see Chapter 1); some of the assumptions are utilized in both the risk and deterministic analysis procedures.

Hydrologic and Reservoir Uncertainty (above Handoff Locations)

The first type of uncertainty is related to the hydrology. The uncertainty in the inflow discharge-exceedance probability relationship at the handoff locations includes the uncertainties in the determination of the unregulated and regulated discharges. It was assumed for the present study that the inflow discharge-exceedance probability relationship for the unregulated conditions at these locations represents the median relationship and the uncertainty in the relationship can be estimated using the direct analytical approach documented in Bulletin 17B (USGS, 1982) and in EM 1110-2-1415 (USACE, 1993). The uncertainty in the regulated discharges includes the uncertainty in the reservoir releases and the routing of discharges to the handoff locations. The uncertainty of regulated inflows could be derived from a sensitivity analysis of reservoir inflows and routings with variations to the outlet works and spillway ratings, outlet works operation, shape and volume of inflow hydrograph, assumed initial release conditions, and safety issues.

Since the required sensitivity analysis was not conducted for the Comprehensive Study (CESPK, 2002), or for the present study, the total uncertainty at the handoff locations was estimated using the following procedure that equates the EYR to the combined uncertainty of the unregulated and regulated flow conditions:

a. Determine the standard deviation and variance of the uncertainty for the unregulated discharge. The standard deviation of the uncertainty was estimated using the direct analytical approach documented in Bulletin 17B (USGS, 1982) and information (statistics and EYR) about the relationship documented in the Comprehensive Study (CESPK, 2002). The variance is determined as the square of the standard deviation.

b. Determine the standard deviation and variance of the uncertainty for the regulated discharge. The standard deviation was estimated assuming that that the 95% confidence boundaries are defined as ±10% of the median value. The variance is determined as the square of the standard deviation.

c. Determine the standard deviation of the combined uncertainty for the unregulated and regulated conditions. The combination of uncertainty is accomplished by taking the square root of the summation of the variances for the unregulated and regulated conditions.

d. Determine the EYR. The EYR is determined by using a trial-and-error procedure until the standard deviation calculated using the equations in Bulletin 17B (USGS, 1982) for an assumed EYR equals the standard deviation determined from the previous step.

The above procedure was completed for a variety of exceedance probability events, but the results for the 0.01 exceedance probability was used in the analysis since HEC-FDA requires a single EYR value. The EYR determined using the above procedure is provided in Table 7. The uncertainty in the inflow discharge-exceedance probability relationship for the local inflow locations was determined using information provided in the Comprehensive Study (CESPK, 2002) and the guidance provided in EM 1110-2-1619 (USACE, 1996). The EYR considered at these locations are also provided in Table 7.

The uncertainties from handoff and local inflow locations had to be transferred to each of the index locations. The transfer was accomplished by a discharge weighted average of the EYR for the various sources contributing to each index location site. The resulting EYR at each of the index locations is provided in Table 8.

Hydraulics Uncertainty

The second type of uncertainty is related to the hydraulics of the system. The hydraulic uncertainties related to the stage-outflow discharge relationship and the outflow discharges

Table 7. Equivalent Years of Record (EYR) at Handoff Locations.

Location	Type	Method	Number of Years	Equivalent Years of Record (EYR)
Upstream Sacramento	Regulated	Order statistics using FDA	76	68
Upstream Feather River	Regulated	Order statistics using FDA	96	89
Yuba River	Regulated	Order statistics using FDA	94	88
Bear River	Regulated	Order statistics using FDA	93	85
American River	Regulated	Order statistics using FDA	93	87
Putah Creek	Regulated	Order statistics using FDA	68	62
Cache Creek	Regulated	Order statistics using FDA	73	66
Local Inflow				
NEMDC at RS6.425	Unregulated	Order statistics using FDA	-	25
NEMDC at RS6.425	Unregulated	Order statistics using FDA	-	25
Sutter Bypass	Diversion	Order statistics using FDA	-	55
Yuba River at RS 13.59 (Deer Creek)	Regulated	Order statistics using FDA	62	56
Yuba River at RS 13.34 (Dry Creek)	Regulated	Order statistics using FDA	-	56
Tributaries to Cross Canal	Unregulated	Order statistics using FDA	-	25
Honcut Creek (Local inflow to SA Robinson)	Unregulated	Order statistics using FDA	-	48

within the system are defined by routing the inflow hydrographs. The uncertainty in both the stage and outflow (routed) discharge at the index locations was estimated from a sensitivity analysis.

Because of the large number of cross sections in the baseline hydraulic model, a twenty percent decrease and increase in the assigned Manning's n-value was used to bracket the realistic range and was applied globally to the entire model for the main channel only. A similar exercise was applied to the weir coefficients for both the inline structures and lateral structures in the model. The uncertainty in the downstream boundary of the hydraulic model was defined using the order statistics method and equivalent years of record for the data. With a high and low uncertainty band defined for n-values, weir coefficients, and downstream boundary conditions, eight separate sensitivity analysis plans were constructed in the HEC-RAS model:

1. high n-value, high weir coefficient, high downstream stage
2. high n-value, high weir coefficient, low downstream stage
3. high n-value, low weir coefficient, high downstream stage
4. high n-value, low weir coefficient, low downstream stage
5. low n-value, high weir coefficient, high downstream stage
6. low n-value, high weir coefficient, low downstream stage
7. low n-value, low weir coefficient, high downstream stage
8. low n-value, low weir coefficient, low downstream stage.

The HEC-RAS results for all the plans, at each of the index locations, were imported into an Excel® spreadsheet and the standard deviation of error in stage and flow was estimated from the minimum and maximum values obtained from the model. The resulting standard deviation of error in stage was used if it was greater than the minimum standard deviation of 0.7 feet selected from the information provided in EM 1110-2-1619 (USACE, 1996), otherwise the minimum

Table 8. Equivalent Years of Record (EYR) at the Index Locations.

Index Location	System	River Mile (RM)	Sources of Inflow	Equivalent Years of Record (EYR)
RA01	Feather River	42.24	Feather handoff and Honcut	84
RA02	Yuba River	7.00	Yuba handoff, Yuba (Dry), and Yuba (Deer)	81
RA03	Feather River	29.00	Feather handoff and Honcut	84
RA04	Sutter Bypass	88.79	Sutter Bypass (UNET)	55
RA05	Sacramento River	119.75	Sacramento handoff	68
RA06	Bear River	1.75	Bear River handoff	85
RA07	Feather River	9.00	Feather handoff, Honcut, Yuba handoff, Yuba (Dry), and Yuba (Deer)	83
RA08	Sacramento River	90.00	Sacramento handoff	68
RA09	Sacramento River	86.50	Sacramento handoff	68
RA10	Sacramento River	79.21	Feather handoff, Honcut, Yuba handoff, Yuba (Dry), and Yuba (Deer), Sutter Bypass (UNET), Sacramento handoff, and Cross Canal	71
RA11	Sacramento River	76.25	Feather handoff, Honcut, Yuba handoff, Yuba (Dry), and Yuba (Deer), Sutter Bypass (UNET), Sacramento handoff, and Cross Canal	71
RA12	Yolo Bypass	48.84	Sacramento handoff, KLRC, and Cache Creek handoff	72
RA13	Sacramento River	63.82	Feather handoff, Honcut, Yuba handoff, Yuba (Dry), and Yuba (Deer), Sutter Bypass (UNET), Sacramento handoff, and Cross Canal	71
RA14	American River	11.00	American handoff	87 (106)*
RA15	American River	3.75	American handoff	87 (106)*
RA16	Sacramento River	59.75	Feather handoff, Honcut, Yuba handoff, Yuba (Dry), and Yuba (Deer), Sutter Bypass (UNET), Sacramento handoff, Cross Canal American handoff, and NEMDC	73
RA17	Sacramento River	46.50	Same as RA16	73
RA18	Sacramento River	36.50	Same as RA16	73
RA19	Sutter Slough	25.23	Same as RA16	73
RA20	Georgiana Slough	12.36	Same as RA16	73
RA21	Miner Slough	19.11	Same as RA16	73
RA22	Sacramento River	14.75	Same as RA16	73

* The uncertainty calculated for the initial EYR was significantly greater than the uncertainty for the unregulated discharges. For all other index locations, the upper bound of the 0.002 exceedance probability discharge was 1.1 to 2.0 times the median value. At Index Location RA11, the upper bound of the 0.002 exceedance probability discharge was calculated to be fifteen times the median value. Therefore, the EYR was increased to provide a more reasonable upper and lower bound of the relationship.

recommended value was used. The minimum value was not considered for the stage associated with a zero discharge at the index locations that are tidally influenced. The uncertainty in the stage, defined from the measured water level for the 0.999 exceedance probability, was determined to be 0.05 feet for all three tide gages. The standard deviation of error in stage at each of the index locations is summarized in Table 9, while the standard deviation of error in the outflow (routed) discharge error is provided in Table 10.

Operational Uncertainty

The third type of uncertainty is related to the operational uncertainty of the levee system performance and potential flood fight activities. For this study, the levee system performance was directly evaluated based on the criteria described previously in this report (see Section

3.1.2). The uncertainty regarding flood fight activities was not considered due to the unpredictable nature of such occurrences and recognition that the intent of SRFCP is to provide the necessary level of protection without relying on this activity. None of the information was utilized in the deterministic analysis procedure (see Section 3.2).

Table 9. Standard Deviation of Error in Stage at the Index Locations (feet).

Index	0.50 Exceedance Probability Flood	0.10 Exceedance Probability Flood	0.04 Exceedance Probability Flood	0.02 Exceedance Probability Flood	0.01 Exceedance Probability Flood	0.005 Exceedance Probability Flood	0.002 Exceedance Probability Flood
RA01	0.7	0.7	0.7	0.7	0.8	0.8	0.8
RA02	0.7	0.7	0.7	0.7	0.8	0.8	0.8
RA03	0.8	0.8	0.8	0.8	0.8	1.0	1.0
RA04	0.7	0.8	0.9	1.1	1.1	1.1	1.1
RA05	0.9	0.9	1.0	1.1	1.1	1.2	1.2
RA06	0.7	0.7	0.7	0.7	0.8	0.8	0.8
RA07	0.7	0.7	0.7	0.8	0.9	0.9	0.9
RA08	0.7	0.7	0.7	0.7	0.8	0.8	0.8
RA09	0.7	0.7	0.7	0.7	0.8	0.8	0.8
RA10	0.7	0.7	0.7	0.7	0.8	0.8	0.8
RA11	0.7	0.7	0.7	0.7	0.8	0.8	0.8
RA12	0.7	0.8	0.9	0.9	0.9	0.9	0.9
RA13	0.7	0.7	0.7	0.7	0.8	0.8	0.8
RA14	0.8	0.8	1.1	1.1	1.2	1.2	1.2
RA15	0.7	0.7	0.7	0.7	0.8	0.8	0.8
RA16	0.7	0.7	0.7	0.7	0.8	0.8	0.8
RA17	0.7	0.7	0.7	0.7	0.8	0.8	0.8
RA18	0.7	0.7	0.7	0.7	0.8	0.8	0.8
RA19	0.7	0.7	0.7	0.7	0.8	0.8	0.8
RA20	0.7	0.7	0.7	0.7	0.8	0.8	0.8
RA21	0.7	0.7	0.7	0.7	0.8	0.8	0.8
RA22	0.7	0.7	0.7	0.7	0.8	1.1	1.1

3.1.11 Risk Analysis

The risk analysis was completed using HEC-FDA Version 1.2.4 (HEC, 2008). The model results of AEP and assurance (CNP) were manually entered into an Excel® spreadsheet. The return interval associated with the 90% assurance (CNP) of containment was estimated from the assurance (CNP) results by interpolation or extrapolation. None of the information presented above was utilized in the deterministic analysis procedure.

3.1.12 Identification of Potential Impacts

Tables 11 through 20 present summaries of risk analysis results at all of the index locations for each of the EIP scenarios. Tables 11 and 12 provide the median and expected AEP, respectively. The median AEP is computed directly from the inflow discharge-exceedance probability, inflow-

Table 10. Standard Deviation of Error in the Outflow (Routed) Discharge (cfs) at the Index Locations.

Index Location	0.50 Exceedance Probability Flood	0.10 Exceedance Probability Flood	0.04 Exceedance Probability Flood	0.02 Exceedance Probability Flood	0.01 Exceedance Probability Flood	0.005 Exceedance Probability Flood	0.002 Exceedance Probability Flood
RA01	50 (0.1 %)	110 (0.1 %)	700 (0.4 %)	800 (0.5 %)	880 (0.5 %)	990 (0.6 %)	9,900 (3.5 %)
RA02	25 (0.1 %)	70 (0.1 %)	105 (0.1 %)	130 (0.1 %)	290 (0.2 %)	6,150 (3.3 %)	7,740 (3.4 %)
RA03	50 (0.1 %)	180 (0.2 %)	1,260 (1.0 %)	1,300 (1.0 %)	1,500 (1.1 %)	3,920 (2.3 %)	16,100 (6.6 %)
RA04	10 (0.02 %)	40 (0.04 %)	80 (0.1 %)	90 (0.1 %)	1,180 (0.6 %)	1,200 (0.6 %)	6,950 (2.2 %)
RA05	50 (0.1 %)	50 (0.1 %)	90 (0.2 %)	100 (0.2 %)	330 (0.6 %)	640 (1.1 %)	3,590 (5.3 %)
RA06	310 (1.2 %)	370 (1.5 %)	670 (2.1 %)	780 (2.1 %)	2,190 (5.4 %)	3,110 (7.6 %)	4,300 (10.5 %)
RA07	60 (0.1 %)	1,570 (0.9 %)	4,440 (1.7 %)	4,500 (1.6 %)	5,500 (1.7 %)	6,720 (1.8 %)	31,900 (7.1 %)
RA08	100 (0.3 %)	880 (2.9 %)	950 (2.9 %)	1,320 (3.7 %)	2,910 (7.5 %)	6,600 (17.0 %)	7,240 (18.6 %)
RA09	100 (0.4 %)	820 (2.7 %)	890 (2.7 %)	1,610 (4.6 %)	3,250 (8.5 %)	4,790 (12.5 %)	4,850 (12.6 %)
RA10	1,090 (1.5 %)	9,310 (10.7 %)	12,800 (12.9 %)	13,200 (12.7 %)	14,200 (13.6 %)	14,300 (12.9 %)	16,300 (14.3 %)
RA11	1,070 (1.5 %)	9,310 (11.7 %)	12,800 (12.9 %)	13,200 (12.7 %)	14,200 (13.6 %)	14,300 (12.9 %)	16,300 (14.3 %)
RA12	1,370 (1.1 %)	7,510 (3.2 %)	8,600 (2.5 %)	8,900 (2.3 %)	21,700 (4.9 %)	36,100 (8.0 %)	59,000 (11.9 %)
RA13	1,050 (1.6 %)	9,310 (13.7 %)	12,800 (18.3 %)	13,100 (17.3 %)	14,100 (13.5 %)	14,200 (13.6 %)	16,200 (15.5 %)
RA14	20 (0.1 %)	30 (0.1 %)	70 (0.1 %)	70 (0.1 %)	120 (0.1 %)	18,900 (6.5 %)	20,600 (6.9 %)
RA15	20 (0.1 %)	130 (0.5 %)	320 (0.5 %)	350 (0.5 %)	550 (0.5 %)	20,000 (9.6 %)	23,700 (11.3 %)
RA16	500 (0.6 %)	7,890 (8.1 %)	8,050 (8.1 %)	8,145 (8.1 %)	9,460 (8.1 %)	12,200 (9.3 %)	13,900 (9.8 %)
RA17	500 (0.6 %)	7,845 (8.0 %)	7,850 (8.0 %)	8,000 (8.0 %)	9,410 (8.0 %)	12,600 (9.9 %)	14,200 (10.6 %)
RA18	500 (0.6 %)	7,990 (8.2 %)	7,995 (8.2 %)	8,150 (8.2 %)	9,590 (8.2 %)	12,700 (10.2 %)	14,800 (11.1 %)
RA19	140 (0.6 %)	2,800 (11.1 %)	2,810 (11.1 %)	2,880 (11.3 %)	3,360 (11.3 %)	3,700 (11.0 %)	5,390 (15.9 %)
RA20	90 (0.6 %)	1,000 (6.2 %)	1,120 (6.6 %)	1,200 (6.7 %)	1,700 (8.0 %)	2,130 (9.7 %)	3,340 (15.1 %)
RA21	600 (4.1 %)	625 (22.3 %)	645 (22.2 %)	755 (22.2 %)	1,380 (22.3 %)	1,930 (30.6 %)	2,240 (35.0 %)
RA22	190 (1.0 %)	2,350 (9.0 %)	2,560 (9.2 %)	2,960 (10.6 %)	4,370 (13.1 %)	5,950 (17.8 %)	7,190 (21.5 %)

Note: The value in the parentheses provided in the above table corresponds to percentage that the standard deviation is of the median value of the outflow discharge.

outflow, and stage-outflow discharge relationships defined at each of the index locations, whereas the expected AEP is obtained from annual exceedance probability curves with uncertainty included, which is calculated as part of the Monte Carlo simulation within HEC-FDA. Both AEP values are based on the top of levee elevation with no failure prior to overtopping. If necessary, the AEP can be estimated for any desired target stage, such as the

Table 11. Median AEP (based on Top of Levee) Results at the Index Locations.

Index Location	River	Reach	River Station	Baseline	Bear EIP	Feather EIP	Bear-Feather EIP	Star Bend (SB) EIP	Bear-Feather-SB EIP	Natomas EIP	Bear Feather-SB-Natomas EIP
RA01	Feather River	Honcut to Jack	42.24	0.0020	0.0020	0.0020	0.0020	0.0020	0.0020	0.0020	0.0020
RA02	Yuba River	Upper	7.00	0.0092	0.0092	0.0091	0.0091	0.0092	0.0091	0.0092	0.0091
RA03	Feather River	Jack Slough - Yuba River	29.00	0.0026	0.0026	0.0026	0.0026	0.0026	0.0026	0.0026	0.0026
RA04	Sutter Bypass	Butte Slough-Wads	88.60	0.0070	0.0070	0.0070	0.0070	0.0070	0.0070	0.0070	0.0070
RA05	Sacramento River	Colusa-Feather	119.75	0.0009	0.0009	0.0009	0.0009	0.0009	0.0009	0.0009	0.0009
RA06	Bear River	Lower	1.75	0.0032	0.0014	**0.0035**	0.0018	0.0032	0.0018	0.0032	0.0018
RA07	Feather River	Reach 35	9.00	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003
RA08	Sacramento River	Colusa-Feather	90.00	0.0153	**0.0154**	**0.0155**	**0.0156**	**0.0154**	**0.0157**	**0.0154**	**0.0158**
RA09	Sacramento River	Colusa-Feather	86.50	0.0040	**0.0041**	**0.0042**	**0.0044**	0.0040	**0.0044**	**0.0052**	**0.0054**
RA10	Sacramento River	NCC to NEMDC	79.21	0.0005	0.0005	**0.0006**	**0.0006**	0.0005	**0.0007**	0.0005	0.0003
RA11	Sacramento River	NCC to NEMDC	76.25	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0002	0.0003
RA12	Yolo Bypass	KRLC to Sac BP	48.84	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	**0.0004**	**0.0004**
RA13	Sacramento River	NCC to NEMDC	63.82	0.0003	**0.0004**	**0.0004**	0.0003	**0.0004**	0.0003	**0.0004**	**0.0004**
RA14	American River	Reach 1	11.00	0.0056	0.0056	0.0056	0.0056	0.0056	0.0056	0.0056	0.0056
RA15	American River	Reach 1	3.75	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003
RA16	Sacramento River	DS American	59.75	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
RA17	Sacramento River	DS American	46.50	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
RA18	Sacramento River	DS American	36.50	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
RA19	Sutter Slough	Lower Reach	25.23	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
RA20	Georgiana Slough	Reach	12.36	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
RA21	Miner Slough	Reach 1	19.11	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
RA22	Sacramento River	RM 14.6 to 26.5	14.75	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001

Notes: (1) The median AEP is computed directly from the inflow discharge-exceedance probability, inflow-outflow, and stage-outflow discharge relationships defined at each of the index locations, and it does not account for the uncertainties in stage and discharge. (2) The median AEP values in the above tables are relative on the top of levee elevation with overtopping flow being the only main mechanism for levee failure. If necessary, the AEP can be estimated for any desired target stage, such as the authorized project design level. (3) Bold values within the shaded cells (green) correspond to where there is an increase in the median AEP.

Table 12 Expected AEP (based on Top of Levee) Results at the Index Locations.

Index Location	River	Reach	River Station	Baseline	Bear EIP	Feather EIP	Bear-Feather EIP	Star Bend (SB) EIP	Bear-Feather-SB EIP	Natomas EIP	Bear-Feather-SB-Natomas EIP
RA01	Feather River	Honcut to Jack	42.24	0.0016	0.0016	0.0016	0.0016	0.0016	0.0016	0.0016	0.0016
RA02	Yuba River	Upper	7.00	0.0142	0.0142	0.0142	0.0142	0.0142	0.0142	0.0142	0.0142
RA03	Feather River	Jack Sl - Yuba R	29.00	0.0027	0.0027	0.0026	0.0026	0.0027	0.0026	0.0027	0.0026
RA04	Sutter Bypass	ButteSl-Wads	88.60	0.0079	0.0079	0.0079	0.0079	0.0079	0.0079	0.0079	0.0079
RA05	Sacramento River	Colusa-Feather	119.75	0.0011	0.0011	0.0011	0.0011	0.0011	0.0011	0.0011	0.0011
RA06	Bear River	Lower	1.75	0.0076	0.0067	0.0076	0.0069	0.0076	0.0069	0.0076	0.0069
RA07	Feather River	Reach 35	9.00	0.0002	0.0002	0.0002	**0.0003**[a]	0.0002	**0.0003**[a]	0.0002	**0.0003**[a]
RA08	Sacramento River	Colusa-Feather	90.00	0.0153	**0.0154**[b]	**0.0156**[b]	**0.0157**[b]	**0.0154**[a]	**0.0158**[b]	**0.0154**[b]	**0.0159**[b]
RA09	Sacramento River	Colusa-Feather	86.50	0.0052	**0.0053**[b]	**0.0055**[b]	**0.0057**[b]	0.0052	**0.0057**[b]	**0.0061**[b]	**0.0067**[b]
RA10	Sacramento River	NCC to NEMDC	79.21	0.0083	0.0082	0.0080	0.0081	0.0083	0.0077	0.0022	0.0007
RA11	Sacramento River	NCC to NEMDC	76.25	0.0061	0.0061	0.0057	0.0056	0.0061	0.0056	0.0010	0.0009
RA12	Yolo Bypass	KRLC to SacBP	48.84	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	**0.0004**[b]	**0.0004**[a]
RA13	Sacramento River	NCC to NEMDC	63.82	0.0141	0.0140	0.0140	0.0140	0.0141	0.0140	0.0139	0.0138
RA14	American River	Reach 1	11.00	0.0054	0.0054	0.0054	0.0054	0.0054	0.0054	0.0054	0.0054
RA15	American River	Reach 1	3.75	0.0021	0.0021	0.0021	0.0021	0.0021	0.0021	0.0021	0.0021
RA16	Sacramento River	DS American	59.75	0.0004	0.0003	0.0003	0.0003	0.0003	0.0003	0.0004	0.0003
RA17	Sacramento River	DS American	46.50	0.0004	0.0004	0.0004	**0.0005**[b]	0.0004	0.0004	**0.0005**[b]	**0.0005**[b]
RA18	Sacramento River	DS American	36.50	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	**0.0003**[b]	**0.0003**[b]
RA19	Sutter Slough	Lower Reach	25.23	0.0040	0.0040	0.0040	0.0040	0.0040	0.0040	0.0040	0.0040
RA20	Georgiana Slough	Reach	12.36	0.0038	0.0038	0.0035	0.0038	0.0038	0.0038	**0.0039**[a]	**0.0041**[a]
RA21	Miner Slough	Reach 1	19.11	0.0046	0.0046	**0.0050**[b]	0.0044	0.0044	**0.0047**[a]	**0.0047**[b]	**0.0049**[a]
RA22	Sacramento River	RM 14.6 to 26.5	14.75	0.0080	0.0080	0.0080	0.0079	0.0080	0.0079	0.0079	**0.0081**[a]

Notes: (1) The expected AEP is obtained from the expected exceedance probability curves calculated as part of the Monte Carlo simulation in HEC-FDA. The expected exceedance curves are annual exceedance probability curves with uncertainty included, and they represent the average values during the Monte Carlo simulation. (2) The expected AEP values in the above table are relative on the top of levee elevation with overtopping flow being the only main mechanism for levee failure. If necessary, the AEP can be estimated for any desired target stage, such as the authorized project design level. (3) Bold values within the shaded cells (green) correspond to where there is an increase in the expected AEP. (4) Differences near the downstream boundary (RA19 through RA22) are very unlikely, so the results are suspect. A more detailed evaluation of the model results at the downstream boundary should be completed for any future evaluation.

[a] Difference is related to changes in the stage reflected in the stage-outflow discharge relationship.
[b] Difference is related to changes in the stage and outflow discharges reflected in the stage-outflow discharge and inflow-outflow relationships.

Table 13. Assurance (CNP) for the 0.001 Exceedance Probability Flood at the Index Locations.

Index Location	River	Reach	River Station	Baseline	Bear EIP	Feather EIP	Bear-Feather EIP	Star Bend (SB) EIP	Bear-Feather-SB EIP	Natomas EIP	Bear-Feather-SB-Natomas EIP
RA01	Feather River	Honcut to Jack	42.24	0.9981	0.9981	0.9982	0.9982	0.9981	0.9982	0.9981	0.9982
RA02	Yuba River	Upper	7.00	0.5912	0.5912	0.5926	0.5926	0.5912	0.5926	0.5912	0.5926
RA03	Feather River	Jack Sl - Yuba R	29.00	0.9935	0.9936	0.9955	0.9955	0.9935	0.9955	0.9935	0.9955
RA04	Sutter Bypass	ButteSl-Wads	88.60	0.7344	0.7344	**0.7342**[a]	0.7349	0.7344	0.7349	0.7349	0.7349
RA05	Sacramento River	Colusa-Feather	119.75	0.9891	0.9891	0.9892	**0.9889**[a]	0.9891	**0.9889**[b]	0.9892	**0.9887**[a]
RA06	Bear River	Lower	1.75	0.7232	0.7413	**0.7217**[b]	0.7340	0.7232	0.7340	**0.7231**[a]	0.7337
RA07	Feather River	Reach 35	9.00	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
RA08	Sacramento River	Colusa-Feather	90.00	0.3723	**0.3671**[b]	**0.3668**[b]	**0.3635**[b]	**0.3710**[a]	**0.3622**[b]	**0.3690**[b]	**0.3574**[b]
RA09	Sacramento River	Colusa-Feather	86.50	0.7229	**0.7153**[b]	**0.7065**[b]	**0.6960**[b]	0.7229	**0.6960**[b]	**0.6714**[b]	**0.6445**[b]
RA10	Sacramento River	NCC to NEMDC	79.21	0.8111	0.8119	0.8165	0.8157	**0.8109**[c]	0.8183	0.9385	0.9823
RA11	Sacramento River	NCC to NEMDC	76.25	0.8524	**0.8514**[a]	0.8610	0.8630	**0.8519**[c]	0.8630	0.9664	0.9760
RA12	Yolo Bypass	KRLC to SacBP	48.84	0.9994	0.9994	0.9994	0.9994	0.9994	0.9994	**0.9979**[a]	**0.9981**[a]
RA13	Sacramento River	NCC to NEMDC	63.82	0.6171	0.6186	0.6182	0.6194	0.6171	0.6194	0.6194	0.6213
RA14	American River	Reach 1	11.00	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
RA15	American River	Reach 1	3.75	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
RA16	Sacramento River	DS American	59.75	0.9991	**0.9990**[a]	**0.9990**[b]	**0.9990**[b]	**0.9990**[a]	**0.9990**[b]	**0.9988**[b]	**0.9989**[b]
RA17	Sacramento River	DS American	46.50	0.9968	**0.9967**[a]	0.9968	0.9968	0.9968	0.9968	**0.9962**[b]	**0.9962**[b]
RA18	Sacramento River	DS American	36.50	0.9995	**0.9994**[a]	0.9995	**0.9994**[b]	0.9995	0.9995	**0.9993**[b]	**0.9993**[b]
RA19	Sutter Slough	Lower Reach	25.23	0.8875	0.8875	0.8875	0.8875	0.8875	**0.8874**[a]	0.8895	0.8875
RA20	Georgiana Slough	Reach	12.36	0.8562	**0.8551**[a]	0.8670	**0.8541**[a]	**0.8561**[a]	**0.8541**[a]	**0.8531**[a]	**0.8458**[a]
RA21	Miner Slough	Reach 1	19.11	0.8272	0.8276	**0.8139**[a]	0.9346	0.8353	**0.8256**[a]	**0.8260**[b]	**0.8171**[a]
RA22	Sacramento River	RM 14.6 to 26.5	14.75	0.7439	0.7449	0.7442	0.7485	0.7439	0.7477	0.7470	**0.7435**[a]

Notes: (1) The assurance (CNP) values in the above table are relative to the top of levee elevation with overtopping flow being the only main mechanism for levee failure. If necessary, the assurance (CNP) can be estimated for any desired target stage, such as the authorized project design level. (2) Bold values within the shaded cells (green) correspond to where there is a reduction in the assurance (CNP). (3) Differences near the downstream boundary (RA19 through RA22) are very unlikely, so the results are suspect. A more detailed evaluation of the model results at the downstream boundary should be completed for any future evaluation.

[a] Difference is related to changes in the stage reflected in the stage-outflow discharge relationship.

[b] Difference is related to changes in the stage and outflow discharges reflected in the stage-outflow discharge and inflow-outflow relationships.

[c] Difference is related to changes in the outflow discharge reflected in the stage-outflow discharge and inflow-outflow relationships.

Table 14. Assurance (CNP) for the 0.004 Exceedance Probability Flood at the Index Locations.

Index Location	River	Reach	River Station	Baseline	Bear EIP	Feather EIP	Bear-Feather EIP	Star Bend (SB) EIP	Bear-Feather-SB EIP	Natomas EIP	Bear-Feather-SB-Natomas EIP
RA01	Feather River	Honcut to Jack	42.24	0.9600	0.9600	**0.9599**[a]	0.9601	0.9600	0.9601	0.9600	0.9601
RA02	Yuba River	Upper	7.00	0.1142	0.1142	0.1147	0.1147	0.1142	0.1147	0.1142	0.1147
RA03	Feather River	Jack Sl - Yuba R	29.00	0.8931	0.8931	0.9056	0.9057	0.8931	0.9057	0.8931	0.9057
RA04	Sutter Bypass	ButteSl-Wads	88.60	0.2471	0.2471	0.2471	0.2486	0.2471	0.2486	0.2486	0.2486
RA05	Sacramento River	Colusa-Feather	119.75	0.9274	0.9286	0.9290	0.9285	0.9274	0.9285	0.9293	**0.9262**[a]
RA06	Bear River	Lower	1.75	0.6492	0.6678	**0.6472**[b]	0.6592	0.6492	0.6592	0.6492	0.6590
RA07	Feather River	Reach 35	9.00	0.9998	**0.9997**[a]	**0.9995**[a]	**0.9988**[a]	0.9998	**0.9991**[a]	0.9998	**0.9989**[a]
RA08	Sacramento River	Colusa-Feather	90.00	0.3660	**0.3601**[b]	**0.3609**[b]	**0.3580**[b]	**0.3649**[a]	**0.3570**[b]	**0.3623**[b]	**0.3552**[b]
RA09	Sacramento River	Colusa-Feather	86.50	0.6648	**0.6561**[b]	**0.6465**[b]	**0.6337**[b]	0.6648	**0.6337**[b]	**0.6046**[b]	**0.5743**[b]
RA10	Sacramento River	NCC to NEMDC	79.21	0.7022	0.7040	0.7050	0.7038	0.7022	0.7040	0.8511	0.9236
RA11	Sacramento River	NCC to NEMDC	76.25	0.7537	**0.7529**[a]	0.7609	0.7627	**0.7535**[c]	0.7627	0.9100	0.9102
RA12	Yolo Bypass	KRLC to SacBP	48.84	0.9872	**0.9868**[a]	**0.9867**[a]	**0.9865**[a]	0.9872	**0.9865**[a]	**0.9775**[b]	**0.9748**[a]
RA13	Sacramento River	NCC to NEMDC	63.82	0.5320	0.5327	0.5326	0.5329	0.5323	0.5329	0.5322	0.5328
RA14	American River	Reach 1	11.00	0.1155	0.1159	0.1157	0.1157	0.1155	0.1221	0.1155	0.1219
RA15	American River	Reach 1	3.75	0.5968	0.5982	0.5971	0.5971	0.5971	0.5971	0.5970	0.5970
RA16	Sacramento River	DS American	59.75	0.9540	**0.9516**[a]	**0.9512**[b]	**0.9520**[b]	**0.9508**[a]	**0.9516**[b]	**0.9420**[b]	**0.9483**[b]
RA17	Sacramento River	DS American	46.50	0.9373	**0.9347**[a]	**0.9354**[b]	**0.9350**[b]	**0.9354**[a]	**0.9358**[b]	**0.9258**[b]	**0.9262**[b]
RA18	Sacramento River	DS American	36.50	0.9671	**0.9661**[a]	**0.9666**[b]	**0.9648**[b]	**0.9667**[a]	**0.9668**[b]	**0.9605**[b]	**0.9610**[b]
RA19	Sutter Slough	Lower Reach	25.23	0.6757	0.6757	0.6757	0.6757	0.6757	**0.6756**[a]	0.6769	0.6757
RA20	Georgiana Slough	Reach	12.36	0.6703	**0.6642**[a]	0.6761	**0.6583**[a]	**0.6701**[a]	**0.6583**[a]	**0.6657**[a]	**0.6515**[a]
RA21	Miner Slough	Reach 1	19.11	0.6672	0.6673	**0.6494**[a]	0.6780	0.6780	**0.6661**[a]	**0.6657**[b]	**0.6547**[a]
RA22	Sacramento River	RM 14.6 to 26.5	14.75	0.6003	0.6008	0.6006	0.6060	0.6006	0.6059	0.6049	**0.5999**[a]

Notes: (1) The assurance (CNP) values in the above table are relative to the top of levee elevation with overtopping flow being the only main mechanism for levee failure. If necessary, the assurance (CNP) can be estimated for any desired target stage, such as the authorized project design level. (2) Bold values within the shaded cells (green) correspond to where there is a reduction in the assurance (CNP). (3) Differences near the downstream boundary (RA19 through RA22) are very unlikely, so the results are suspect. A more detailed evaluation of the model results at the downstream boundary should be completed for any future evaluation.

[a] Difference is related to changes in the stage reflected in the stage-outflow discharge relationship.

[b] Difference is related to changes in the stage and outflow discharges reflected in the stage-outflow discharge and inflow-outflow relationships.

[c] Difference is related to changes in the outflow discharge reflected in the stage-outflow discharge and inflow-outflow relationships.

Table 15. Assurance (CNP) for the 0.002 Exceedance Probability Flood at the Index Locations.

Index Location	River	Reach	River Station	Baseline	Bear EIP	Feather EIP	Bear-Feather EIP	Star Bend (SB) EIP	Bear-Feather-SB EIP	Natomas EIP	Bear-Feather-SB-Natomas EIP
RA01	Feather River	Honcut to Jack	42.24	0.6098	0.6098	**0.6070**[a]	**0.6081**[a]	0.6098	**0.6081**[a]	0.6098	**0.6081**[a]
RA02	Yuba River	Upper	7.00	0.0267	0.0267	0.0268	0.0268	0.0267	0.0268	0.0267	0.0268
RA03	Feather River	Jack Sl - Yuba R	29.00	0.2946	0.2946	0.3007	0.3006	0.2946	0.3006	0.2946	0.3006
RA04	Sutter Bypass	ButteSl-Wads	88.60	0.1180	0.1180	0.1180	0.1185	0.1180	0.1185	0.1185	0.1185
RA05	Sacramento River	Colusa-Feather	119.75	0.8290	0.8303	0.8323	**0.8265**[a]	**0.8285**[a]	0.8303	0.8308	**0.8160**[a]
RA06	Bear River	Lower	1.75	0.6110	0.6294	**0.6085**[b]	0.6202	0.6110	0.6202	**0.6109**[a]	0.6200
RA07	Feather River	Reach 35	9.00	0.9811	**0.9781**[a]	**0.9710**[a]	**0.9583**[a]	**0.9809**[b]	**0.9613**[a]	**0.9805**[b]	**0.9595**[a]
RA08	Sacramento River	Colusa-Feather	90.00	0.3758	**0.3695**[b]	**0.3705**[b]	**0.3673**[b]	**0.3746**[a]	**0.3662**[b]	**0.3721**[b]	**0.3627**[b]
RA09	Sacramento River	Colusa-Feather	86.50	0.6647	**0.6556**[b]	**0.6443**[b]	**0.6327**[b]	0.6647	**0.6327**[b]	**0.6030**[b]	**0.5731**[b]
RA10	Sacramento River	NCC to NEMDC	79.21	0.6106	0.6127	**0.6051**[a]	**0.6014**[a]	0.6106	**0.5956**[a]	0.7294	0.7985
RA11	Sacramento River	NCC to NEMDC	76.25	0.6632	**0.6630**[a]	**0.6626**[a]	**0.6610**[a]	**0.6631**[c]	**0.6610**[a]	0.8221	0.7837
RA12	Yolo Bypass	KRLC to SacBP	48.84	0.9176	**0.9160**[a]	**0.9149**[a]	**0.9135**[a]	0.9177	**0.9138**[a]	**0.8979**[b]	**0.8768**[a]
RA13	Sacramento River	NCC to NEMDC	63.82	0.5141	0.5144	0.5144	0.5144	0.5143	0.5144	**0.5136**[a]	**0.5137**[a]
RA14	American River	Reach 1	11.00	0.0273	0.0280	0.0276	0.0276	0.0273	0.0280	0.0273	0.0276
RA15	American River	Reach 1	3.75	0.5172	0.5187	0.5175	0.5175	0.5175	0.5175	0.5175	0.5175
RA16	Sacramento River	DS American	59.75	0.8898	**0.8864**[a]	**0.8858**[b]	**0.8871**[b]	**0.8851**[a]	**0.8864**[b]	**0.8710**[b]	**0.8817**[b]
RA17	Sacramento River	DS American	46.50	0.8762	**0.8721**[a]	**0.8731**[b]	**0.8723**[b]	**0.8731**[a]	**0.8736**[b]	**0.8588**[b]	**0.8594**[b]
RA18	Sacramento River	DS American	36.50	0.9175	**0.9159**[a]	**0.9168**[b]	**0.9136**[b]	**0.9169**[a]	**0.9172**[b]	**0.9064**[b]	**0.9071**[b]
RA19	Sutter Slough	Lower Reach	25.23	0.6217	0.6217	0.6217	0.6217	0.6217	0.6216	0.6225	0.6217
RA20	Georgiana Slough	Reach	12.36	0.6281	**0.6219**[a]	0.6317	**0.6158**[a]	**0.6279**[a]	**0.6158**[a]	**0.6236**[a]	**0.6103**[a]
RA21	Miner Slough	Reach 1	19.11	0.6334	0.6335	**0.6158**[a]	0.6437	0.6434	**0.6327**[a]	**0.6315**[a]	**0.6214**[a]
RA22	Sacramento River	RM 14.6 to 26.5	14.75	0.5803	0.5806	0.5805	0.5853	0.5803	0.5852	0.5844	**0.5799**[a]

Notes: (1) The assurance (CNP) values in the above table are relative to the top of levee elevation with overtopping flow being the only main mechanism for levee failure. If necessary, the assurance (CNP) can be estimated for any desired target stage, such as the authorized project design level. (2) Bold values within the shaded cells (green) correspond to where there is a reduction in the assurance (CNP). (3) Differences near the downstream boundary (RA19 through RA22) are very unlikely, so the results are suspect. A more detailed evaluation of the model results at the downstream boundary should be completed for any future evaluation.

[a] Difference is related to changes in the stage reflected in the stage-outflow discharge relationship.
[b] Difference is related to changes in the stage and outflow discharges reflected in the stage-outflow discharge and inflow-outflow relationships.
[c] Difference is related to changes in the outflow discharge reflected in the stage-outflow discharge and inflow-outflow relationships.

Table 16. Return Interval for the 90% Assurance of Containment.

Index Location	River	Reach	River Station	Baseline	Bear EIP	Feather EIP	Bear-Feather EIP	Star Bend (SB) EIP	Bear-Feather-SB EIP	Natomas EIP	Bear-Feather-SB-Natomas EIP
RA01	Feather River	Honcut to Jack	42.24	282	282	**281**[a]	**281**[a]	282	**281**[a]	282	**281**[a]
RA02	Yuba River	Upper	7.00	29	29	29	29	29	29	29	29
RA03	Feather River	Jack Slough - Yuba River	29.00	235	235	252	252	235	252	235	252
RA04	Sutter Bypass	Butte Slough - Wads	88.60	60	60	60	60	60	60	60	60
RA05	Sacramento River	Colusa-Feather	119.75	303	306	308	303	303	306	307	**295**[a]
RA06	Bear River	Lower	1.75	35	37	35	37	35	37	35	37
RA07	Feather River	Reach 35	9.00	> 500	> 500	> 500	> 500	> 500	> 500	> 500	> 500
RA08	Sacramento River	Colusa-Feather	90.00	29	**28**[b]	**28**[b]	**28**[b]	**28**[a]	**28**[b]	**28**[b]	**28**[b]
RA09	Sacramento River	Colusa-Feather	86.50	57	**56**[b]	**56**[b]	**55**[b]	57	**55**[b]	**54**[b]	**53**[b]
RA10	Sacramento River	NCC to NEMDC	79.21	31	31	34	33	**30**[c]	37	150	285
RA11	Sacramento River	NCC to NEMDC	76.25	57	57	62	63	57	63	271	264
RA12	Yolo Bypass	KRLC to SacBP	48.84	> 500	> 500	> 500	> 500	> 500	> 500	**491**[b]	**424**[a]
RA13	Sacramento River	NCC to NEMDC	63.82	16	17	17	17	16	17	17	17
RA14	American River	Reach 1	11.00	111	111	111	111	111	111	111	111
RA15	American River	Reach 1	3.75	126	126	126	126	126	126	126	126
RA16	Sacramento River	DS American	59.75	448	**433**[a]	**430**[b]	**436**[b]	**427**[a]	**433**[b]	**377**[b]	**413**[b]
RA17	Sacramento River	DS American	46.50	382	**367**[a]	**371**[b]	**368**[b]	**371**[a]	**373**[b]	**326**[b]	**328**[b]
RA18	Sacramento River	DS American	36.50	> 500	> 500	> 500	> 500	> 500	> 500	> 500	> 500
RA19	Sutter Slough	Lower Reach	25.23	90	90	90	90	90	90	92	90
RA20	Georgiana Slough	Reach	12.36	73	73	78	73	73	73	**72**[a]	**70**[a]
RA21	Miner Slough	Reach 1	19.11	63	63	**60**[a]	65	65	**62**[a]	**62**[b]	**60**[a]
RA22	Sacramento River	RM 14.6 to 26.5	14.75	36	36	36	38	36	37	37	36

Notes: (1) The values in the above table are relative to the top of levee elevation with overtopping flow being the only main mechanism for levee failure. If necessary, any desired target stage, such as the authorized project design level, can be evaluated. (2) Bold values within the shaded cells (green) correspond to where there is a reduction in the assurance (CNP). (3) Differences near the downstream boundary (RA19 through RA22) are very unlikely, so the results are suspect. A more detailed evaluation of the model results at the downstream boundary should be completed for any future evaluation.

[a] Difference is related to changes in the stage reflected in the stage-outflow discharge relationship.
[b] Difference is related to changes in the stage and outflow discharges reflected in the stage-outflow discharge and inflow-outflow relationships.
[c] Difference is related to changes in the outflow discharge reflected in the stage-outflow discharge and inflow-outflow relationships.

Table 17. Percent Changes in Risk Analysis Results (Assurance (CNP) for 0.001 Exceedance Probability Flood).

Index Location	Bear EIP	Feather EIP	Bear-Feather No. 1 EIP	Feather No. 2 EIP	Bear-Feather No. 1-Feather No. 2 EIP	Natomas EIP	Bear-Feather No. 1-Feather No. 2-Natomas EIP
RA01	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
RA02	0.0%	0.2%	0.2%	0.0%	0.2%	0.0%	0.2%
RA03	0.0%	0.2%	0.2%	0.0%	0.2%	0.0%	0.2%
RA04	0.0%	0.0%	0.1%	0.0%	0.1%	0.1%	0.1%
RA05	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
RA06	2.5%	**-0.2%**[b]	1.5%	0.0%	1.5%	0.0%	1.5%
RA07	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
RA08	**-1.4%**[b]	**-1.5%**[b]	**-2.4%**[b]	**-0.3%**[a]	**-2.7%**[b]	**-0.9%**[b]	**-4.0%**[b]
RA09	**-1.1%**[b]	**-2.3%**[b]	**-3.7%**[b]	0.0%	**-3.7%**[b]	**-7.1%**[b]	**-10.8%**[b]
RA10	0.1%	0.7%	0.6%	0.0%	0.9%	15.7%	21.1%
RA11	**-0.1%**[a]	1.0%	1.2%	**-0.1%**[c]	1.2%	13.4%	14.5%
RA12	0.0%	0.0%	0.0%	0.0%	0.0%	**-0.2%**[a]	**-0.1%**[a]
RA13	0.2%	0.2%	0.4%	0.0%	0.4%	0.4%	0.7%
RA14	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
RA15	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
RA16	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
RA17	0.0%	0.0%	0.0%	0.0%	0.0%	**-0.1%**[b]	**-0.1%**[b]
RA18	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
RA19	0.0%	0.0%	0.0%	0.0%	0.0%	0.2%	0.0%
RA20	**-0.1%**[a]	1.3%	**-0.2%**[a]	0.0%	**-0.2%**[a]	**-0.4%**[a]	**-1.2%**[a]
RA21	0.0%	**-1.6%**[a]	0.9%	1.0%	**-0.2%**[a]	**-0.1%**[c]	**-1.2%**[a]
RA22	0.1%	0.0%	0.6%	0.0%	0.5%	0.4%	**-0.1%**[a]

Notes: (1) Levee failure (LF) corresponds to where return interval for 90% assurance was significantly greater than the 0.002 exceedance probability event. The percentage of change was not determined at these locations. (2) Bold values within the shaded cells (green) correspond to where there is a reduction in the assurance (CNP) or return interval for the 90% assurance of containment. (3) It should be noted that the percentage of change in the above table is relative to an extremely small number. So, a small change in the value can show as a substantial percent of change. Therefore, the percent change must be viewed with caution due to the extremely low numeric values involved and the limits in the ability to accurately model complex hydraulic systems. (4) Differences near the downstream boundary (RA19 through RA22) are very unlikely, so the results are suspect. A more detailed evaluation of the model results at the downstream boundary should be completed for any future evaluation.

[a] Difference is related to changes in the stage reflected in the stage-outflow discharge relationship.
[b] Difference is related to changes in the stage and outflow discharges reflected in the stage-outflow discharge and inflow-outflow relationships.
[c] Difference is related to changes in the outflow discharge reflected in the stage-outflow discharge and inflow-outflow relationships.

Table 18. Percent Changes in Risk Analysis Results (Assurance (CNP) for 0.004 Exceedance Probability Flood).

Index Location	Bear EIP	Feather EIP	Bear-Feather No. 1 EIP	Feather No. 2 EIP	Bear-Feather No. 1-Feather No. 2 EIP	Natomas EIP	Bear-Feather No. 1-Feather No. 2-Natomas EIP
RA01	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
RA02	0.0%	0.4%	0.4%	0.0%	0.4%	0.0%	0.4%
RA03	0.0%	1.4%	1.4%	0.0%	1.4%	0.0%	1.4%
RA04	0.0%	0.0%	0.6%	0.0%	0.5%	0.5%	0.5%
RA05	0.1%	0.2%	0.1%	0.0%	0.1%	0.2%	**-0.1%**[a]
RA06	2.8%	**-0.3%**[b]	1.5%	0.0%	1.5%	0.0%	1.5%
RA07	0.0%	0.0%	**-0.1%**[a]	0.0%	**-0.1%**[a]	0.0%	**-0.1%**[a]
RA08	**-1.7%**[b]	**-1.4%**[b]	**-2.3%**[b]	**-0.3%**[a]	**-2.6%**[b]	**-1.1%**[b]	**-3.6%**[b]
RA09	**-1.2%**[b]	**-2.6%**[b]	**-4.5%**[b]	0.0%	**-4.5%**[b]	**-8.9%**[b]	**-13.4%**[b]
RA10	0.3%	0.4%	0.2%	0.0%	0.3%	21.2%	31.5%
RA11	**-0.1%**[a]	1.0%	1.2%	0.0%	1.2%	20.7%	20.8%
RA12	0.0%	**-0.1%**[a]	**-0.1%**[a]	0.0%	**-0.1%**[a]	**-1.0%**[b]	**-1.3%**[a]
RA13	0.1%	0.1%	0.2%	0.1%	0.2%	0.0%	0.2%
RA14	0.3%	0.2%	0.2%	0.0%	0.3%	0.0%	0.2%
RA15	0.2%	0.1%	0.1%	0.1%	0.1%	0.0%	0.0%
RA16	**-0.3%**[a]	**-0.3%**[b]	**-0.2%**[b]	**-0.3%**[a]	**-0.3%**[b]	**-1.3%**[b]	**-0.6%**[b]
RA17	**-0.3%**[a]	**-0.2%**[b]	**-0.2%**[b]	**-0.2%**[a]	**-0.2%**[b]	**-1.2%**[b]	**-1.2%**[b]
RA18	**-0.1%**[a]	**-0.1%**[b]	**-0.2%**[b]	0.0%	0.0%	**-0.7%**[b]	**-0.6%**[b]
RA19	0.0%	0.0%	0.0%	0.0%	0.0%	0.2%	0.0%
RA20	**-0.9%**[a]	0.9%	**-1.8%**[a]	0.0%	**-1.8%**[a]	**-0.7%**[a]	**-2.8%**[a]
RA21	0.0%	**-2.6%**[a]	1.6%	1.6%	**-0.1%**[a]	**-0.2%**[b]	**-1.8%**[a]
RA22	0.1%	0.0%	0.9%	0.0%	0.9%	0.8%	**-0.1%**[a]

Notes: (1) Levee failure (LF) corresponds to where return interval for 90% assurance was significantly greater than the 0.002 exceedance probability event. The percentage of change was not determined at these locations. (2) Bold values within the shaded cells (green) correspond to where there is a reduction in the assurance (CNP) or return interval for the 90% assurance of containment. (3) It should be noted that the percentage of change in the above table is relative to an extremely small number. So, a small change in the value can show as a substantial percent of change. Therefore, the percent change must be viewed with caution due to the extremely low numeric values involved and the limits in the ability to accurately model complex hydraulic systems. (4) Differences near the downstream boundary (RA19 through RA22) are very unlikely, so the results are suspect. A more detailed evaluation of the model results at the downstream boundary should be completed for any future evaluation.

[a] Difference is related to changes in the stage reflected in the stage-outflow discharge relationship.

[b] Difference is related to changes in the stage and outflow discharges reflected in the stage-outflow discharge and inflow-outflow relationships.

Table 19. Percent Changes in Risk Analysis Results (Assurance (CNP) for 0.002 Chance Exceedance Flood).

Index Location	Bear EIP	Feather EIP	Bear-Feather No. 1 EIP	Feather No. 2 EIP	Bear-Feather No. 1-Feather No. 2 EIP	Natomas EIP	Bear-Feather No. 1-Feather No. 2-Natomas EIP
RA01	0.0%	**-0.5%**[a]	**-0.3%**[a]	0.0%	**-0.3%**[a]	0.0%	**-0.3%**[a]
RA02	0.0%	0.4%	0.4%	0.0%	0.4%	0.0%	0.4%
RA03	0.0%	2.1%	2.0%	0.0%	2.0%	0.0%	2.0%
RA04	0.0%	0.0%	0.4%	0.0%	0.4%	0.4%	0.4%
RA05	0.2%	0.4%	**-0.3%**[a]	**-0.1%**[a]	0.2%	0.2%	**-1.6%**[a]
RA06	3.0%	**-0.4%**[b]	1.5%	0.0%	1.5%	0.0%	1.5%
RA07	**-0.3%**[a]	**-1.0%**[a]	**-2.3%**[a]	0.0%	**-2.0%**[a]	**-0.1%**[b]	**-2.2%**[a]
RA08	**-1.7%**[b]	**-1.4%**[b]	**-2.3%**[b]	**-0.3%**[b]	**-2.6%**[b]	**-1.0%**[b]	**-3.5%**[b]
RA09	**-1.4%**[b]	**-3.1%**[b]	**-4.8%**[b]	0.0%	**-4.8%**[b]	**-9.3%**[b]	**-13.8%**[b]
RA10	0.3%	**-0.9%**[a]	**-1.5%**[a]	0.0%	**-2.5%**[a]	19.5%	30.8%
RA11	0.0%	**-0.1%**[a]	**-0.3%**[a]	0.0%	**-0.3%**[a]	24.0%	18.2%
RA12	**-0.2%**[a]	**-0.3%**[a]	**-0.4%**[a]	0.0%	**-0.4%**[a]	**-2.1%**	**-4.4%**[a]
RA13	0.1%	0.1%	0.1%	0.0%	0.1%	**-0.1%**[a]	**-0.1%**[a]
RA14	2.6%	1.1%	1.1%	0.0%	2.6%	0.0%	1.1%
RA15	0.3%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%
RA16	**-0.4%**[a]	**-0.4%**[b]	**-0.3%**[b]	**-0.5%**[a]	**-0.4%**[b]	**-2.1%**[b]	**-0.9%**[b]
RA17	**-0.5%**[a]	**-0.4%**[b]	**-0.4%**[b]	**-0.4%**[a]	**-0.3%**[b]	**-2.0%**[b]	**-1.9%**[b]
RA18	**-0.2%**[a]	**-0.1%**[b]	**-0.4%**[b]	**-0.1%**[a]	0.0%	**-1.2%**[b]	**-1.1%**[b]
RA19	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.0%
RA20	**-1.0%**[a]	0.6%	**-2.0%**[a]	0.0%	**-2.0%**[a]	**-0.7%**[a]	**-2.8%**[a]
RA21	0.0%	**-2.8%**[a]	1.6%	1.6%	**-0.1%**[a]	**-0.3%**[b]	**-1.9%**[a]
RA22	0.1%	0.0%	0.9%	0.0%	0.8%	0.7%	**-0.1%**[a]

Notes: (1) Levee failure (LF) corresponds to where return interval for 90% assurance was significantly greater than the 0.002 exceedance probability event. The percentage of change was not determined at these locations. (2) Bold values within the shaded cells (green) correspond to where there is a reduction in the assurance (CNP) or return interval for the 90% assurance of containment. (3) It should be noted that the percentage of change in the above table is relative to an extremely small number. So, a small change in the value can show as a substantial percent of change. Therefore, the percent change must be viewed with caution due to the extremely low numeric values involved and the limits in the ability to accurately model complex hydraulic systems. (4) Differences near the downstream boundary (RA19 through RA22) are very unlikely, so the results are suspect. A more detailed evaluation of the model results at the downstream boundary should be completed for any future evaluation.

[a] Difference is related to changes in the stage reflected in the stage-outflow discharge relationship.

[b] Difference is related to changes in the stage and outflow discharges reflected in the stage-outflow discharge and inflow-outflow relationships.

Table 20. Percent Changes in Risk Analysis Results (Return Interval for 90% Assurance of Containment).

Index Location	Bear EIP	Feather EIP	Bear-Feather No. 1 EIP	Feather No. 2 EIP	Bear-Feather No. 1-Feather No. 2 EIP	Natomas EIP	Bear-Feather No. 1-Feather No. 2-Natomas EIP
RA01	0.0%	**-0.4%**[a]	**-0.4%**[a]	0.0%	**-0.4%**[a]	0.0%	**-0.4%**[a]
RA02	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
RA03	0.0%	7.2%	7.2%	0.0%	7.2%	0.0%	7.2%
RA04	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
RA05	1.0%	1.7%	0.0%	0.0%	1.0%	1.3%	**-2.6%**[a]
RA06	5.7%	0.0%	5.7%	0.0%	5.7%	0.0%	5.7%
RA07	LF	LF	LF	LF	LF	LF	LF
RA08	**-3.4%**[b]	**-3.4%**[b]	**-3.4%**[b]	**-3.4%**[a]	**-3.4%**[b]	**-3.4%**[b]	**-3.4%**[b]
RA09	**-1.8%**[b]	**-1.8%**[b]	**-3.5%**[b]	0.0%	**-3.5%**[b]	**-5.3%**[b]	**-7.0%**[b]
RA10	0.0%	9.7%	6.5%	**-3.2%**[c]	19.4%	383.9%	819.4%
RA11	0.0%	8.8%	10.5%	0.0%	10.5%	375.4%	363.2%
RA12	LF	LF	LF	LF	LF	**-17.6%**[b]	**-28.9%**[a]
RA13	6.3%	6.3%	6.3%	0.0%	6.3%	6.3%	6.3%
RA14	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
RA15	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
RA16	**-3.3%**[a]	**-4.0%**[b]	**-2.7%**[b]	**-4.7%**[a]	**-3.3%**[b]	**-15.8%**[b]	**-7.8%**[b]
RA17	**-3.9%**[a]	**-2.9%**[b]	**-3.7%**[b]	**-2.9%**[a]	**-2.4%**[b]	**-14.7%**[b]	**-14.1%**[b]
RA18	LF	LF	LF	LF	LF	LF	LF
RA19	0.0%	0.0%	0.0%	0.0%	0.0%	2.2%	0.0%
RA20	0.0%	6.8%	0.0%	0.0%	0.0%	**-1.4%**[a]	**-4.1%**[a]
RA21	0.0%	**-4.8%**[a]	3.2%	3.2%	**-1.6%**[a]	**-1.6%**[b]	**-4.8%**[a]
RA22	0.0%	0.0%	5.6%	0.0%	2.8%	2.8%	0.0%

Notes: (1) Levee failure (LF) corresponds to where return interval for 90% assurance was significantly greater than the 0.002 exceedance probability event. The percentage of change was not determined at these locations. (2) Bold values within the shaded cells (green) correspond to where there is a reduction in the assurance (CNP) or return interval for the 90% assurance of containment. (3) It should be noted that the percentage of change in the above table is relative to an extremely small number. So, a small change in the value can show as a substantial percent of change. Therefore, the percent change must be viewed with caution due to the extremely low numeric values involved and the limits in the ability to accurately model complex hydraulic systems. (4) Differences near the downstream boundary (RA19 through RA22) are very unlikely, so the results are suspect. A more detailed evaluation of the model results at the downstream boundary should be completed for any future evaluation.

[a] Difference is related to changes in the stage reflected in the stage-outflow discharge relationship.

[b] Difference is related to changes in the stage and outflow discharges reflected in the stage-outflow discharge and inflow-outflow relationships.

[c] Difference is related to changes in the outflow discharge reflected in the stage-outflow discharge and inflow-outflow relationships.

authorized project design level. An increase in the AEP (which is a reflection that the levee is more likely to be overtopped in any given year) caused by the proposed EIPs is reflected in the table as bold values and their cells highlighted in light green. Comparing the Tables 11 and 12 indicates that the expected AEP is more sensitive (more locations with an increase in the value) to the changes caused by an EIP. The reason for the difference is related to the magnitude of the values. In general, the expected AEP is significantly larger than the median AEP because it includes the uncertainty of the various relationships. As an example, the median AEP at Index Location RA13 is 0.0003 (Table 11) for the baseline condition, while the expected AEP at Index Location RA13 is 0.0142 (Table 12) for the baseline condition.

The assurance (CNP) for the 0.01, 0.004, and 0.002 exceedance probability floods are provided in Tables 13 through 15, respectively. In general, the results show that the EIPs will cause both an increase and decrease in the assurance (CNP) for all of the flood events with larger changes (and more locations) occurring for the 0.002 exceedance probability flood. Several locations, which are indicated in bold, have a reduction in the assurance (CNP). The changes are associated with the changes in the water surface elevations and/or downstream discharge hydrograph (peak discharge and timing). The main cause of the change is identified in all of the risk analysis results tables.

The return interval for the 90% assurance of containment was estimated from the assurance (CNP) results, and they are provided in Table 16. Any reduction in this value is identified as a bold value and the cell is highlighted in light green. Finally, the percentage of change for the values in Tables 13 through 16 is provided in Table 17 through 20. These tables show that there are differences in the changes to the assurance (CNP) and 90% assurance event for the combined EIPs scenario as compared to the EIPs as separate projects. This result indicates that cumulative effects are an important consideration when evaluating the EIPs. Therefore, it is important for future evaluations that a baseline condition, which is based on the conditions prior to the first EIP, be adopted and that the evaluation of an EIP be evaluated separately and combined with all other EIPs in-place.

Overall, the adverse changes in the AEP are consistent with adverse changes in assurance (CNP) and 90% assurance of containment. For a few index locations an adverse change with one of the values occurs, but there is no change to the other value. The reasons are: (1) AEP has an extremely low value and changes in assurance (CNP) do not result in a change in AEP, (2) differences in assurance (CNP) are small (ranging from 0.0001 to 0.002), and/or (3) AEP is significantly smaller than the 0.01 exceedance probability considered in the assurance (CNP).

3.2 Demonstration of Deterministic Analysis Process

Traditionally, levee improvement projects have been designed and analyzed using deterministic hydraulic modeling approaches. Best engineering judgment is used to evaluate uncertain model input parameters such as survey data, channel and overbank roughness, discharge coefficients, and hydrology. Typically, calibration and sensitivity analyses are performed to narrow the uncertainty bands and to fully understand the confidence levels of the selected parameters, but ultimately, the range of uncertainty of a given parameter is reduced to a single value and a single "deterministic" answer is developed. Uncertainty is reflected through freeboard, in the case of levee design, or change in water surface, in the case of a levee improvement evaluation.

3.2.1 Analysis Conditions

Information related to the analysis conditions is the same information discussed for the risk analysis process in Section 3.1.1 of this report.

3.2.2 Identify Analysis Criteria

For the deterministic analysis the following analysis criteria were considered:

Agency policy and guidance: No specific agency policy or guidance was considered for demonstration of the deterministic analysis process; however, typically such policy could be expected to define requirements for level of flood protection and freeboard.

Level of flood protection: No specific level of flood protection was evaluated. A range of flood frequencies was considered in the hydraulic evaluation conducted for the demonstration of the deterministic analysis.

Required freeboard: No specific freeboard requirement was evaluated. However, the available freeboard was calculated for the 0.01, 0.005, and 0.002 exceedance probability flood events as part of the deterministic analysis.

Criteria for Levee Failure: Consistent with the risk analysis process, the analysis considered the potential for levee failure when the levee was overtopped for a specific depth and duration. The criteria utilized for the analysis is discussed in Section 3.1.6 of this report.

Definition of Potential Impact: The definition of potential impact for the deterministic analysis was considered as simply an increase in water surface elevation and a decrease in the associated freeboard.

3.2.3 Data Collection

The data collected is the same data collected for the risk analysis process discussed in Section 3.1.3 of this report.

3.2.4 Hydrology

The hydrology is the same hydrology considered for the risk analysis process discussed in Section 3.1.4 of this report.

3.2.5 Baseline Hydraulic Model Development

Information about the development of the baseline hydraulic model is the same information discussed for the risk analysis process in Section 3.1.5 of this report.

3.2.6 Levee Failures

The criteria for levee failures are the same as applied in the risk analysis and discussed previously in Section 3.1.6 of this report.

3.2.7 Calibration/Verification of Baseline Hydraulic Model

Calibration and verification was previously discussed in Sections 3.1.7 and 3.1.5 of this report.

3.2.8 Development of Hydraulic Models for Proposed Conditions

The EIPs considered for the deterministic analysis process are the same EIPs discussed for the risk analysis process in Section 3.1.8 of this report.

3.2.9 Evaluation of Proposed Hydraulic Conditions

All of the models were run using HEC-RAS Version 4.0 (HEC, 2008). The maximum water surface elevations at the index locations were copied into an Excel® spreadsheet on separate worksheets corresponding to the various scenarios. The maximum water surface elevation was subtracted from the top of levee elevation (Table 3, see Section 3.1.1) to determine the freeboard at each location. For the Bear River EIP scenario, the top of levee for Index Location RA06 was increased to be three feet above the water surface elevation for the 0.005 exceedance probability flood commensurate with the State's current design criteria as mandated by State law. For the Natomas River EIP, the top of levee for Index Locations RA10 and RA11 was increased to an elevation obtained from information by CESPK. The water surface elevations for each EIP scenario were also compared to the water surface elevations for the baseline condition to determine the changes in water surface elevations caused by the EIPs.

3.2.10 Sensitivity Analysis

When calibration is not possible due to a lack of high water marks, or calibration is not thorough enough, a sensitivity analysis is warranted to gage the confidence level of the remaining uncertainity parameters. Typically, for design studies, the most conservative, but still realistic set of parameters is used. However, for a levee improvement or levee design study, choosing the conservative range for each of the parameters can compound, resulting in a significant over-design. Uncertainty parameters associated with the deterministic analysis process include:

1. Survey data
2. Hydrologic data
3. Manning's n values
4. Ineffective flow areas
5. Discharge coefficients (levees, inline weirs, gates, bridges, culverts, etc.)
6. Levee breach size, rate of development, and failure mechanism/trigger.
7. Downstream boundary condition.

In this study, potential impacts from seven EIP scenarios were compared to the baseline condition. Since the change in water surface elevation from an established calibrated model is the evaluation parameter, a sensitivity analysis is not necessarily required. However, it is important to consider significant simulation events triggered by a high or low set of uncertainty parameters that may yield significantly different results, such as, levee overtopping and/or breaching. Once a levee has breached, flow volumes downstream and water surface elevations throughout the model can change significantly. This could possibly indicate an improvement for one set of uncertainty parameters, and the opposite for another set. Conversely, a model without levee breaching (or other significant simulation events) should not require a sensitivity analysis, as potential impacts are unlikely to change significantly from one set of uncertainty parameters to another, as long as they are held constant between the different proposed conditions. Because of the occurrence of significant simulation events, this particular type of study for a deterministic modeling approach warrants a sensitivity study, but was not part of the scope of the current study.

3.2.11 Consequence Evaluation

An assessment of the economic cost of flood inundation may be conducted as part of a flood control impact evaluation. Such an analysis requires the development of stage-damage functions. For the current demonstration of deterministic analysis process, no consequence evaluation was conducted.

3.2.12 Identification of Potential Impacts

Tables 21 through 31 present a summary of results from the deterministic evaluation. All index locations are included with the computed levee freeboard for the 0.02 through 0.002 exceedance probability floods. The results for the baseline condition (Table 21) indicate that overtopping would occur at one location for the 0.01 exceedance probability event, four locations for the 0.005 exceedance probability flood, and eight locations for the 0.002 exceedance probability flood. Also, there are several locations where the freeboard is less than three feet. For example, Index Location RA11 only has 2.4 feet of freeboard for the 0.01 exceedance probability flood.

The results for the Bear River EIP are provided in Table 22. The results show that this EIP will cause both an increase and decrease in water surface elevations for all of the flood events with larger changes occurring for the 0.002 exceedance probability flood. Several index locations, indicated in bold, have an increase in the water surface elevations and the levee freeboard is less than three feet. This result typically occurs for the index locations on the Sacramento River system.

The results for the Feather River EIP are provided in Table 23. The results, in general, are similar to the results for the Bear River EIP. However, slight differences are found in the magnitude of change in water surface elevations.

The combination Bear River and Feather River EIP (Table 24) has similar results as the two individual EIPs. The results for the other EIP scenarios are provided in Tables 25 through 28. Tables 29 through 31 summarizes all eight EIP scenarios and their respective changes in water surface elevation relative to the baseline condition for the 0.01, 0.005, and 0.002 exceedance

Table 21. Deterministic Analysis Results for Baseline Condition.

Index Location	River	Reach	River Station	Freeboard (ft)			
				0.02 Exceedance Probability Flood (50-yr)	0.01 Exceedance Probability Flood (100-yr)	0.005 Exceedance Probability Flood (200-yr)	0.002 Exceedance Probability Flood (500-yr)
RA01	Feather River	Honcut to Jack	42.24	8.6	7.7	6.0	-0.1*
RA02	Yuba River	Upper	7.00	1.4	0.2	-1.8	-2.7
RA03	Feather River	Jack Slough - Yuba River	29.00	9.0	7.1	4.2	-0.2
RA04	Sutter Bypass	Butte Slough - Wads	88.60	2.7	0.8	-0.9	-1.4
RA05	Sacramento River	Colusa-Feather	119.75	3.8	2.5	1.9	1.2
RA06	Bear River	Lower	1.75	3.2	2.0	0.8	-0.8
RA07	Feather River	Reach 35	9.00	8.5	7.3	5.7	4.2
RA08	Sacramento River	Colusa-Feather	90.00	0.4	-0.7	-1.2	-1.4
RA09	Sacramento River	Colusa-Feather	86.50	1.8	0.8	0.1	-0.3
RA10	Sacramento River	NCC to NEMDC	79.21	2.9	1.9	1.2	0.9
RA11	Sacramento River	NCC to NEMDC	76.25	3.6	2.4	1.8	1.6
RA12	Yolo Bypass	KRLC to SacBP	48.84	4.9	3.4	3.1	2.8
RA13	Sacramento River	NCC to NEMDC	63.82	6.6	4.3	3.1	2.3
RA14	American River	Reach 1	11.00	15.3	8.6	-3.1	-3.7
RA15	American River	Reach 1	3.75	13.6	9.5	4.4	4.2
RA16	Sacramento River	DS American	59.75	7.9	5.0	3.5	2.5
RA17	Sacramento River	DS American	46.50	7.5	4.8	3.7	2.9
RA18	Sacramento River	DS American	36.50	6.2	4.2	3.6	3.2
RA19	Sutter Slough	Lower Reach	25.23	7.7	6.8	6.5	6.8
RA20	Georgiana Slough	Reach	12.36	6.7	5.2	4.9	5.1
RA21	Miner Slough	Reach 1	19.11	5.0	4.5	4.6	4.5
RA22	Sacramento River	RM 14.6 to 26.5	14.75	13.3	12.5	12.3	11.8

* A negative value corresponds to the depth of the water surface elevation above the top of levee.

Table 22. Deterministic Analysis Results for Bear River EIP.

Index Location	River	Reach	River Station	0.02 Exceedance Probability Flood (50-yr) Change in WS Elev. (ft)	0.02 Exceedance Probability Flood (50-yr) Freeboard (ft)	0.01 Exceedance Probability Flood (100-yr) Change in WS Elev. (ft)	0.01 Exceedance Probability Flood (100-yr) Freeboard (ft)	0.005 Exceedance Probability Flood (200-yr) Change in WS Elev. (ft)	0.005 Exceedance Probability Flood (200-yr) Freeboard (ft)	0.002 Exceedance Probability Flood (500-yr) Change in WS Elev. (ft)	0.002 Exceedance Probability Flood (500-yr) Freeboard (ft)
RA01	Feather River	Honcut to Jack	42.24	0.00	8.6	0.00	7.7	0.00	6.0	0.00	-0.1
RA02	Yuba River	Upper	7.00	0.00	1.4	0.00	0.2	0.00	-1.8	0.00	-2.7
RA03	Feather River	Jack Slough - Yuba River	29.00	0.00	9.0	0.00	7.1	0.00	4.2	0.00	-0.2
RA04	Sutter Bypass	Butte Slough - Wads	88.60	0.00	2.7	0.00	0.8	0.00	-0.9	0.00	-1.4
RA05	Sacramento River	Colusa-Feather	119.75	0.00	3.8	0.00	2.5	-0.01	1.9	-0.01	1.2
RA06	Bear River	Lower	1.75	-0.58	5.9	-0.45	4.6	-0.15	3.1	**0.41**	**0.9**
RA07	Feather River	Reach 35	9.00	0.07	8.5	0.10	7.2	0.06	5.7	0.15	4.1
RA08	Sacramento River	Colusa-Feather	90.00	**0.01**	**0.4**	**0.02**	**-0.7**	**0.01**	**-1.2**	**0.02**	**-1.4**
RA09	Sacramento River	Colusa-Feather	86.50	**0.02**	**1.8**	**0.03**	**0.7**	**0.01**	**0.1**	**0.03**	**-0.3**
RA10	Sacramento River	NCC to NEMDC	79.21	**0.03**	**2.9**	**0.03**	**1.8**	**0.01**	**1.2**	**0.02**	**0.9**
RA11	Sacramento River	NCC to NEMDC	76.25	0.03	3.6	**0.04**	**2.3**	**0.02**	**1.7**	**0.02**	**1.6**
RA12	Yolo Bypass	KRLC to SacBP	48.84	0.03	4.9	0.02	3.4	0.01	3.1	**0.02**	**2.8**
RA13	Sacramento River	NCC to NEMDC	63.82	0.00	6.6	0.02	4.3	-0.01	3.1	**0.03**	**2.2**
RA14	American River	Reach 1	11.00	0.00	15.3	0.00	8.6	0.00	-3.1	0.00	-3.7
RA15	American River	Reach 1	3.75	0.00	13.6	0.01	9.5	0.00	4.4	0.06	4.2
RA16	Sacramento River	DS American	59.75	0.02	7.9	0.02	5.0	0.00	3.5	**0.03**	**2.5**
RA17	Sacramento River	DS American	46.50	0.03	7.4	0.01	4.8	-0.01	3.7	**0.04**	**2.8**
RA18	Sacramento River	DS American	36.50	0.02	6.2	0.00	4.2	-0.01	3.6	0.02	3.1
RA19	Sutter Slough	Lower Reach	25.23	0.03	7.7	-0.01	6.8	-0.01	6.5	0.01	6.7
RA20	Georgiana Slough	Reach	12.36	0.00	6.7	0.00	5.2	0.02	4.9	0.02	5.1
RA21	Miner Slough	Reach 1	19.11	0.00	5.0	-0.02	4.5	0.00	4.6	0.00	4.5
RA22	Sacramento River	RM 14.6 to 26.5	14.75	0.00	13.3	-0.02	12.5	0.00	12.3	-0.25	12.0

Notes: (1) Bold values within the shaded cells (green) correspond to locations where there is less than three feet of freeboard and the EIP causes an increase in water surface elevation. (2) Differences near the downstream boundary (RA19 through RA22) are very unlikely, so the results are suspect. A more detailed evaluation of the model results at the downstream boundary should be completed for any future evaluation.

Table 23. Deterministic Analysis Results for Feather River No. 1 EIP.

Index Location	River	Reach	River Station	0.02 Exceedance Probability Flood (50-yr)		0.01 Exceedance Probability Flood (100-yr)		0.005 Exceedance Probability Flood (200-yr)		0.002 Exceedance Probability Flood (500-yr)	
				Change in WS Elev. (ft)	Freeboard (ft)	Change in WS Elev. (ft)	Freeboard (ft)	Change in WS Elev. (ft)	Freeboard (ft)	Change in WS Elev. (ft)	Freeboard (ft)
RA01	Feather River	Honcut to Jack	42.24	-0.10	8.7	-0.07	7.8	-0.37	6.4	**0.04**	**-0.2**
RA02	Yuba River	Upper	7.00	0.00	1.4	-0.01	0.3	0.00	-1.8	-0.01	-2.7
RA03	Feather River	Jack Slough - Yuba River	29.00	-0.53	9.6	-0.62	7.7	-0.79	5.0	-0.11	0.0
RA04	Sutter Bypass	Butte Slough - Wads	88.60	0.00	2.7	0.00	0.8	0.00	-0.9	0.00	-1.4
RA05	Sacramento River	Colusa-Feather	119.75	0.01	3.8	0.00	2.5	-0.01	1.9	-0.02	1.2
RA06	Bear River	Lower	1.75	0.04	3.1	**0.04**	**2.0**	**0.04**	**0.7**	**0.26**	**-1.1**
RA07	Feather River	Reach 35	9.00	0.05	8.5	0.05	7.3	0.05	5.7	0.38	3.8
RA08	Sacramento River	Colusa-Feather	90.00	**0.02**	**0.4**	**0.02**	**-0.7**	**0.01**	**-1.2**	**0.04**	**-1.4**
RA09	Sacramento River	Colusa-Feather	86.50	**0.02**	**1.8**	**0.02**	**0.7**	**0.01**	**0.1**	**0.08**	**-0.3**
RA10	Sacramento River	NCC to NEMDC	79.21	**0.02**	**2.9**	**0.02**	**1.8**	**0.01**	**1.2**	**0.07**	**0.8**
RA11	Sacramento River	NCC to NEMDC	76.25	0.02	3.6	**0.02**	**2.3**	**0.01**	**1.8**	**0.06**	**1.5**
RA12	Yolo Bypass	KRLC to SacBP	48.84	0.03	4.9	0.01	3.4	0.00	3.1	**0.03**	**2.8**
RA13	Sacramento River	NCC to NEMDC	63.82	-0.01	6.6	0.01	4.3	-0.02	3.1	**0.02**	**2.3**
RA14	American River	Reach 1	11.00	0.00	15.3	0.00	8.6	0.00	-3.1	0.00	-3.7
RA15	American River	Reach 1	3.75	-0.02	13.6	0.01	9.5	-0.01	4.4	0.06	4.2
RA16	Sacramento River	DS American	59.75	0.01	7.9	0.01	5.0	-0.01	3.5	**0.03**	**2.5**
RA17	Sacramento River	DS American	46.50	0.01	7.4	0.01	4.8	-0.02	3.7	**0.02**	**2.9**
RA18	Sacramento River	DS American	36.50	0.01	6.2	0.00	4.2	-0.01	3.6	0.00	3.2
RA19	Sutter Slough	Lower Reach	25.23	0.02	7.7	0.02	6.8	0.00	6.5	0.64	6.1
RA20	Georgiana Slough	Reach	12.36	0.01	6.7	0.00	5.2	-0.02	4.9	0.00	5.1
RA21	Miner Slough	Reach 1	19.11	0.01	5.0	0.02	4.5	0.01	4.6	1.01	3.4
RA22	Sacramento River	RM 14.6 to 26.5	14.75	0.01	13.3	0.00	12.5	0.00	12.3	-0.30	12.1

Notes: (1) Bold values within the shaded cells (green) correspond to locations where there is less than three feet of freeboard and the EIP causes an increase in water surface elevation. (2) Differences near the downstream boundary (RA19 through RA22) are very unlikely, so the results are suspect. A more detailed evaluation of the model results at the downstream boundary should be completed for any future evaluation.

Table 24. Deterministic Analysis Results for Bear River and Feather River No. 1 EIPs.

Index Location	River	Reach	River Station	0.02 Exceedance Probability Flood (50-yr) Change in WS Elev. (ft)	0.02 Exceedance Probability Flood (50-yr) Freeboard (ft)	0.01 Exceedance Probability Flood (100-yr) Change in WS Elev. (ft)	0.01 Exceedance Probability Flood (100-yr) Freeboard (ft)	0.005 Exceedance Probability Flood (200-yr) Change in WS Elev. (ft)	0.005 Exceedance Probability Flood (200-yr) Freeboard (ft)	0.002 Exceedance Probability Flood (500-yr) Change in WS Elev. (ft)	0.002 Exceedance Probability Flood (500-yr) Freeboard (ft)
RA01	Feather River	Honcut to Jack	42.24	-0.10	8.7	-0.07	7.8	-0.37	6.4	**0.03**	**-0.1**
RA02	Yuba River	Upper	7.00	0.00	1.4	-0.01	0.3	0.00	-1.8	-0.01	-2.7
RA03	Feather River	Jack Slough - Yuba River	29.00	-0.53	9.6	-0.62	7.7	-0.79	5.0	-0.11	0.0
RA04	Sutter Bypass	Butte Slough - Wads	88.60	0.00	2.7	0.00	0.8	**-0.01**	**-0.8**	0.00	-1.4
RA05	Sacramento River	Colusa-Feather	119.75	0.01	3.8	**0.01**	**2.5**	-0.01	1.9	**-0.01**	**1.2**
RA06	Bear River	Lower	1.75	-0.53	5.9	-0.40	4.6	-0.09	3.0	**0.92**	**0.4**
RA07	Feather River	Reach 35	9.00	0.11	8.4	0.15	7.2	0.11	5.6	0.62	3.6
RA08	Sacramento River	Colusa-Feather	90.00	**0.03**	**0.4**	**0.04**	**-0.7**	**0.01**	**-1.2**	**0.07**	**-1.5**
RA09	Sacramento River	Colusa-Feather	86.50	**0.04**	**1.8**	**0.05**	**0.7**	**0.02**	**0.1**	**0.13**	**-0.4**
RA10	Sacramento River	NCC to NEMDC	79.21	**0.05**	**2.9**	**0.06**	**1.8**	**0.02**	**1.1**	**0.11**	**0.8**
RA11	Sacramento River	NCC to NEMDC	76.25	0.05	3.5	**0.06**	**2.3**	**0.03**	**1.7**	**0.09**	**1.5**
RA12	Yolo Bypass	KRLC to SacBP	48.84	0.05	4.8	0.04	3.3	0.01	3.1	**0.04**	**2.8**
RA13	Sacramento River	NCC to NEMDC	63.82	-0.01	6.6	0.03	4.3	-0.03	3.1	**0.02**	**2.3**
RA14	American River	Reach 1	11.00	0.00	15.3	0.00	8.6	0.00	-3.1	0.00	-3.7
RA15	American River	Reach 1	3.75	-0.02	13.6	0.02	9.4	-0.01	4.4	0.06	4.2
RA16	Sacramento River	DS American	59.75	0.03	7.9	0.03	5.0	-0.02	3.5	**0.02**	**2.5**
RA17	Sacramento River	DS American	46.50	0.04	7.4	0.02	4.8	-0.03	3.8	**0.02**	**2.9**
RA18	Sacramento River	DS American	36.50	0.03	6.2	0.02	4.2	-0.02	3.6	0.00	3.2
RA19	Sutter Slough	Lower Reach	25.23	0.05	7.7	0.01	6.8	0.00	6.5	0.04	6.7
RA20	Georgiana Slough	Reach	12.36	0.00	6.7	0.01	5.2	-0.02	4.9	0.00	5.1
RA21	Miner Slough	Reach 1	19.11	0.02	5.0	0.01	4.5	0.01	4.6	0.05	4.4
RA22	Sacramento River	RM 14.6 to 26.5	14.75	0.01	13.3	0.00	12.5	0.01	12.3	-0.30	12.1

Notes: (1) Bold values within the shaded cells (green) correspond to locations where there is less than three feet of freeboard and the EIP causes an increase in water surface elevation. (2) Differences near the downstream boundary (RA19 through RA22) are very unlikely, so the results are suspect. A more detailed evaluation of the model results at the downstream boundary should be completed for any future evaluation.

Table 25. Deterministic Analysis Results for Feather River No. 2 (Star Bend) EIP.

Index Location	River	Reach	River Station	0.02 Exceedance Probability Flood (50-yr)		0.01 Exceedance Probability Flood 100-yr)		0.005 Exceedance Probability Flood (200-yr)		0.002 Exceedance Probability Flood (500-yr)	
				Change in WS Elev. (ft)	Freeboard (ft)	Change in WS Elev. (ft)	Freeboard (ft)	Change in WS Elev. (ft)	Freeboard (ft)	Change in WS Elev. (ft)	Freeboard (ft)
RA01	Feather River	Honcut to Jack	42.24	0.00	8.6	0.00	7.7	0.00	6.0	0.00	-0.1
RA02	Yuba River	Upper	7.00	0.00	1.4	0.00	0.2	0.00	-1.8	0.00	-2.7
RA03	Feather River	Jack Slough - Yuba River	29.00	0.00	9.0	0.00	7.1	0.00	4.2	0.00	-0.2
RA04	Sutter Bypass	Butte Slough - Wads	88.60	0.00	2.7	0.00	0.8	0.00	-0.9	0.00	-1.4
RA05	Sacramento River	Colusa-Feather	119.75	0.00	3.8	0.00	2.5	0.00	1.9	0.00	1.2
RA06	Bear River	Lower	1.75	0.00	5.3	0.00	4.2	-0.01	2.9	0.00	1.3
RA07	Feather River	Reach 35	9.00	0.00	8.5	0.00	7.3	0.00	5.7	0.00	4.2
RA08	Sacramento River	Colusa-Feather	90.00	**0.01**	**0.4**	0.00	-0.7	0.00	-1.2	0.00	-1.4
RA09	Sacramento River	Colusa-Feather	86.50	0.00	1.8	0.00	0.8	0.00	0.1	0.00	-0.3
RA10	Sacramento River	NCC to NEMDC	79.21	0.00	2.9	0.00	1.9	0.00	1.2	0.00	0.9
RA11	Sacramento River	NCC to NEMDC	76.25	0.00	3.6	0.00	2.4	0.00	1.8	0.00	1.6
RA12	Yolo Bypass	KRLC to SacBP	48.84	0.01	4.9	0.00	3.4	0.00	3.1	0.00	2.8
RA13	Sacramento River	NCC to NEMDC	63.82	0.00	6.6	0.00	4.3	0.00	3.1	0.03	2.2
RA14	American River	Reach 1	11.00	0.00	15.3	0.00	8.6	0.00	-3.1	0.00	-3.7
RA15	American River	Reach 1	3.75	0.00	13.6	0.00	9.5	0.00	4.4	0.06	4.2
RA16	Sacramento River	DS American	59.75	0.00	7.9	0.00	5.0	0.00	3.5	**0.04**	**2.5**
RA17	Sacramento River	DS American	46.50	0.00	7.5	0.00	4.8	0.00	3.7	**0.04**	**2.8**
RA18	Sacramento River	DS American	36.50	0.00	6.2	-0.01	4.2	-0.01	3.6	0.02	3.1
RA19	Sutter Slough	Lower Reach	25.23	0.00	7.7	0.00	6.8	0.00	6.5	0.00	6.8
RA20	Georgiana Slough	Reach	12.36	0.00	6.7	-0.02	5.2	0.00	4.9	0.02	5.1
RA21	Miner Slough	Reach 1	19.11	0.00	5.0	0.00	4.5	0.00	4.6	0.00	4.5
RA22	Sacramento River	RM 14.6 to 26.5	14.75	0.00	13.3	-0.03	12.5	0.00	12.3	0.00	11.8

Notes: (1) Bold values within the shaded cells (green) correspond to locations where there is less than three feet of freeboard and the EIP causes an increase in water surface elevation. (2) Differences near the downstream boundary (RA19 through RA22) are very unlikely, so the results are suspect. A more detailed evaluation of the model results at the downstream boundary should be completed for any future evaluation.

Table 26. Deterministic Analysis Results for Bear River, Feather River No.1, and Feather River No. 2 (Star Bend) EIPs.

Index Location	River	Reach	River Station	0.02 Exceedance Probability Flood (50-yr)		0.01 Exceedance Probability Flood (100-yr)		0.005 Exceedance Probability Flood (200-yr)		0.002 Exceedance Probability Flood (500-yr)	
				Change in WS Elev. (ft)	Freeboard (ft)	Change in WS Elev. (ft)	Freeboard (ft)	Change in WS Elev. (ft)	Freeboard (ft)	Change in WS Elev. (ft)	Freeboard (ft)
RA01	Feather River	Honcut to Jack	42.24	-0.10	8.7	-0.07	7.8	-0.37	6.4	**0.03**	**-0.1**
RA02	Yuba River	Upper	7.00	0.00	1.4	-0.01	0.3	0.00	-1.8	-0.01	-2.7
RA03	Feather River	Jack Slough - Yuba River	29.00	-0.53	9.6	-0.62	7.7	-0.80	5.0	-0.11	0.0
RA04	Sutter Bypass	Butte Slough - Wads	88.60	0.00	2.7	0.00	0.8	**-0.01**	**-0.8**	0.00	-1.4
RA05	Sacramento River	Colusa-Feather	119.75	0.01	3.8	**0.01**	**2.5**	-0.01	1.9	**-0.01**	**1.2**
RA06	Bear River	Lower	1.75	-0.53	5.9	-0.40	4.6	-0.09	3.0	**0.92**	**0.4**
RA07	Feather River	Reach 35	9.00	0.11	8.4	0.15	7.2	0.11	5.6	0.62	3.6
RA08	Sacramento River	Colusa-Feather	90.00	**0.04**	**0.4**	**0.04**	**-0.7**	**0.01**	**-1.2**	**0.07**	**-1.5**
RA09	Sacramento River	Colusa-Feather	86.50	**0.04**	**1.8**	**0.05**	**0.7**	**0.02**	**0.1**	**0.13**	**-0.4**
RA10	Sacramento River	NCC to NEMDC	79.21	**0.06**	**2.9**	**0.06**	**1.8**	**0.02**	**1.1**	**0.11**	**0.8**
RA11	Sacramento River	NCC to NEMDC	76.25	0.05	3.5	**0.06**	**2.3**	**0.03**	**1.7**	**0.09**	**1.5**
RA12	Yolo Bypass	KRLC to SacBP	48.84	0.06	4.8	0.04	3.3	0.02	3.1	**0.04**	**2.8**
RA13	Sacramento River	NCC to NEMDC	63.82	-0.01	6.6	0.03	4.3	-0.03	3.1	**0.02**	**2.3**
RA14	American River	Reach 1	11.00	0.00	15.3	0.00	8.6	0.00	-3.1	0.00	-3.7
RA15	American River	Reach 1	3.75	-0.02	13.6	0.02	9.4	-0.01	4.4	0.06	4.2
RA16	Sacramento River	DS American	59.75	0.03	7.9	0.03	5.0	-0.02	3.5	**0.02**	**2.5**
RA17	Sacramento River	DS American	46.50	0.04	7.4	0.02	4.8	-0.03	3.8	**0.02**	**2.9**
RA18	Sacramento River	DS American	36.50	0.02	6.2	0.02	4.2	-0.02	3.6	-0.01	3.2
RA19	Sutter Slough	Lower Reach	25.23	0.05	7.7	0.01	6.8	0.00	6.5	0.04	6.7
RA20	Georgiana Slough	Reach	12.36	0.01	6.7	0.01	5.2	-0.02	4.9	0.00	5.1
RA21	Miner Slough	Reach 1	19.11	0.02	5.0	0.01	4.5	0.01	4.6	0.06	4.4
RA22	Sacramento River	RM 14.6 to 26.5	14.75	0.01	13.3	0.00	12.5	0.01	12.3	-0.30	12.1

Notes: (1) Bold values within the shaded cells (green) correspond to locations where there is less than three feet of freeboard and the EIP causes an increase in water surface elevation. (2) Differences near the downstream boundary (RA19 through RA22) are very unlikely, so the results are suspect. A more detailed evaluation of the model results at the downstream boundary should be completed for any future evaluation.

Table 27. Deterministic Analysis Results for Natomas EIP.

Index Location	River	Reach	River Station	0.02 Exceedance Probability Flood (50-yr) Change in WS Elev. (ft)	0.02 Exceedance Probability Flood (50-yr) Freeboard (ft)	0.01 Exceedance Probability Flood (100-yr) Change in WS Elev. (ft)	0.01 Exceedance Probability Flood (100-yr) Freeboard (ft)	0.005 Exceedance Probability Flood (200-yr) Change in WS Elev. (ft)	0.005 Exceedance Probability Flood (200-yr) Freeboard (ft)	0.002 Exceedance Probability Flood (500-yr) Change in WS Elev. (ft)	0.002 Exceedance Probability Flood (500-yr) Freeboard (ft)
RA01	Feather River	Honcut to Jack	42.24	0.00	8.6	0.00	7.7	0.00	6.0	0.00	-0.1
RA02	Yuba River	Upper	7.00	0.00	1.4	0.00	0.2	0.00	-1.8	0.00	-2.7
RA03	Feather River	Jack Slough - Yuba River	29.00	0.00	9.0	0.00	7.1	0.00	4.2	0.00	-0.2
RA04	Sutter Bypass	Butte Slough - Wads	88.60	0.00	2.7	0.00	0.8	-0.01	-0.8	0.00	-1.4
RA05	Sacramento River	Colusa-Feather	119.75	0.00	3.8	0.00	2.5	-0.02	1.9	0.00	1.2
RA06	Bear River	Lower	1.75	0.00	5.3	0.00	4.2	0.00	2.9	**0.01**	**1.3**
RA07	Feather River	Reach 35	9.00	0.00	8.5	0.01	7.3	0.03	5.7	0.04	4.2
RA08	Sacramento River	Colusa-Feather	90.00	0.00	0.4	**0.03**	**-0.7**	**0.06**	**-1.3**	**0.13**	**-1.5**
RA09	Sacramento River	Colusa-Feather	86.50	0.00	1.8	**0.04**	**0.7**	**0.13**	**0.0**	**0.28**	**-0.5**
RA10	Sacramento River	NCC to NEMDC	79.21	0.00	7.1	0.06	5.9	0.33	5.0	0.76	4.3
RA11	Sacramento River	NCC to NEMDC	76.25	-0.01	6.8	0.06	5.5	0.31	4.7	0.78	4.0
RA12	Yolo Bypass	KRLC to SacBP	48.84	-0.01	4.9	0.02	3.4	0.02	3.1	**0.36**	**2.4**
RA13	Sacramento River	NCC to NEMDC	63.82	0.00	6.6	0.02	4.3	0.00	3.1	**0.17**	**2.1**
RA14	American River	Reach 1	11.00	0.00	15.3	0.00	8.6	0.00	-3.1	0.00	-3.7
RA15	American River	Reach 1	3.75	-0.09	13.7	0.02	9.4	0.00	4.4	0.12	4.1
RA16	Sacramento River	DS American	59.75	-0.09	8.0	0.03	5.0	0.00	3.5	**0.16**	**2.4**
RA17	Sacramento River	DS American	46.50	-0.06	7.5	0.02	4.8	0.00	3.7	**0.19**	**2.7**
RA18	Sacramento River	DS American	36.50	-0.05	6.3	0.02	4.2	0.00	3.6	0.18	3.0
RA19	Sutter Slough	Lower Reach	25.23	-0.02	7.7	0.01	6.8	0.00	6.5	0.96	5.8
RA20	Georgiana Slough	Reach	12.36	-0.02	6.7	0.01	5.2	0.01	4.9	0.65	4.4
RA21	Miner Slough	Reach 1	19.11	-0.02	5.0	0.00	4.5	0.00	4.6	0.69	3.8
RA22	Sacramento River	RM 14.6 to 26.5	14.75	-0.04	13.3	0.00	12.5	0.07	12.2	0.53	11.3

Notes: (1) Bold values within the shaded cells (green) correspond to locations where there is less than three feet of freeboard and the EIP causes an increase in water surface elevation. (2) Differences near the downstream boundary (RA19 through RA22) are very unlikely, so the results are suspect. A more detailed evaluation of the hydraulic model results at the downstream boundary should be completed for any future evaluation. A review of the results for the 0.002 exceedance probability event also indicates that the results are suspect for that event. Although the hydraulic model runs without crashing, but the results indicate problems with the solution.

Table 28. Deterministic Analysis Results for Bear River, Feather River No.1, Feather River No. 2 (Star Bend), and Natomas EIPs.

Index Location	River	Reach	River Station	0.02 Exceedance Probability Flood (50-yr)		0.01 Exceedance Probability Flood (100-yr)		0.005 Exceedance Probability Flood (200-yr)		0.002 Exceedance Probability Flood (500-yr)	
				Change in WS Elev. (ft)	Freeboard (ft)	Change in WS Elev. (ft)	Freeboard (ft)	Change in WS Elev. (ft)	Freeboard (ft)	Change in WS Elev. (ft)	Freeboard (ft)
RA01	Feather River	Honcut to Jack	42.24	-0.10	8.7	-0.07	7.8	-0.37	6.4	**0.03**	**-0.1**
RA02	Yuba River	Upper	7.00	0.00	1.4	-0.01	0.3	0.00	-1.8	-0.01	-2.7
RA03	Feather River	Jack Slough - Yuba River	29.00	-0.53	9.6	-0.62	7.7	-0.80	5.0	-0.11	0.0
RA04	Sutter Bypass	Butte Slough - Wads	88.60	0.00	2.7	0.00	0.8	**-0.01**	**-0.8**	0.00	-1.4
RA05	Sacramento River	Colusa-Feather	119.75	0.01	3.8	**0.02**	**2.5**	-0.03	2.0	0.00	1.2
RA06	Bear River	Lower	1.75	-0.53	5.9	-0.40	4.6	-0.08	3.0	**0.94**	**0.4**
RA07	Feather River	Reach 35	9.00	0.11	8.4	0.15	7.2	0.15	5.6	0.67	3.5
RA08	Sacramento River	Colusa-Feather	90.00	**0.04**	**0.4**	**0.08**	**-0.8**	**0.08**	**-1.3**	**0.19**	**-1.6**
RA09	Sacramento River	Colusa-Feather	86.50	**0.04**	**1.8**	**0.10**	**0.7**	**0.16**	**-0.1**	**0.43**	**-0.7**
RA10	Sacramento River	NCC to NEMDC	79.21	0.06	7.0	0.13	5.9	0.38	4.9	1.03	4.0
RA11	Sacramento River	NCC to NEMDC	76.25	0.05	6.7	0.13	5.5	0.35	4.6	1.02	3.8
RA12	Yolo Bypass	KRLC to SacBP	48.84	0.06	4.8	0.06	3.3	0.04	3.1	**0.55**	**2.3**
RA13	Sacramento River	NCC to NEMDC	63.82	-0.01	6.6	0.05	4.2	-0.03	3.1	**0.16**	**2.1**
RA14	American River	Reach 1	11.00	0.00	15.3	0.00	8.6	0.00	-3.1	0.00	-3.7
RA15	American River	Reach 1	3.75	-0.02	13.6	0.04	9.4	-0.01	4.4	0.11	4.1
RA16	Sacramento River	DS American	59.75	0.03	7.9	0.05	5.0	-0.02	3.5	**0.15**	**2.4**
RA17	Sacramento River	DS American	46.50	0.04	7.4	0.05	4.8	-0.03	3.8	**0.17**	**2.7**
RA18	Sacramento River	DS American	36.50	0.02	6.2	0.04	4.2	-0.02	3.6	0.16	3.0
RA19	Sutter Slough	Lower Reach	25.23	0.05	7.7	0.02	6.8	0.00	6.5	1.00	5.8
RA20	Georgiana Slough	Reach	12.36	0.01	6.7	0.03	5.2	-0.01	4.9	0.68	4.4
RA21	Miner Slough	Reach 1	19.11	0.02	5.0	0.01	4.5	0.01	4.6	0.75	3.7
RA22	Sacramento River	RM 14.6 to 26.5	14.75	0.01	13.3	0.01	12.5	0.09	12.2	0.48	11.3

Notes: (1) Bold values within the shaded cells (green) correspond to locations where there is less than three feet of freeboard and the EIP causes an increase in water surface elevation. (2) Differences near the downstream boundary (RA19 through RA22) are very unlikely, so the results are suspect. A more detailed evaluation of the model results at the downstream boundary should be completed for any future evaluation.

Table 29. Comparison of Change in Water Surface Elevations for the EIPs (0.01 Exceedance Probability Flood).

Index Location	River	Reach	River Station	Bear (B) EIP	Feather No. 1 (F) EIP	BF EIP	Feather No. 2 (SB) EIP	BFSB EIP	Natomas (N) EIP	BFSBN EIP
RA01	Feather River	Honcut to Jack	42.24	0.00	-0.07	-0.07	0.00	-0.07	0.00	-0.07
RA02	Yuba River	Upper	7.00	0.00	-0.01	-0.01	0.00	-0.01	0.00	-0.01
RA03	Feather River	Jack Slough - Yuba River	29.00	0.00	-0.62	-0.62	0.00	-0.62	0.00	-0.62
RA04	Sutter Bypass	Butte Slough - Wads	88.60	0.00	0.00	0.00	0.00	0.00	0.00	0.00
RA05	Sacramento River	Colusa-Feather	119.75	0.00	0.00	**0.01**	0.00	**0.01**	0.00	**0.02**
RA06	Bear River	Lower	1.75	-0.45	**0.04**	-0.40	0.00	-0.40	0.00	-0.40
RA07	Feather River	Reach 35	9.00	**0.10**	**0.05**	**0.15**	0.00	**0.15**	**0.01**	**0.15**
RA08	Sacramento River	Colusa-Feather	90.00	**0.02**	**0.02**	**0.04**	0.00	**0.04**	**0.03**	**0.08**
RA09	Sacramento River	Colusa-Feather	86.50	**0.03**	**0.02**	**0.05**	0.00	**0.05**	**0.04**	**0.10**
RA10	Sacramento River	NCC to NEMDC	79.21	**0.03**	**0.02**	**0.06**	0.00	**0.06**	**0.06**	**0.13**
RA11	Sacramento River	NCC to NEMDC	76.25	**0.04**	**0.02**	**0.06**	0.00	**0.06**	**0.06**	**0.13**
RA12	Yolo Bypass	KRLC to SacBP	48.84	**0.02**	**0.01**	**0.04**	0.00	**0.04**	**0.02**	**0.06**
RA13	Sacramento River	NCC to NEMDC	63.82	**0.02**	**0.01**	**0.03**	0.00	**0.03**	**0.02**	**0.05**
RA14	American River	Reach 1	11.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
RA15	American River	Reach 1	3.75	**0.01**	**0.01**	**0.02**	0.00	**0.02**	**0.02**	**0.04**
RA16	Sacramento River	DS American	59.75	**0.02**	**0.01**	**0.03**	0.00	**0.03**	**0.03**	**0.05**
RA17	Sacramento River	DS American	46.50	**0.01**	**0.01**	**0.02**	0.00	**0.02**	**0.02**	**0.05**
RA18	Sacramento River	DS American	36.50	0.00	0.00	**0.02**	-0.01	**0.02**	**0.02**	**0.04**
RA19	Sutter Slough	Lower Reach	25.23	-0.01	**0.02**	**0.01**	0.00	**0.01**	**0.01**	**0.02**
RA20	Georgiana Slough	Reach	12.36	0.00	0.00	**0.01**	-0.02	**0.01**	**0.01**	**0.03**
RA21	Miner Slough	Reach 1	19.11	-0.02	**0.02**	**0.01**	0.00	**0.01**	0.00	**0.01**
RA22	Sacramento River	RM 14.6 to 26.5	14.75	-0.02	0.00	0.00	-0.03	0.00	0.00	**0.01**

Notes: (1) Bold values within the shaded cells (green) correspond to locations where there is less than three feet of freeboard and the EIP causes an increase in water surface elevation. (2) Differences near the downstream boundary (RA19 through RA22) are very unlikely, so the results are suspect. A more detailed evaluation of the model results at the downstream boundary should be completed for any future evaluation.

Table 30. Comparison of Change in Water Surface Elevations for the EIPs (0.005 Exceedance Probability Flood).

Index Location	River	Reach	River Station	Bear (B) EIP	Feather No. 1 (F) EIP	BF EIP	Feather No. 2 (SB) EIP	BFSB EIP	Natomas (N) EIP	BFSBN EIP
RA01	Feather River	Honcut to Jack	42.24	0.00	-0.37	-0.37	0.00	-0.37	0.00	-0.37
RA02	Yuba River	Upper	7.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
RA03	Feather River	Jack Slough - Yuba River	29.00	0.00	-0.79	-0.79	0.00	-0.80	0.00	-0.80
RA04	Sutter Bypass	Butte Slough - Wads	88.60	0.00	0.00	-0.01	0.00	-0.01	-0.01	-0.01
RA05	Sacramento River	Colusa-Feather	119.75	-0.01	-0.01	-0.01	0.00	-0.01	-0.02	-0.03
RA06	Bear River	Lower	1.75	-0.15	**0.04**	-0.09	-0.01	-0.09	0.00	-0.08
RA07	Feather River	Reach 35	9.00	**0.06**	**0.05**	**0.11**	0.00	**0.11**	**0.03**	**0.15**
RA08	Sacramento River	Colusa-Feather	90.00	**0.01**	**0.01**	**0.01**	0.00	**0.01**	**0.06**	**0.08**
RA09	Sacramento River	Colusa-Feather	86.50	**0.01**	**0.01**	**0.02**	0.00	**0.02**	**0.13**	**0.16**
RA10	Sacramento River	NCC to NEMDC	79.21	**0.01**	**0.01**	**0.02**	0.00	**0.02**	**0.33**	**0.38**
RA11	Sacramento River	NCC to NEMDC	76.25	**0.02**	**0.01**	**0.03**	0.00	**0.03**	**0.31**	**0.35**
RA12	Yolo Bypass	KRLC to SacBP	48.84	**0.01**	0.00	**0.01**	0.00	**0.02**	**0.02**	**0.04**
RA13	Sacramento River	NCC to NEMDC	63.82	-0.01	-0.02	-0.03	0.00	-0.03	0.00	-0.03
RA14	American River	Reach 1	11.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
RA15	American River	Reach 1	3.75	0.00	-0.01	-0.01	0.00	-0.01	0.00	-0.01
RA16	Sacramento River	DS American	59.75	0.00	-0.01	-0.02	0.00	-0.02	0.00	-0.02
RA17	Sacramento River	DS American	46.50	-0.01	-0.02	-0.03	0.00	-0.03	0.00	-0.03
RA18	Sacramento River	DS American	36.50	-0.01	-0.01	-0.02	-0.01	-0.02	0.00	-0.02
RA19	Sutter Slough	Lower Reach	25.23	-0.01	0.00	0.00	0.00	0.00	0.00	0.00
RA20	Georgiana Slough	Reach	12.36	**0.02**	-0.02	-0.02	0.00	-0.02	**0.01**	-0.01
RA21	Miner Slough	Reach 1	19.11	0.00	**0.01**	**0.01**	0.00	**0.01**	0.00	**0.01**
RA22	Sacramento River	RM 14.6 to 26.5	14.75	0.00	0.00	**0.01**	0.00	**0.01**	**0.07**	**0.09**

Notes: (1) Bold values within the shaded cells (green) correspond to locations where there is less than three feet of freeboard and the EIP causes an increase in water surface elevation. (2) Differences near the downstream boundary (RA19 through RA22) are very unlikely, so the results are suspect. A more detailed evaluation of the model results at the downstream boundary should be completed for any future evaluation.

Table 31. Comparison of Change in Water Surface Elevations for the EIPs (0.002 Exceedance Probability Flood).

Index Location	River	Reach	River Station	Bear (B) EIP	Feather No. 1 (F) EIP	BF EIP	Feather No. 2 (SB) EIP	BFSB EIP	Natomas (N) EIP	BFSBN EIP
RA01	Feather River	Honcut to Jack	42.24	0.00	**0.04**	0.03	0.00	**0.03**	0.00	**0.03**
RA02	Yuba River	Upper	7.00	0.00	-0.01	-0.01	0.00	-0.01	0.00	-0.01
RA03	Feather River	Jack Slough - Yuba River	29.00	0.00	-0.11	-0.11	0.00	-0.11	0.00	-0.11
RA04	Sutter Bypass	Butte Slough - Wads	88.60	0.00	0.00	0.00	0.00	0.00	0.00	0.00
RA05	Sacramento River	Colusa-Feather	119.75	-0.01	-0.02	-0.01	0.00	-0.01	0.00	0.00
RA06	Bear River	Lower	1.75	**0.41**	**0.26**	**0.92**	0.00	**0.92**	**0.01**	**0.94**
RA07	Feather River	Reach 35	9.00	**0.15**	**0.38**	**0.62**	0.00	**0.62**	**0.04**	**0.67**
RA08	Sacramento River	Colusa-Feather	90.00	**0.02**	**0.04**	**0.07**	0.00	**0.07**	**0.13**	**0.19**
RA09	Sacramento River	Colusa-Feather	86.50	**0.03**	**0.08**	**0.13**	0.00	**0.13**	**0.28**	**0.43**
RA10	Sacramento River	NCC to NEMDC	79.21	**0.02**	**0.07**	**0.11**	0.00	**0.11**	**0.76**	**1.03**
RA11	Sacramento River	NCC to NEMDC	76.25	**0.02**	**0.06**	**0.09**	0.00	**0.09**	**0.78**	**1.02**
RA12	Yolo Bypass	KRLC to SacBP	48.84	**0.02**	**0.03**	**0.04**	0.00	**0.04**	**0.36**	**0.55**
RA13	Sacramento River	NCC to NEMDC	63.82	**0.03**	**0.02**	**0.02**	**0.03**	**0.02**	**0.17**	**0.16**
RA14	American River	Reach 1	11.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
RA15	American River	Reach 1	3.75	**0.06**	**0.06**	**0.06**	**0.06**	**0.06**	**0.12**	**0.11**
RA16	Sacramento River	DS American	59.75	**0.03**	**0.03**	**0.02**	**0.04**	**0.02**	**0.16**	**0.15**
RA17	Sacramento River	DS American	46.50	**0.04**	**0.02**	**0.02**	**0.04**	**0.02**	**0.19**	**0.17**
RA18	Sacramento River	DS American	36.50	**0.02**	**0.00**	**0.00**	**0.02**	-0.01	**0.18**	**0.16**
RA19	Sutter Slough	Lower Reach	25.23	**0.01**	**0.64**	**0.04**	0.00	**0.04**	**0.96**	**1.00**
RA20	Georgiana Slough	Reach	12.36	**0.02**	0.00	0.00	**0.02**	0.00	**0.65**	**0.68**
RA21	Miner Slough	Reach 1	19.11	0.00	**1.01**	**0.05**	0.00	**0.06**	**0.69**	**0.75**
RA22	Sacramento River	RM 14.6 to 26.5	14.75	-0.25	-0.30	-0.30	0.00	-0.30	**0.53**	**0.48**

Notes: (1) Bold values within the shaded cells (green) correspond to locations where there is less than three feet of freeboard and the EIP causes an increase in water surface elevation. (2) The freeboard values in the above table do not take into account the level of accuracy associated with the top of levee elevations. (3) Differences near the downstream boundary (RA19 through RA22) are very unlikely, so the results are suspect. A more detailed evaluation of the model results at the downstream boundary should be completed for any future evaluation.

probability floods, respectively. These tables show that the cumulative effect is important for the evaluation of the separate EIPs. For several index locations the changes in water surface elevations for separate EIPs are additive. For example, the change in water surface elevation at Index Location RA07 for the 0.005 exceedance probability flood is 0.05 feet for the Bear River EIP, 0.1 feet for the Feather River EIP, and 0.15 feet for the two EIPs in-place. Therefore, it is important for future evaluations that a baseline condition, which is based on the conditions prior to the first EIP, be adopted for future evaluations and that the evaluation of the EIP be evaluated separately and combined with all other EIPs in-place.

3.3 Comparison of Risk Analysis and Deterministic Results

A comparison was made of results from the risk analysis and deterministic evaluations in an attempt to understand how uncertainties impact the performance indices as compared to a strict deterministic difference. The comparison was also intended to demonstrate the similarities or differences in result trends. Where overtopping occurs for events equal to or less than the 0.002 exceedance probability event, the probability of overtopping computed from the deterministic evaluation was compared to the median AEP from the risk analysis. It should be noted the median AEP is computed directly from the inflow discharge-exceedance probability, inflow-outflow, and stage-discharge relationships defined at each of the index locations, and does not include the uncertainty in these relationships. Noticeable differences would be seen if the expected AEP was used in lieu of the median AEP due to the consideration of uncertainty. The results from the comparison are provided in Table 32. As shown in the table, the values are approximately the same for the two approaches and the locations where potential impacts exist are the same for the two approaches. The table also shows the cumulative effects when considering multiple EIPs for both approaches. For example, the AEP at Index Location R08 is 0.0154 for the Bear River EIP, 0.0155 for Feather River EIP, 0.0156 when considering both of these EIPs in-place, and 0.0158 when considering all of the EIPs in-place.

To highlight comparisons of the two approaches, results are presented graphically at select index locations in Figures 8 through 10. The risk analysis results (median AEP, expected AEP, assurance (CNP)) for various flood events, return interval for the 90% assurance of containment), and the deterministic results (overtopping probability, freeboard for various flood events, changes in water surface elevations for various flood events) are shown in Figures 8 through 10, for Index Locations RA09, RA16, and RA20, respectively. The comparison at these select locations indicates that the general trends from the two approaches are consistent.

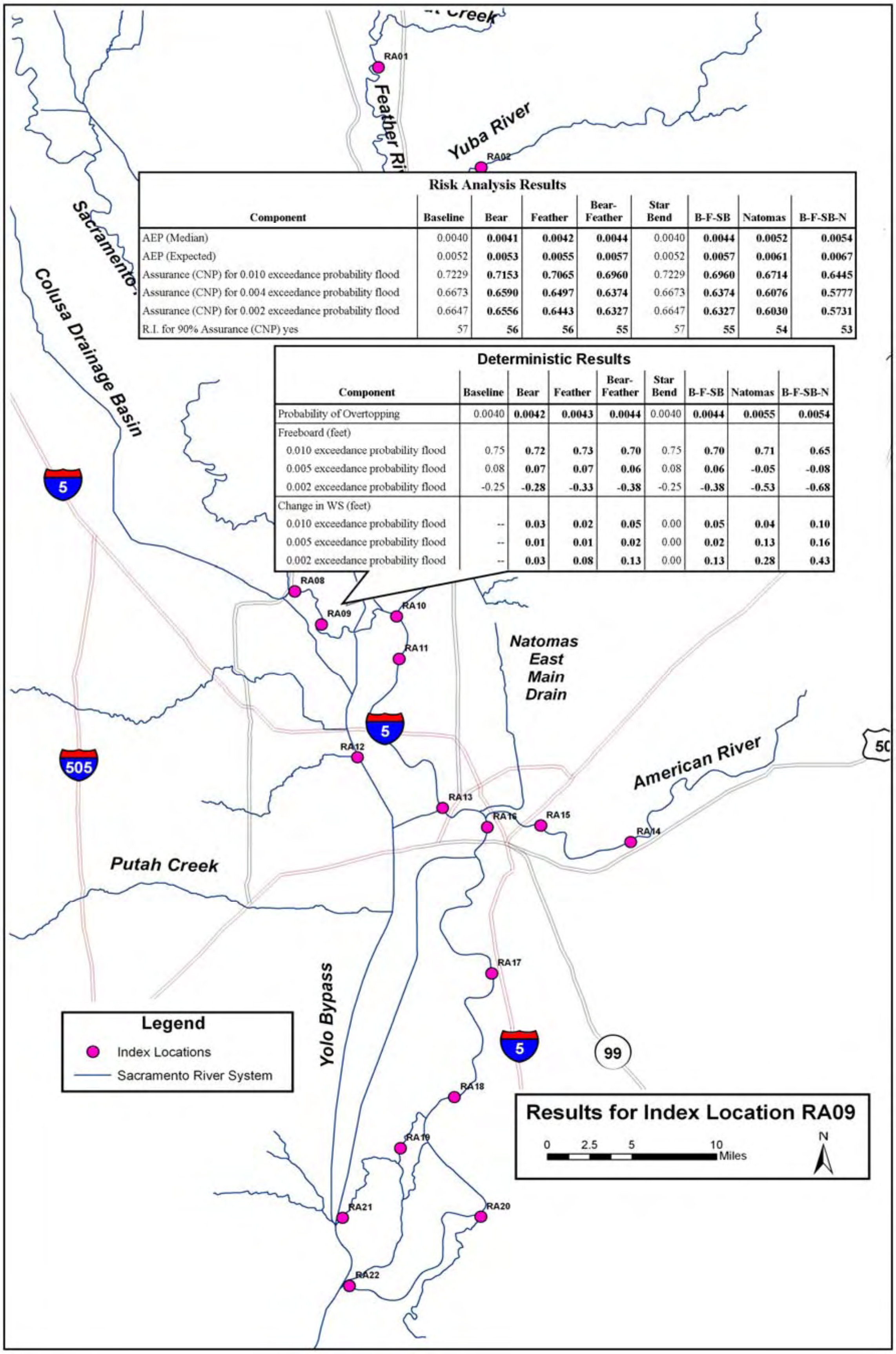
The results for Index Location RA09 are summarized in Figure 8. The results at Index Location RA09 indicate that there will be an increase in both the median and expected AEP for some of the EIPs. The increase in AEP corresponds with the reduction in assurance (CNP) for the 0.01 and 0.002 exceedance probability events. The identification of potential impacts, i.e., an increase in the water surface elevation corresponds with an increase in AEP and reduction in the assurance (CNP), at Index Location RA09 is the same for the two analysis approaches. The change in water surface elevation and assurance (CNP) for the 0.01 and 0.002 exceedance probability events for Index Location RA09 are provided in Table 33. The results in this table show that there is no correlation between the magnitude of change in the water surface elevation and the assurance (CNP). This result is demonstrated by the comparison of the changes in the

Table 32. Comparison of Probability of Overtopping from the Deterministic Analysis Procedure to the AEP from the Risk Analysis Procedure.

Index	Baseline		Bear EIP		Feather No.1 EIP		Bear-Feather No. 1 EIP	
Location	Deterministic[a]	Risk Analysis[b]	Deterministic[a]	Risk Analysis[b]	Deterministic[a]	Risk Analysis[b]	Deterministic[a]	Risk Analysis[b]
RA01	0.0020	0.0020	0.0020	0.0020	0.0020	0.0020	0.0020	0.0020
RA02	0.0092	0.0092	0.0092	0.0092	0.0092	0.0091	0.0092	0.0091
RA03	0.0021	0.0026	0.0021	0.0026	0.0020	0.0026	0.0020	0.0026
RA04	0.0071	0.0070	0.0071	0.0070	0.0071	0.0070	0.0071	0.0070
RA06	0.0032	0.0032	0.0014	0.0014	**0.0035**	**0.0035**	0.0017	0.0018
RA08	0.0153	0.0153	**0.0154**	**0.0154**	**0.0154**	**0.0155**	**0.0156**	**0.0156**
RA09	0.0040	0.0040	**0.0042**	**0.0041**	**0.0043**	**0.0042**	**0.0044**	**0.0044**
RA14	0.0060	0.0056	0.0060	0.0056	0.0060	0.0056	0.0060	0.0056
Index	**Feather No. 2 (Star Bend) EIP**		**Bear-Feather No. 1- Feather No. 2 EIP**		**Natomas EIP**		**Bear-Feather No. 1- Feather No. 2- Natomas EIP**	
Location	**Deterministic[a]**	**Risk Analysis[b]**	**Deterministic[a]**	**Risk Analysis[b]**	**Deterministic[a]**	**Risk Analysis[b]**	**Deterministic[a]**	**Risk Analysis[b]**
RA01	0.0020	0.0020	0.0020	0.0020	0.0020	0.0020	0.0020	0.0020
RA02	0.0092	0.0092	0.0092	0.0091	0.0092	0.0092	0.0092	0.0091
RA03	0.0021	0.0026	0.0020	0.0026	0.0021	0.0026	0.0020	0.0026
RA04	0.0071	0.0070	0.0071	0.0070	0.0071	0.0070	0.0071	0.0070
RA06	0.0009	0.0032	0.0017	0.0018	0.0009	0.0032	0.0017	0.0018
RA08	0.0153	**0.0154**	**0.0156**	**0.0157**	**0.0154**	**0.0154**	**0.0158**	**0.0158**
RA09	0.0040	0.0040	**0.0044**	**0.0044**	**0.0055**	**0.0052**	**0.0054**	**0.0054**
RA14	0.0060	0.0056	0.0060	0.0056	0.0060	0.0056	0.0060	0.0056

[a] The probability of overtopping for the deterministic analysis procedure was determined by interpolating the results from the HEC-RAS model for the water surface elevations bounding the top of levee elevation. For example, the probability of overtopping would be 0.00565 if the top of levee is 41.13 feet and the water surface elevation is 40.48 feet for the 0.01 exceedance probability flood event and 41.21 feet for the 0.005 exceedance probability flood event.

[b] The median AEP value in the above table for the risk analysis procedure was obtained from the HEC-FDA results, and it is based on the top of levee elevation with overtopping being the main mechanism for levee failure. HEC-FDA computes the median value from the inflow discharge-exceedance probability, inflow-outflow, and stage-discharge relationships defined at each of the Index Locations without any consideration of the uncertainty of these relationships.



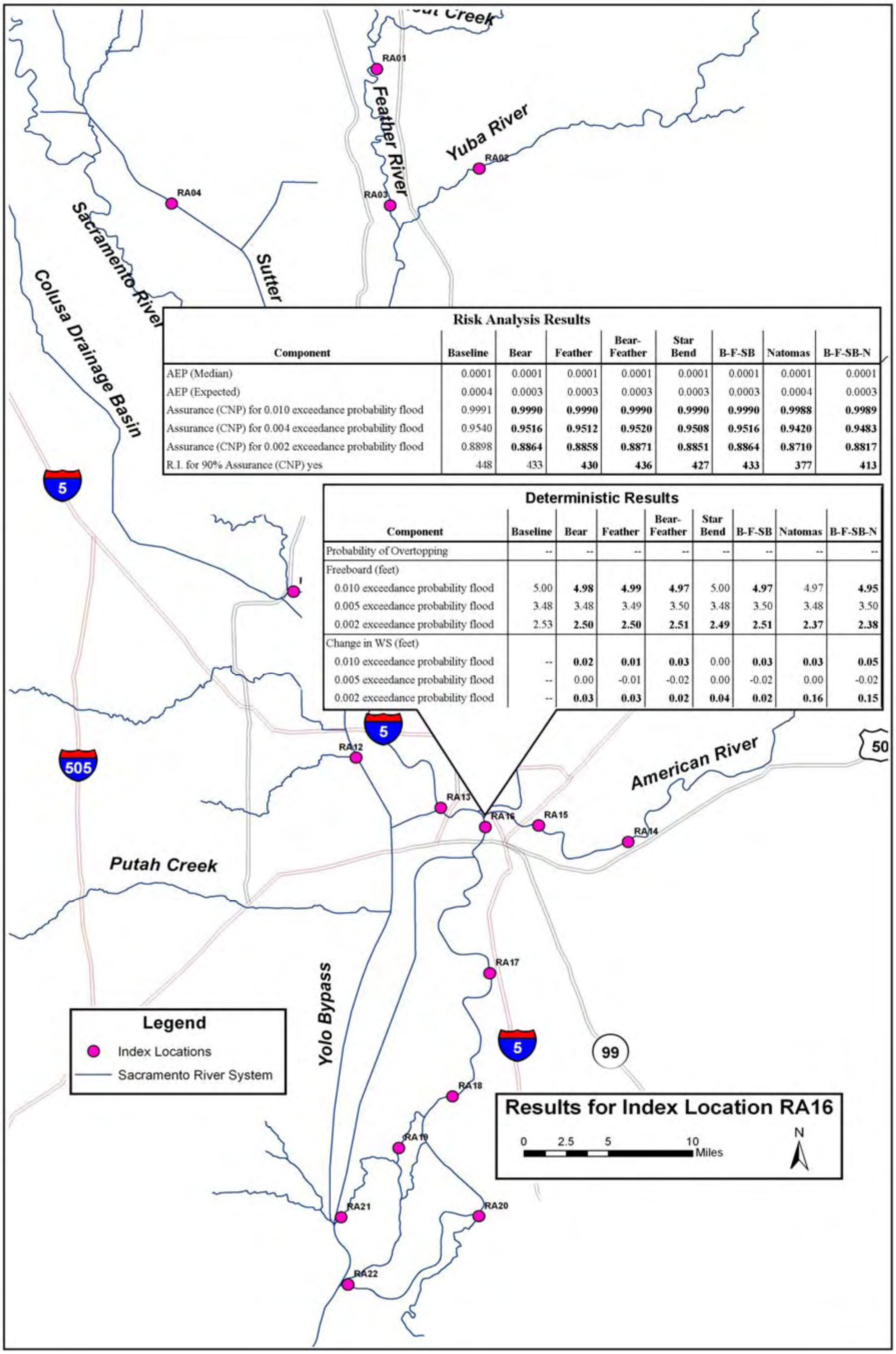
Risk Analysis Results

Component	Baseline	Bear	Feather	Bear-Feather	Star Bend	B-F-SB	Natomas	B-F-SB-N
AEP (Median)	0.0040	**0.0041**	**0.0042**	**0.0044**	0.0040	**0.0044**	**0.0052**	**0.0054**
AEP (Expected)	0.0052	**0.0053**	**0.0055**	**0.0057**	0.0052	**0.0057**	**0.0061**	**0.0067**
Assurance (CNP) for 0.010 exceedance probability flood	0.7229	**0.7153**	**0.7065**	**0.6960**	0.7229	**0.6960**	**0.6714**	**0.6445**
Assurance (CNP) for 0.004 exceedance probability flood	0.6673	**0.6590**	**0.6497**	**0.6374**	0.6673	**0.6374**	**0.6076**	**0.5777**
Assurance (CNP) for 0.002 exceedance probability flood	0.6647	**0.6556**	**0.6443**	**0.6327**	0.6647	**0.6327**	**0.6030**	**0.5731**
R.I. for 90% Assurance (CNP) yes	57	**56**	**56**	**55**	57	**55**	**54**	**53**

Deterministic Results

Component	Baseline	Bear	Feather	Bear-Feather	Star Bend	B-F-SB	Natomas	B-F-SB-N
Probability of Overtopping	0.0040	**0.0042**	**0.0043**	**0.0044**	0.0040	**0.0044**	**0.0055**	**0.0054**
Freeboard (feet)								
0.010 exceedance probability flood	0.75	**0.72**	**0.73**	**0.70**	0.75	**0.70**	**0.71**	**0.65**
0.005 exceedance probability flood	0.08	**0.07**	**0.07**	**0.06**	0.08	**0.06**	**-0.05**	**-0.08**
0.002 exceedance probability flood	-0.25	**-0.28**	**-0.33**	**-0.38**	-0.25	**-0.38**	**-0.53**	**-0.68**
Change in WS (feet)								
0.010 exceedance probability flood	--	**0.03**	**0.02**	**0.05**	0.00	**0.05**	**0.04**	**0.10**
0.005 exceedance probability flood	--	**0.01**	**0.01**	**0.02**	0.00	**0.02**	**0.13**	**0.16**
0.002 exceedance probability flood	--	**0.03**	**0.08**	**0.13**	0.00	**0.13**	**0.28**	**0.43**

Figure 8. Comparison of Results at Index Location RA09



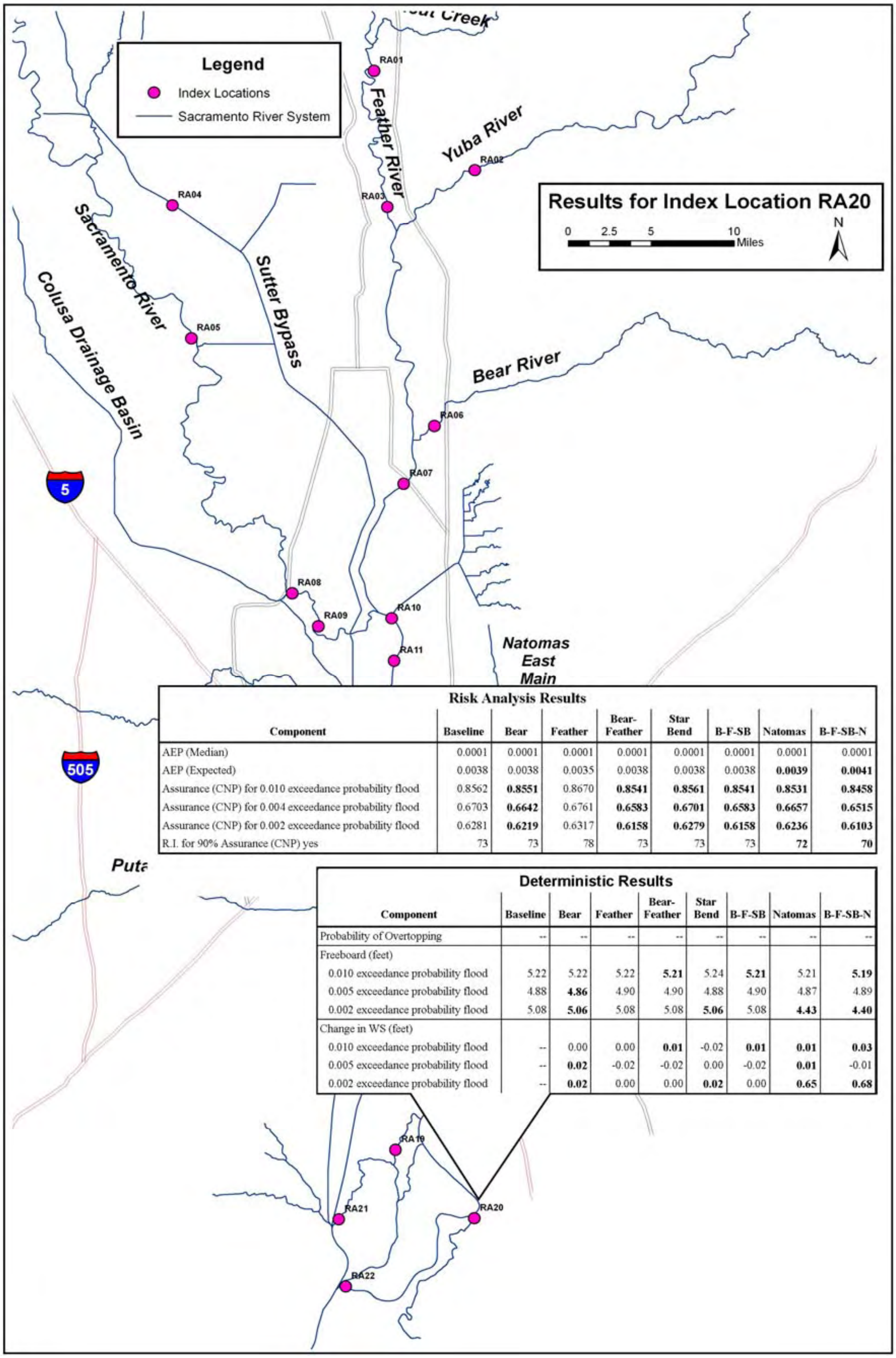
Risk Analysis Results

Component	Baseline	Bear	Feather	Bear-Feather	Star Bend	B-F-SB	Natomas	B-F-SB-N
AEP (Median)	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
AEP (Expected)	0.0004	0.0003	0.0003	0.0003	0.0003	0.0003	0.0004	0.0003
Assurance (CNP) for 0.010 exceedance probability flood	0.9991	**0.9990**	**0.9990**	**0.9990**	**0.9990**	**0.9990**	**0.9988**	**0.9989**
Assurance (CNP) for 0.004 exceedance probability flood	0.9540	**0.9516**	**0.9512**	**0.9520**	**0.9508**	**0.9516**	**0.9420**	**0.9483**
Assurance (CNP) for 0.002 exceedance probability flood	0.8898	**0.8864**	**0.8858**	**0.8871**	**0.8851**	**0.8864**	**0.8710**	**0.8817**
R.I. for 90% Assurance (CNP) yes	448	433	**430**	**436**	**427**	**433**	**377**	**413**

Deterministic Results

Component	Baseline	Bear	Feather	Bear-Feather	Star Bend	B-F-SB	Natomas	B-F-SB-N
Probability of Overtopping	--	--	--	--	--	--	--	--
Freeboard (feet)								
0.010 exceedance probability flood	5.00	**4.98**	**4.99**	**4.97**	5.00	**4.97**	4.97	**4.95**
0.005 exceedance probability flood	3.48	3.48	3.49	3.50	3.48	3.50	3.48	3.50
0.002 exceedance probability flood	2.53	**2.50**	**2.50**	**2.51**	**2.49**	**2.51**	**2.37**	**2.38**
Change in WS (feet)								
0.010 exceedance probability flood	--	**0.02**	**0.01**	**0.03**	0.00	**0.03**	**0.03**	**0.05**
0.005 exceedance probability flood	--	0.00	-0.01	-0.02	0.00	-0.02	0.00	-0.02
0.002 exceedance probability flood	--	**0.03**	**0.03**	**0.02**	**0.04**	**0.02**	**0.16**	**0.15**

Figure 9. Comparison of Results at Index Location RA16



Risk Analysis Results

Component	Baseline	Bear	Feather	Bear-Feather	Star Bend	B-F-SB	Natomas	B-F-SB-N
AEP (Median)	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
AEP (Expected)	0.0038	0.0038	0.0035	0.0038	0.0038	0.0038	**0.0039**	**0.0041**
Assurance (CNP) for 0.010 exceedance probability flood	0.8562	**0.8551**	0.8670	**0.8541**	**0.8561**	**0.8541**	**0.8531**	**0.8458**
Assurance (CNP) for 0.004 exceedance probability flood	0.6703	**0.6642**	0.6761	**0.6583**	**0.6701**	**0.6583**	**0.6657**	**0.6515**
Assurance (CNP) for 0.002 exceedance probability flood	0.6281	**0.6219**	0.6317	**0.6158**	**0.6279**	**0.6158**	**0.6236**	**0.6103**
R.I. for 90% Assurance (CNP) yes	73	73	78	73	73	73	**72**	**70**

Deterministic Results

Component	Baseline	Bear	Feather	Bear-Feather	Star Bend	B-F-SB	Natomas	B-F-SB-N
Probability of Overtopping	--	--	--	--	--	--	--	--
Freeboard (feet)								
0.010 exceedance probability flood	5.22	5.22	5.22	**5.21**	5.24	**5.21**	5.21	**5.19**
0.005 exceedance probability flood	4.88	**4.86**	4.90	4.90	4.88	4.90	4.87	4.89
0.002 exceedance probability flood	5.08	**5.06**	5.08	5.08	**5.06**	5.08	**4.43**	**4.40**
Change in WS (feet)								
0.010 exceedance probability flood	--	0.00	0.00	**0.01**	-0.02	**0.01**	**0.01**	**0.03**
0.005 exceedance probability flood	--	**0.02**	-0.02	-0.02	0.00	-0.02	**0.01**	-0.01
0.002 exceedance probability flood	--	**0.02**	0.00	0.00	**0.02**	0.00	**0.65**	**0.68**

Figure 10. Comparison of Results at Index Location RA20

Table 33. Comparison of Change in Water Surface Elevation (Deterministic Analysis) and Assurance (CNP, Risk Analysis) for the EIP Scenarios.

EIP Scenario	0.01 Exceedance Probability Flood		0.002 Exceedance Probability Flood	
	Change in WS Elevation (ft)	Change in Assurance (CNP)	Change in WS Elevation (ft)	Change in Assurance (CNP)
Index RA09				
Bear River EIP	0.03	-0.0076	0.03	-0.0091
Feather River No. 1 EIP	0.02	-0.0164	0.08	-0.0204
Bear-Feather No. 1 EIP	0.05	-0.0269	0.13	-0.0320
Feather River No. 2 (Star Bend) EIP	0.00	0.0000	0.00	0.0000
Bear-Feather No. 1-Feather River No.2 EIP	0.05	-0.0269	0.13	-0.0320
Natomas EIP	0.04	-0.0515	0.28	-0.0617
Bear-Feather No. 1-Feather River No.2-Natomas EIP	0.10	-0.0784	0.43	-0.0916
Index RA16				
Bear River EIP	0.02	-0.0001	0.03	-0.0034
Feather River No. 1 EIP	0.01	-0.0001	0.03	-0.0040
Bear-Feather No. 1 EIP	0.03	-0.0001	0.02	-0.0027
Feather River No. 2 (Star Bend) EIP	0.00	-0.0001	0.04	-0.0047
Bear-Feather No. 1-Feather River No.2 EIP	0.03	-0.0001	0.02	-0.0034
Natomas EIP	0.03	-0.0003	0.16	-0.0188
Bear-Feather No. 1-Feather River No.2-Natomas EIP	0.05	-0.0002	0.15	-0.0081
Index RA20				
Bear River EIP	0.00	-0.0011	0.02	-0.0062
Feather River No. 1 EIP	0.00	0.0108	0.00	0.0036
Bear-Feather No. 1 EIP	0.01	-0.0021	0.00	-0.0123
Feather River No. 2 (Star Bend) EIP	-0.02	-0.0001	0.02	-0.0002
Bear-Feather No. 1-Feather River No.2 EIP	0.01	-0.0021	0.00	-0.0123
Natomas EIP	0.01	-0.0031	0.65	-0.0045
Bear-Feather No. 1-Feather River No.2-Natomas EIP	0.03	-0.0104	0.68	-0.0178

table for the Bear EIP, Feather EIP, and Bear-Feather EIP for the 0.01 exceedance probability flood. For this flood event, the Bear River EIP has a change in water surface elevation of 0.03 feet and a change in assurance (CNP) of -0.0076, the Feather River EIP has a change in water surface elevation of 0.02 feet and a change in assurance (CNP) of -0.0164, and the Bear-Feather River EIP has a change in water surface elevation of 0.05 feet and a change in assurance (CNP) of -0.0269. The fact that there is no correlation was anticipated since the deterministic approach is related to a specific flood event while the risk analysis is influenced by the entire discharge exceedance probability relationship.

Index Location RA09 is located upstream of the Freemont Weir where it is expected that any downstream increases in water surface elevations would not extend upstream of this structure. However, the model results indicate that the increase in water surface elevations extend upstream of this structure. The increased water surface elevations result in more flow through the Yolo

Bypass, but it appears the efficiency of the weir is influenced by the downstream conditions of the bypass since the structure is highly submerged for the 0.01 exceedance probability flood. Additional evaluation of the hydraulic model could be conducted to determine if the modeled results are reasonable and any modifications are required to the hydraulic model within the vicinity of this structure.

The results (see Figure 8) at the Index Location RA09 also indicate the cumulative effects when considering multiple EIPs for both approaches. For example (see Figure 8), the assurance (CNP) for the 0.01 exceedance probability flood is 0.7153 for the Bear River EIP, 0.7065 for Feather River EIP, 0.6960 when considering both of these EIPs in-place, and 0.6445 when considering all of the EIPs in-place. For the deterministic approach, the change in water surface elevation for the 0.01 exceedance probability flood is +0.03 ft for the Bear River EIP, +0.02 ft for Feather River EIP, +0.05 ft when considering both of these EIPs in-place, and +0.10 when considering all of the EIPs in-place.

The results for Index Location RA16 are summarized in Figure 9. The results at Index Location RA16 indicate that there will be no changes in either the median or expected AEP since the extremely small probability of overtopping is not being influenced by the potentially small changes in water surface elevations and discharge. The identification of potential impacts at Index Location RA16 is the same for the two approaches except for the Star Bend EIP. Under that EIP and the 0.01 exceedance probability flood, there is no increase in water surface elevation, but there is a minor reduction of 0.001 in the assurance (CNP). The reduction in assurance (CNP) is related to an increase in the stage caused by this EIP for an extreme event, i.e., the Star Bend EIP will cause an increase of 0.04 feet in the water surface elevation for the 0.002 exceedance probability flood.

The change in water surface elevation and assurance (CNP) for the 0.01 and 0.002 exceedance probability events for Index Location RA16 are also provided in Table 33. Similar to Index Location RA09, there is no correlation between the magnitude of change in the water surface elevation and the assurance (CNP), which is demonstrated by the comparison of the changes in the table for the Bear EIP, Feather EIP, and Bear-Feather EIP for the 0.01 exceedance probability flood. For this flood event, the Bear River EIP has a change in water surface elevation of 0.02 feet and a change in assurance (CNP) of -0.0001, the Feather River EIP has a change in water surface elevation of 0.01 feet and a change in assurance (CNP) of -0.0001, and the Bear-Feather River EIP has a change in water surface elevation of 0.03 feet and a change in assurance (CNP) of -0.0001.

The cumulative effects associated with multiple EIPs are also demonstrated from the results (see Figure 9) at Index Location RA16 for both approaches. For example (see Figure 9), the assurance (CNP) for the 0.002 exceedance probability flood is 0.8864 for the Bear River EIP and 0.8817 when considering all of the EIPs in-place. For the deterministic approach, the change in water surface elevation for the 0.01 exceedance probability flood is 0.02 feet for the Bear River EIP, 0.01 feet for Feather River EIP, 0.03 feet when considering both of these EIPs in-place, and 0.05 when considering all of the EIPs in-place. The results at Index Location RA16 show that changes in one EIP can be offset by changes in another EIP or combination of EIPs. For example (see Figure 9), the assurance (CNP) for the 0.002 exceedance probability flood increases from 0.8710 for the Natomas EIP to 0.8817 for all of the EIPs in-place.

The results for Index Location RA20 are summarized in Figure 10. The results at Index Location RA20 indicate that there will be no changes in the median AEP and a minor increase in the expected AEP for some of the EIPs. The increase in the expected AEP corresponds with a reduction in the assurance (CNP) for the last two EIP scenarios. For the other scenarios, the minor reduction in assurance (CNP) does not equate to a change in the expected AEP. For Index Location RA20, the risk analysis approach identified more potential impacts than for the deterministic approach. This condition is related to changes in the stage-outflow discharge relationship not accounted for in the deterministic approach. The change in water surface elevation and assurance (CNP) for the 0.01 and 0.002 exceedance probability events for Index Location RA20 are also provided in Table 33. Similar to the other two index locations previously discussed, there is no correlation between the magnitude of change in the water surface elevation and the assurance (CNP). Index Location RA20 is located near the upstream end of Georgiana Slough. It is unlikely that the EIPs will cause a change near the downstream boundary (RA19 through RA22). As a result, the risk analysis and deterministic analysis results are considered suspect at these index locations. A more detailed evaluation of the hydraulic model results in the vicinity of the downstream boundary should be completed for any future evaluation.

The change in water surface elevation and assurance (CNP) for the 0.01 exceedance probability flood at each index location for the first three EIP scenarios (Bear River EIP, Feather River EIP, and Bear-Feather EIP) is summarized in Table 34. The summary demonstrates the need for completing a system-wide assessment of potential hydraulic impacts. Using the Bear River EIP as an example, modifications to the downstream end of Bear Creek will influence the timing and magnitude of the downstream flow hydrograph that will result in changes in discharge and water surface elevations through the system. The Bear River EIP will cause a reduction in the water surface elevation at Index Location RA06 near the proposed modifications and an increase in water surface elevations within the entire lower reach of the Sacramento River (Index Locations RA08 thru RA11, RA16 and RA17), downstream reach of the Feather River (Index Location RA08), and the downstream end of the American River (Index Location RA15) that is caused by the increase in the Sacramento River. For this EIP, the largest increase in water surface elevation will be just downstream of the confluence of the Feather River with the Sacramento River and the increase in water surface gradually decreases in the upstream and downstream directions. Also for this EIP, the largest increase in water surface elevation will be on the Feather River. Changes in the assurance (CNP) for the 0.01 exceedance probability flood also occur throughout the system, but at fewer locations as compared to the deterministic analysis results. Only Georgiana Slough (Index Location RA20) is identified as a potential impact location that was not identified by the deterministic analysis for the 0.01 exceedance probability flood. As stated earlier, the results at Index Location RA20 are potentially suspect. Changes in the assurance (CNP) occurred within the reach of the Sacramento River from RM 46.5 to RM 90 with the largest change occurring just downstream of the Feather River and Sacramento River confluence.

The number of potential impacts predicted by the two approaches is summarized in Table 35. A potential impact simply corresponds to an increase in water surface elevation for the deterministic analysis and a reduction in the assurance (CNP) for the risk analysis. In general, the deterministic approach has more potential impacts and most of the potential impacts identified by the risk analysis also occur in the deterministic approach. The only exception is for Bear River EIP for the 0.01 exceedance probability flood; Feather River No. 1 EIP, Feather River No. 2 (Star Bend) EIP and the Natomas EIP for both the 0.01 and 0.002 exceedance

Table 34. Comparison of Change in Water Surface Elevation (Deterministic Analysis) and Assurance (CNP, Risk Analysis) for the 0.01 Exceedance Probability Flood at the Index Locations (Bear River EIP, Feather River EIP, and Bear-Feather EIP).

Index Location	River	Reach	River Station	Bear River EIP		Feather River EIP		Bear-Feather River EIP	
				Change in WS Elevation (ft)	Change in Assurance (CNP)	Change in WS Elevation (ft)	Change in Assurance (CNP)	Change in WS Elevation (ft)	Change in Assurance (CNP)
RA01	Feather River	Honcut to Jack	42.24	0.00	0.0000	-0.07	0.0001	-0.07	0.0001
RA02	Yuba River	Upper	7.00	0.00	0.0000	-0.01	0.0014	-0.01	0.0014
RA03	Feather River	Jack Sl - Yuba River	29.00	0.00	0.0001	-0.62	0.0020	-0.62	0.0020
RA04	Sutter Bypass	ButteSl-Wads	88.60	0.00	0.0000	0.00	**-0.0002**	0.00	0.0005
RA05	Sacramento River	Colusa-Feather	119.75	0.00	0.0000	0.00	0.0001	**0.01**	**-0.0002**
RA06	Bear River	Lower	1.75	-0.45	0.0181	**0.04**	**-0.0015**	-0.40	0.0108
RA07	Feather River	Reach 35	9.00	**0.10**	0.0000	**0.05**	0.0000	**0.15**	0.0000
RA08	Sacramento River	Colusa-Feather	90.00	**0.02**	**-0.0052**	**0.02**	**-0.0055**	**0.04**	**-0.0088**
RA09	Sacramento River	Colusa-Feather	86.50	**0.03**	**-0.0076**	**0.02**	**-0.0164**	**0.05**	**-0.0269**
RA10	Sacramento River	NCC to NEMDC	79.21	**0.03**	0.0008	**0.02**	0.0054	**0.06**	0.0046
RA11	Sacramento River	NCC to NEMDC	76.25	**0.04**	**-0.0010**	**0.02**	0.0086	**0.06**	0.0106
RA12	Yolo Bypass	KRLC to SacBP	48.84	**0.02**	0.0000	**0.01**	0.0000	**0.04**	0.0000
RA13	Sacramento River	NCC to NEMDC	63.82	**0.02**	0.0015	**0.01**	0.0011	**0.03**	0.0023
RA14	American River	Reach 1	11.00	0.00	0.0000	0.00	0.0000	0.00	0.0000
RA15	American River	Reach 1	3.75	**0.01**	0.0000	**0.01**	0.0000	**0.02**	0.0000
RA16	Sacramento River	DS American	59.75	**0.02**	**-0.0001**	**0.01**	**-0.0001**	**0.03**	**-0.0001**
RA17	Sacramento River	DS American	46.50	**0.01**	**-0.0001**	**0.01**	0.0000	**0.02**	0.0000
RA18	Sacramento River	DS American	36.50	0.00	**-0.0001**	0.00	0.0000	**0.02**	**-0.0001**
RA19	Sutter Slough	Lower Reach	25.23	-0.01	0.0000	**0.02**	0.0000	**0.01**	0.0000
RA20	Georgiana Slough	Reach	12.36	0.00	**-0.0011**	0.00	0.0108	**0.01**	**-0.0021**
RA21	Miner Slough	Reach 1	19.11	-0.02	0.0004	**0.02**	**-0.0133**	**0.01**	0.0074
RA22	Sacramento River	RM 14.6 to 26.5	14.75	-0.02	0.0010	0.00	0.0003	0.00	0.0046

Note: Bold values within the shaded cells (green) correspond to locations where there is potential impact.

Table 35. Number of Potential Impacts Determined from the Deterministic Analysis Approach and the Risk Analysis Approach.

EIP Scenario	0.01 Exceedance Probability Flood		0.002 Exceedance Probability Flood	
	Deterministic Approach	**Risk Analysis Approach**	**Deterministic Approach**	**Risk Analysis Approach**
Bear River EIP	10	7	14	9
Feather River No. 1 EIP	13	6	14	12
Bear-Feather No. 1 EIP	15	6	14	12
Feather River No. 2 (Star Bend) EIP	0	5	6	8
Bear-Feather No. 1-Feather River No.2 EIP	10	7	14	9
Natomas EIP	13	9	14	11
Bear-Feather No. 1-Feather River No. 2-Natomas EIP	16	7	14	13

probability flood; and the Bear-Feather No. 1 EIP, Bear-Feather No. 1-Feather River No.2 EIP, and Bear-Feather No. 1-Feather River No. 2-Natomas EIP for the 0.002 exceedance probability flood. The noted differences are either related to the change in stage, discharge, or both the stage and discharge.

Chapter 4

Conclusions and Recommendations

In the preceding chapters a process for using risk analysis in a system-wide numerical evaluation of potential hydraulic impacts associated with modifications to the SRFCP was defined and demonstrated. The risk analysis process developed as part of this study is limited to the evaluation of risk associated with levee performance related to overtopping, and it is not a comprehensive example of risk analysis for flood damage consequences. The risk analysis process was defined using the guidance in EM 1110-2-1619 (USACE, 1996) and the policies established in ER 1105-2-101 (USACE, 2006). The steps for completing the risk analysis assessment are summarized in Appendix A and example calculations for developing the various relationships used in the risk analysis process are provided in Appendix B. Additionally, a comparison of the risk analysis and deterministic analysis procedures was presented. The HEC-FDA input data for the various EIP scenarios evaluated are provided in Appendix C. A discussion related to the sensitivity of various HEC-FDA input data is provided in Appendix D. Comments received on the final draft of this report are provided in Appendix E.

4.1 Conclusions

Conclusions of the study are provided in the following sections.

4.1.1 Policy

It is recognized that USACE policy (ER 1105-2-101, USACE 2006a) is to utilize risk analysis and its results in planning flood risk management studies. The goal of the policy is a comprehensive approach in which the key variables, parameters, and components of flood risk management studies are subject to probabilistic analysis. A full range of floods is to be used in formulation and evaluation of project alternatives.

4.1.2 System-Wide Assessment

The SRFCP is a large system that includes regulated and unregulated inflows, watercourses, bypasses, hydraulic structures, and tidally influences. Identification and management of potential hydraulic impacts resulting from modifications to the system requires a comprehensive approach that considers all relevant hydraulic interactions of its elements. Although a complex undertaking, notable steps have been taken, and are continuing to be made, to develop the tools and information necessary to simulate the hydrologic and hydraulic characteristics of the system. Notable accomplishments in this regard include the Comprehensive Study (CESPK, 2002) and the CESPK HEC-RAS hydraulic model. Although arguably imperfect, such recently developed tools are recognized to be the state of art and remarkable improvements over previous tools for assessing the hydraulic conditions of the system and the potential impacts of modifications to it.

The hydraulic modeling results of this study clearly demonstrate the need for system-wide assessment of potential hydraulic impacts, which is consistent with USACE policy. The results demonstrate that potential hydraulic impacts can exist at extended distances from proposed modifications to the system, including potential impacts on separate watercourses, due to influences on the timing and magnitude of flow. Consequently, a traditional steady flow, reach specific approach to hydraulic impact identification and evaluation should not be relied upon to identify the potential impacts of proposed modifications to the SRFCP.

4.1.3 Cumulative Affects

The system-wide assessment approach was also demonstrated to evaluate the potential of cumulative impacts associated with multiple projects. Results of the hydraulic analysis indicated that results for individual EIP projects are different than those when multiple EIP projects are considered. Potential cumulative impacts to both water surface elevations and risk analysis results were demonstrated. The importance of considering potential cumulative impacts to the SRFCP is illustrated by the fact that analysis results for separate EIP Projects were found to be less than potential cumulative impacts.

4.1.4 Risk Analysis Process

A process for estimating potential system-wide hydraulic impacts resulting from modifications to the SRFCP was defined. The identified risk analysis process is very similar to the traditional deterministic analysis process. As detailed in Table 2 (see Chapter 2), the analysis steps are nearly identical for both procedures.

While "definition of uncertainty" is required for the risk analysis process, the traditional deterministic analysis process requires a "sensitivity analysis". Fundamentally, these analysis steps have the same purpose. Whereas the definition of uncertainty is used in the risk analysis to define a function for describing the range of risk, the sensitivity analysis information describes risk as a discrete result.

Similarly, "risk analysis" estimates how risk and associated consequences (flooding, economic damage, life safety) vary over the full range of potential flooding probabilities, while "consequence evaluation" is conducted to deterministically define expected consequences for specific flood events.

4.1.5 Benefits of Risk Analysis

The benefit of the proposed process for the evaluation of proposed modifications to the SRFCP is an increased understanding of the risk inherent in proposed modification alternatives. The risk analysis process accomplishes this objective by considering the full range of potential flood probability, not just specific design floods, and how the uncertainty associated with the involved variables, parameters and components correspondingly varies. Risk analysis will quantify assurance (CNP) in the expected flood protection and provide confidence that a proposed modification project is appropriate.

4.1.6 Limitations of Proposed Process

It is recognized that current tools and data used for conducting the proposed risk analysis process need to be improved. Various assumptions were required to conduct the analysis. Most notable, is the applicability of the available hydrology for the study area and the criteria used to define when and how a levee will fail. Modifications to these assumptions would affect a hydraulic impact assessment. However, based on the current data and technology, the assumptions utilized are necessary for the purpose of defining a general process for identifying potential hydraulic impacts. Similar assumptions will be required as part of the risk analysis conducted for Section 408 permit applications. All employed assumptions need to be documented and justified by the permit applicants.

It is also recognized that as better data and tools become available, the proposed risk analysis process can be improved. It is further noted that since many assumptions in both approaches are inherently deterministic, adjustment of the employed assumptions would influence similarly the results of both risk analysis and deterministic analysis procedures. The deterministic assumptions utilized for this study are summarized in Table 1 (see Chapter 1).

The current available hydrology for the project area has the limitation that uncertainty was not rigorously evaluated as part of its development. However, it is recognized that efforts to update the hydrology and characterize its uncertainty is currently on-going.

The criteria used to define when a levee fails is currently limited to overtopping conditions, which is considered adequate for consideration of Section 408 permitting issues. However, it is recognized that levees can fail from a variety of mechanisms in addition to overtopping. At this time, only additional future research and evaluation into levee failure modes can be expected to refine the means for defining the probability of levee failure. It is additionally noted that for this demonstration of process the conditions of how a levee breach occurs are also assumed. Research of historic levee breaches within the SRFCP could be conducted to refine the breach criteria that have occurred historically.

4.1.7 Significance of Potential Impacts

The magnitude of potential impacts identified from comparison of risk analysis results for existing and alternative conditions can be small. Development of criteria to assess the significance of the potential impacts and determination of whether the potential impact would be classified as an impact is needed. Examination of the risk analysis probabilities indicates that rounding them to a maximum three significant figures seems appropriate considering that small exceedance probabilities with greater than three significant figures implies return periods in the excess of 1,000 years.

4.1.8 Comparison of Risk and Deterministic Results

A comparison was made of the results from the results of the risk analysis and deterministic analysis procedures. The efforts included: (1) comparing the probability of overtopping (deterministic analysis) to the median AEP (risk analysis), (2) graphically comparing changes in water surface elevations and freeboard (deterministic analysis) to the changes in the assurance

(CNP, risk analysis) at selected index locations for specific flood events, and (3) comparing the locations of increased water surface elevations (deterministic analysis) to decreases in assurance (CNP, risk analysis). The comparisons indicate general consistency between the two methods. Probability of overtopping is the same as the median AEP, and increases in water surface elevations are reflected as a reduction in assurance (CNP). It was observed that there were more locations of increased water surface elevations (deterministic analysis) than decreases in assurance (CNP, risk analysis). This is attributed to the small magnitude that involved changes in water surface elevation and the corresponding values associated with the stage-outflow discharge rating curves. All noted changes are potential impacts. Potential impacts can be positive or negative and large or small and must be assessed for significance.

4.1.9 Additional Work Effort Required to Conduct Risk Analysis

Based on an examination of the labor hours expended for this study, it was identified that approximately thirty-eight percent of the work effort was attributed to conducting the risk analysis. About eight percent of the work effort was attributable solely to the deterministic analysis and fifty-four percent of the work effort was common to both approaches. Thus, the risk analysis required an increase of forty-eight percent in the level of work effort compared to the deterministic analysis. It is noted that the amount of work effort required is generally unique to every project and dependent on the objectives of the study, the size and complexity of the study area, experience of the modelers, and the availability of existing data and information. It is recognized that for a large complex system such as the SRFCP, the development of hydrology and hydraulic models are very significant work efforts, but required for either risk analysis or deterministic analysis methods. For the current study, both hydrologic and hydraulic models were available. Therefore, for future studies where the hydrologic and hydraulic models have not been built the percentage of time spent on risk analysis will decrease significantly. Furthermore, it is recognized that the risk assessment process could be improved; hence the level of effort for future risk analysis project will require further refinement for both the process and its application. However, it is likely that the level of effort to conduct future studies will reduce as the risk analysis process becomes more routinely employed.

4.2 Recommendations

4.2.1 Single Model

During the development of the HEC-RAS models for the various EIPs considered in the current study, differences were noted between the geometry in the baseline HEC-RAS model and the models that were used in developing the EIP models. The analysis indicated that cumulative effects of the EIPs are important when evaluating potential hydraulic impacts. Therefore, accurate evaluation of project specific and cumulative modeled hydraulic changes and potential impacts requires consistency in the hydraulic models employed. To avoid discrepancies, it is recommended that a single HEC-RAS hydraulic model of the baseline condition be developed and maintained. The adopted system-wide baseline model would be available to all stakeholders for use. The baseline model could then be modified to simulate and evaluate proposed conditions. As modifications are constructed, the proposed condition model would then become the current condition model. Comparison of proposed condition model results to baseline condition model results would be used to inform an analysis of potential cumulative hydraulic impacts. Comparison of proposed condition model results to current condition model results will establish the specific potential hydraulic impacts of the proposed modifications.

4.2.2 Index Locations

The index locations considered in the current study were selected to evaluate modeled hydraulic changes and potential impacts throughout the system. Appropriate index locations should be selected for evaluation of potential hydraulic impacts for each specific proposed SRFCP modification. Additionally, to ensure that potential system-wide impacts are properly evaluated, a set of designated index locations should be defined by the stakeholders responsible for SRFCP. Index locations should be selected in the vicinity of the proposed modifications. Areas where there is high potential for flood risk, economic damage and life safety consequences should be considered in the selection of index locations. It is noted that tidally influenced locations have complex stage-discharge relations that are influenced by the assumed boundary conditions, hence a limited number of index locations may be appropriate in that area.

4.2.3 Levee Fragility

Due to the Section 408 permit process requirements, our analysis did not consider the geotechnical performance of levees. Failure of levees was assumed to be only a function of overtopping magnitude and duration. Various additional factors can influence levee failure, including hydraulic loading, rapid drawdown, seepage and piping, and earthquakes, among others. Future risk analysis may need to include these failure modes in the definition of levee fragility and associated uncertainty. Additional research and software improvements will be required.

4.2.4 Hydrology

This analysis is based on the Comprehensive Study for the Sacramento River Mainstem at Latitude of Sacramento Centering. It was assumed that the discharge-exceedance probability for the unregulated conditions at the various handoff locations represented the median relationship and the uncertainty in the relationship can be estimated using the direct analytical approach documented in Bulletin 17B (USGS, 1982) and in EM 1110-2-1415 (USACE, 1993). The uncertainty of regulated inflows should be derived from a sensitivity analysis of reservoir inflows and routings with variations to the outlet works and spillway ratings, outlet works operation, shape and volume of inflow hydrograph, assumed initial release conditions, and safety issues. Since such an analysis was not conducted for the Comprehensive Study (CEPSK, 2002), or for the present study, the total uncertainty at the handoff locations was estimated using a procedure that equates the Equivalent Years of Record (EYR) to the combined uncertainty of the unregulated and regulated flow conditions.

It is recommended that the hydrology for the system should be re-evaluated and a sensitivity analysis be conducted to define the uncertainty in the regulated discharge-exceedance probability relationship at all of the handoff locations. DWR has commissioned CESPK to update estimates of the flow frequency throughout the Sacramento River basin. The study will have results that are similar to the Comprehensive Study (CEPSK, 2002) results, and uncertainty about the regulated flow frequency curves will not be identified.

The analysis was completed using a single centering that is currently based near the downstream end of the watershed. It is recommended that future evaluations consider, as a minimum, two centerings. One of the centerings should be the same as that considered for this study and the other being defined by the location of the proposed modifications.

4.2.5 HEC-FDA Improvements

Overall, the HEC-FDA program is easy to utilize. However, it was noted that data entry and result extraction could be made more efficient via cut and paste options or similar. Data import/export and enhanced printing issues/capabilities will be addressed in upcoming versions of HEC-FDA.

Chapter 5

References

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Appendix A

Steps for Evaluating Potential Hydraulic Impacts Using Risk Analysis Process

Step	Task	Discussion
1	**Define Analysis Conditions**	
1a	Define Study Area	Identify involved watercourses, hydrologic regulation, hydraulic controls and boundary conditions.
1b	Define Index Locations	Identify index locations where risk analysis will be performed and the potential hydraulic impacts will be evaluated. To ensure that potential system-wide impacts are properly evaluated, a set of designated index locations should be defined by the stakeholders responsible for flood risk management within the study area. Areas where there is high potential for flood risk, economic damage and life safety consequences should be considered in the selection of index locations. Complex stage-discharge relations in tidally influenced locations may limit the utility of index locations in those areas. In addition to the designated index locations, index locations immediately adjacent to proposed levee modifications and locations where the maximum changes in the water surface elevations are identified for the proposed condition should also be considered in the evaluation. Initial selection of index locations could be updated once more information is available from the hydraulic evaluation.
2	**Identify Analysis Criteria**	
2a	Determine Agency Policy and Guidance	Specific criteria by which the proposed project modifications will be evaluated must be identified. Fundamental is the identification of applicable law, guidance and policies, such as: 33 United State Code (U.S.C.) Section 408; 33 C.F.R. 208.10; and, local ordinances of the entity who regulates the flood control projects and floodplain.
2b	Define Criteria for Levee Breach	Levee breaches can have significant impact on discharge and water surface elevations within the study area. If levee failures have historically occurred within the study area and there is a high possibility for future breaches to occur, the minimum criteria for occurrence of levee failure must be defined. The criteria necessary for the evaluation could include: (1) whether or not to include levee failure in the evaluation, (2) mechanism of levee breaching (overtopping or use of levee fragility curve), (3) geotechnical information for levees, (4) overtopping depths and duration to initiate levee failure for overtopping breaches, and (5) breach dimensions, including width and side slopes. If data is available, the last two items could be assessed from past flood events.
2c	Define Potential Impact	For a risk analysis, potential hydraulic impacts are assessed by changes to the median and expected Annual Exceedance Probability (AEP) and assurance (CNP). AEP is the probability that flooding will occur in any given year considering the full range of possible annual floods if levee fragility is included in the evaluation, or it is the probability that a specific elevation is exceeded if a levee fragility is not included. An increase in AEP would be considered as an adverse change.

Step	Task	Discussion
2c	Define Potential Impact (continued)	Assurance (CNP) is defined as the likelihood of containing a specific exceedance probability within a specified target stage, given the occurrence of the flood event. A decrease in the assurance (CNP) would be considered as an adverse change. The significance of change must be defined to identify what is considered to be an impact. The AEP and assurance (CNP) are based on a specified target stage, which could be the top of levee, a specified depth below the top of levee, or the project design level.
3	**Data Collection**	A wide range of existing data and information should be collected and reviewed, such as: (1) topographic data, (2) hydrologic data, (3) previous studies, (4) aerial photography, (5) hydraulic roughness estimates, (6) flow and stage measurement records, (7) levee data, (8) geotechnical information, and (9) hydraulic structure data.
4	**Hydrology**	
4a	Develop Hydrology for Baseline Condition	Develop the hydrology of the study area using appropriate hydrological analysis techniques as described in EM 1110-2-1419, *"Hydrologic Engineering Requirements for Flood Damage Studies"*, (USACE, January 1995). The hydrology must be defined for the 0.50, 0.20, 0.10, 0.04, 0.02, 0.01, 0.005 and 0.002 exceedance probability flood events.
4b	Develop Hydrology for Proposed Condition	If proposed revisions change the inflow hydrology to the study site, develop the hydrology for the proposed condition using appropriate hydrological techniques as described in EM 1110-2-1419, *"Hydrologic Engineering Requirements for Flood Damage Studies"*, (USACE, January 1995). The hydrology must be defined for the 0.50, 0.20, 0.10, 0.04, 0.02, 0.01, 0.005 and 0.002 exceedance probability flood events.
5	**Hydraulic Model Development**	Develop an unsteady flow hydraulic model of the study area for the baseline condition using the data and information collected as part of the study. The model should be used to determine the hydraulic conditions for flood events ranging from 0.50 to 0.002 exceedance probability events. If HEC-RAS is utilized, levees that could potentially be overtopped should be defined as a lateral structure in the model. Model should have adequate resolution to define the hydraulic conditions necessary to evaluate proposed projects and identify impacts. The required resolution of the model will be project specific and depend on a variety of factors, including, available data and resources, and significance of impacts.

Step	Task	Discussion
6	**Levee Failures**	If effects of levee breaches are included in the potential hydraulic impact evaluation, then the potential levee failure locations must be identified and incorporated in the unsteady flow hydraulic model. The model developed in Step 5 can be run for the condition of no levee failure, and the results can be reviewed to indentify locations of potential levee breaching.
7	**Calibration/Verification of Baseline Hydraulic Model**	It is extremely important that the baseline hydraulic model be calibrated to available and reliable measured data (high water marks and/or gages), prior to introducing proposed hydraulic conditions. High water marks are used for calibration of maximum stages whereas gage data can be used to calibrate the full range of stages during a recorded flood event. Typically, roughness values (Manning's n values) are adjusted for reach-wide calibration to stage, and discharge coefficients, ineffective flow area definitions, and boundary conditions are adjusted for more localized calibration. Whenever possible, models should be calibrated to stage data as opposed to flow data because of the uncertainties associated with the flow determination. It is noted that flow data is typically computed from stage readings by use of an established rating curve. Verify the calibrated model with another set of measured data if data is available.
8	**Develop Hydraulic Model for Proposed Condition**	Develop an unsteady flow hydraulic model for the proposed condition. As in the baseline condition, the model should be used to determine the hydraulic conditions for flood events ranging from 0.50 to 0.002 exceedance probability events.
9	**Evaluate Proposed Hydraulic Conditions**	
9.1	**Evaluate Baseline Condition**	
9.1a	Hydrology at Inflow Locations	From the hydrological analysis, define the inflow discharge-exceedance probability at all of the upstream model boundaries. To facilitate the determination of this relationship at each of the index locations, it is recommended that the computed hydrographs are imported into an Excel® spreadsheet.
9.1b	Define Inflow Discharge at Index Locations	Calculate the inflow-exceedance probability relationship at each of the index locations using the following steps: A. Copy all of the inflow hydrographs into an Excel® spreadsheet. B. Determine the inflow locations that can contribute flow to each index location. C. For each exceedance probability, determine the combined inflow hydrograph by adding up the ordinates of all the hydrographs that contribute flow to each of the index locations. D. Determine the inflow-exceedance probability relationship by obtaining the maximum value from the combined hydrograph.

Step	Task	Discussion
9.1b	Define Inflow Discharge at Index Locations (continued)	The above relationship is defined using flow data with an exceedance probabilities ranging between 0.50 and 0.002. To improve the uncertainty estimate for this relationship, the discharges for the exceedance probabilities of 0.999 and 0.001 should be determine by extrapolating the defined relationship.
9.1c	Define Inflow-Outflow Relationship at Index Locations	Determine the inflow-outflow relationship at the index locations by using the inflow discharge-exceedance probability relationship (see Step 9.1b) and the outflow (routed) discharge from the hydraulic model for the various flood events. The discharge is associated with the maximum stage from the hydraulic simulation. This relationship should also be extended to include the maximum possible discharge sampled from the inflow discharge versus exceedance probability relationship, i.e., upper bound of the relationship defined from the uncertainty estimated in Step 10.
9.1d	Adjustment to Inflow-Outflow Relationship at Index Locations	HEC-FDA requires that the outflow increase with increasing inflow, i.e., outflow must increase with decreasing exceedance probabilities. If this is not the case, adjust the inflow-outflow locations using one of the following two approaches: A. If the reduction in outflow discharge is related to levee breaches and/or increased floodplain storage, then use a discharge slightly greater than the discharge for the next larger exceedance probability flood. B. If the reduction in outflow discharge is not related to levee breaches and/or increased floodplain storage, then use the bounding exceedance probability floods to interpolate a value that would be increasing (e.g., if the discharge for the 0.2 exceedance probability is less than the discharge for the 0.5 exceedance probability, then the adopted discharge for the 0.2 exceedance probability can be determined using by interpolation using the discharges for the 0.5 and 0.1 exceedance probabilities). Similar to the inflow discharge relationship, the outflow discharges for the exceedance probabilities of 0.999 and 0.001 should be determined by extrapolation from the defined relationship.
9.1e	Estimate Stage-Outflow Discharge Relationship at Index Locations	The stage-outflow discharge relationship at each index location can be determined using one of the two options: A. Determine the relationship directly from the outflow discharge–exceedance probability relationship and the maximum stage from the hydraulic model for the various flood events.

Step	Task	Discussion
9.1e	Estimate Stage-Outflow Discharge Relationship at Index Locations (continued)	B. Determine by a best fit line of all the stage and corresponding discharge results from the hydraulic model for the entire range of simulated flood events. **Alternatively, or more appropriately, this relationship can be developed assuming that all of the flow is conveyed through the main channel with no attenuation within the floodplain. This approach would eliminate the need to make the revisions discussed in Step 9.1f. For this relationship, a new hydraulic model would need to be developed to simulate all of the flow within the channel.** The resulting stage-outflow discharge relationship can be determined using either of the two approaches discussed above.
9.1f	Adjustment to Stage-Outflow Discharge Relationship at Index Locations	HEC-FDA requires that this relationship increase with decreasing exceedance probabilities and that the relationship extend above the top of levee elevation. When the first criterion is not met, then the stage-outflow discharge relationship can be adjusted by interpolation using the results from the bounding exceedance probabilities (e.g., if the stage for the 0.2 exceedance probability is less than the discharge for the 0.5 exceedance probability, then the adopted discharge for the 0.2 exceedance probability can be determined by using interpolation, using the discharges for the 0.5 and 0.1 exceedance probabilities). If levee failures cause the stage-outflow discharge relation to flatten out and the 0.002 exceedance probability flood is below the top of levee, the stage-discharge relationship could be extended by: (1) extrapolate out to the 0.001 exceedance probability flood and then increase it to be above the top of levee elevation for the maximum discharge, or (2) extend the relationship to be above the top of levee elevation for the maximum discharge. In general, the second relationship will result in a slight reduction in the assurance (CNP) values and a slight increase in the AEP values.
9.2	**Evaluate Proposed Condition**	
9.2a	Hydrology at Inflow Locations	If there are significant changes to the hydrology for the proposed condition, determine the inflow discharge-exceedance probability relationship at all of the inflow locations using the same approach described in Step 9.1a. Otherwise, use the same relationship developed for the baseline condition.
9.2b	Define Inflow Discharge at Index Locations	If there are significant changes to the hydrology for the proposed condition, determine the discharge-exceedance probability relationship at the index locations using the same approach described in Step 9.1b. Otherwise, use the same relationship developed for the baseline condition.

Step	Task	Discussion
9.2c	Define Inflow-Outflow Relationship at Index Locations	Use the same approach described in Step 9.1c.
9.2d	Adjustment to Inflow-Outflow Relationship at Index Locations	Use the same approach described in Step 9.1d.
9.2e	Estimate Stage-Outflow Discharge Relationship at Index Locations	Use the same approach described in Step 9.1e.
9.2f	Adjustment to Stage-Outflow Discharge Relationship at Index Locations	Use the same approach described in Step 9.1f.
10	**Definition of Uncertainty**	
10.1	**Uncertainty for the Baseline Condition**	
10.1a	Uncertainty at Inflow Discharge Locations	***Unregulated***. Two approaches can be utilized in estimating the uncertainty of the inflow discharge-exceedance probability relationship. If the relationship can be fitted by a Log Pearson Type III distribution (considered to be an analytical relationship), then the uncertainty of the relationship can be estimated using the direct analytical approach documented in "*Guidelines for Determining Flood Flow Frequency"*, Bulletin 17B, (USGS, 1982) and in EM 1110-2-1415, *"Hydrologic Frequency Analysis"*, (USACE, 1993). For the analytical relationship, the uncertainty can be calculated using HEC-FDA and the Log Pearson Type III statistics (mean, standard deviation, skew, and equivalent record length). If the function does not fit the Log Person Type III distribution, then the uncertainty should be estimated using the non-analytical order statistics method as documented in ETL 1110-2-537, *"Uncertainty Estimates for Nonanalytic Frequency Curves*, (USACE, 1995). HEC-FDA software can calculate the uncertainty for a non-analytical relationship from the defined discharge-exceedance probability relationship and the Equivalent Years of Record (EYR). Guidance on estimation of EYR is provided in EM 1110-2-1619, *"Risk-Based Analysis for Flood Damage Reduction Studies"*, (USACE, 1996). ***Regulated***. Ideally, the uncertainty of regulated inflows should be derived from a sensitivity analysis of the reservoir inflows and routings with variations to the outlet works and spillway ratings, outlet works operation, shape and volume of inflow hydrographs, assumed initial release conditions, and safety issues. From the sensitivity analysis results, the standard deviation of the range of flow is calculated by dividing the difference between the lower and upper discharge by four, which assumes that the difference contains 95 percent of the flow uncertainty range.

Step	Task	Discussion
10.1a	Uncertainty at Inflow Discharge Locations (continued)	In lieu of a sensitivity analysis, the uncertainty can be estimated using the following procedure that equates the EYR to the combined uncertainty of the unregulated and regulated flow conditions: A. Determine the standard deviation and variance of the uncertainty for the unregulated discharge. The standard deviation of the uncertainty can be estimated using the same procedures described previously for either an analytical or non-analytical relationship. The variance is the square of the standard deviation. B. Determine the standard deviation and variance of the uncertainty for the regulated discharge. This can be accomplished by completing a sensitivity analysis of the parameters related to the reservoir regulation without taking into account the uncertainty of the inflow. If such analysis cannot be completed, the standard deviation can be assumed to be between ± 5 to 10% of the median value (estimated assuming that 95% confidences boundaries). C. Determine the standard deviation of the combined uncertainty for the unregulated and regulated conditions. This is accomplished by taking the square root of the summation of the variances for the unregulated and regulated conditions. D. Determine the EYR. The EYR is determined by using a trial-and-error procedure until the standard deviation calculated using the equations in Bulletin 17B (USGS, 1982) for an assumed EYR equals the standard deviation determined from the previous step. The above procedure should be computed using the exceedance probability of interest, which is often the 0.01 exceedance probability.
10.1b	Estimate Uncertainty of the Inflow Discharge at Index Locations	Transfer the uncertainties at the inflow and local inflow locations to each of the index locations ***Unregulated***. Determine the standard deviation at the index locations by a discharge weighted average of the standard deviation of all of the inflow locations for each of the various sources contributing to each index location site. ***Regulated***. Determine the standard deviation at the index locations by a discharge weighted average of the EYR of all of the inflow locations contributing to each index location site.

Step	Task	Discussion
10.1c	Estimate Uncertainty in Inflow-Outflow Relationships	Conduct a sensitivity analysis to determine the uncertainty in the inflow-outflow relationship (routed) versus exceedance probability relationship. The sensitivity analysis should consider both upper and lower bounds of hydraulic parameters that can influence this relationship, including Manning's n-values, weir coefficients, structure coefficients, downstream boundary conditions, levee breach criteria, and levee breach dimensions. The bounds may be defined based on guidance and/or professional judgment. The results of the sensitivity analysis can be imported into an Excel® spreadsheet and the standard deviation of error in discharge can be estimated from the minimum and maximum values obtained from the model (assume that the difference contains 95 percent of the discharge uncertainty range, so the standard deviation is estimated by dividing the difference by four). If sensitivity analysis reveals an asymmetric distribution of uncertainty, a triangular distribution can be used with uncertainties represented by maximum and minimum limits.
10.1d	Estimate Uncertainty of Stage-Outflow Discharge Relationship at Index Locations	From the results of the sensitivity analysis described in Step 10.1c, determine the standard deviation of error in stage by dividing the minimum and maximum values obtained from the model by four (assume that the difference contains 95 percent of the stage uncertainty range). Use information presented in EM 1110-2-1619, *"Risk-Based Analysis for Flood Damage Reduction Studies"*, (USACE, 1996) to define the minimum standard deviation to account for uncertainties associated with the topographic data utilized in developing the hydraulic model. Compare the standard deviation from the sensitivity analysis, and utilize that value if it is greater than the minimum standard deviation selected from the information provided in EM 1110-2-1619 (USACE, 1996); otherwise, use the minimum recommended value
10.2	**Uncertainty for Proposed Condition**	
10.2a	Uncertainty at Inflow Discharge Locations	If there are significant changes to the hydrology for the proposed condition, determine the uncertainty in inflow discharge-exceedance probability relationship at all of the inflow locations using the same approach described in Step 10.1a. Otherwise, use the uncertainties determined for the baseline condition.
10.2b	Estimate Uncertainty of the Inflow Discharge at Index Locations	If there are significant changes to the hydrology for the proposed condition, determine the uncertainty in inflow discharge-exceedance probability relationship at the index locations using the same approach described in Step 10.1b. Otherwise, use the uncertainties determined for the baseline condition.
10.2c	Estimate Uncertainty in Inflow-Outflow Relationships	Use the same approach described in Step 10.1c.

Step	Task	Discussion
10.2d	Estimate Uncertainty of Stage-Outflow Discharge Relationship at Index Locations	Use the same approach described in Step 10.1d.
11	**Risk Analysis**	
11a	Develop HEC-FDA model for the Baseline Condition	Develop the HEC-FDA model using the following steps: A. Open up HEC-FDA. B. Create a new study (from the **File** menu, click **New Study**). C. Create the different watercourses (streams) where the index locations are located (from the **Configure** menu, click **Study Streams**). D. Define damage reaches for each of the index locations (from the **Configure** menu, click **Study Damage Reaches**). E. Define the analysis years - base and future year (from the **Configure** menu, click **Study Analysis Years**). F. For the baseline condition use the default plan - Without which has already been created. G. Define the inflow discharge-exceedance probability relationship (graphical) for each combination of plan, analysis year, stream, and damage reach, from the **HydEng** menu; click **Exceedance Probability Functions with Uncertainty**. The **Exceedance Probability Functions with Uncertainty** dialog box will open, click **Graphical**. Be sure to include the Equivalent Years of Record (EYR) for calculating the uncertainty of the relationship. H. If you need to define an inflow-outflow relationship and uncertainty values for each discharge-exceedance probability relationship, from the **Probability Function - Type Graphical** dialog box, click **Transform Flow (reg vs. unreg)**. I. Define the stage-outflow discharge relationship (i.e., rating curve, stage-discharge) and uncertainty values for each combination of plan, analysis year, stream, and damage reach, from the **HydEng** menu; click **Stage-Discharge Function with Uncertainty**.

Step	Task	Discussion
11a	Develop HEC-FDA model for the Baseline Condition (continue)	J. Define the target stage for the basis of the risk analysis for each combination of plan, analysis year, stream, and damage reach, from the **HydEng** menu, click **Levee Features**. K. To define an artificial set of economic data first you must define a damage category. From the **Economics** menu, click **Study Damage Categories** and create a damage category (e.g., Total). Once the damage category is created now define the stage-damage functions for each combination of plan, analysis year, damage category, stream, and damage reach, from the **Economics** menu, click **Enter/Edit/View Reach Stage-Damage Function with Uncertainty**. L. Once the data has been entered, check to make sure all the data required is available for calculation. From the **Evaluation** menu, click **Study Status Report** and review the report to make sure all the data that is required has been entered. Now that the check has been made, from the **Evaluation** menu, click **Evaluation of Plans by Analysis Year**. From the **Evaluation of Plans by Analysis Year** dialog box, highlight the **Without** plan for both analysis years, click **Compute**. The **EAD Computation Status** dialog box will open, & the EAD calculation will proceed.
11b	Evaluate HEC-FDA Results for the Baseline Condition	Place the AEP and assurance (CNP) results into an Excel® spreadsheet.
11c	Develop HEC-FDA model for the Proposed Condition	Use the same approach described in Step 11a with the information developed for the proposed condition.
11d	Evaluate HEC-FDA Results for the Proposed Conditions	Use the same approach described in Step 11b.
12	**Comparison of the Proposed Condition to Baseline Condition**	Utilize Excel® to compare the AEP and assurance (CNP) over the 0.50 to 0.002 exceedance probability floods for the baseline and proposed conditions. An increase in AEP and decrease in assurance (CNP) would be considered a potential impact. Potential impacts should be evaluated to assess their significance. The significance of the potential impacts might be defined by such things as policies (Federal, State and Local), flood damage consequences, and model resolution.

Appendix B

Example Calculations of the Risk Analysis Process for Index Locations RA07 and RA17

Appendix B

Example Calculations of the Risk Analysis Process for Index Locations RA07 and RA17

This appendix includes an example calculation for Steps 9.1 through 12 of the risk analysis process presented in Appendix A. The calculations are provided to illustrate the process and how the various relationships required for the process were determined. The calculations were performed for Index Locations RA07 and RA17. Information about these index locations is provided in Table B-1.

Table B-1. Information About Index Locations Considered for Example Calculations

Index Locations	System	River Mile (RM)	Bank	Top of Levee Elevation
RA07	Feather River	9.0	Right	56.55
RA17	Sacramento River	46.5	Right	29.64

Step 9.1 - Evaluate Baseline Condition

9.1a - Hydrology at Inflow Locations

Information related to the inflow hydrology is provided in Section 3.1.4 of this report. The peak discharges at the inflow locations are summarized in Table 4 (see Chapter 3, Section 3.1.4) of this report.

9.1b - Inflow Discharge at Index Locations

The inflow to Index Location RA07 includes: (1) Feather River, (2) Honcut Creek, (3) Yuba River, (4) Yuba River inflow at 13.59, (5) Yuba River inflow at 13.34, and (6) Bear River. The inflow discharge for each exceedance probability is estimated based on the maximum value from the summation of all the inflow hydrographs to the point of interest. An example calculation for the 0.01 exceedance probability is shown in Figure B-1. The resulting inflow discharge versus exceedance probability relationship for Index Location RA07 is shown in Figure B-2 and summarized in Table B-2.

As shown in the Figure B-1 and Table B-2, the inflow discharge-exceedance probability relationship was extended to include values for the 0.999 and 0.001 exceedance probabilities by linear extrapolation as demonstrated in the calculation for the 0.999 exceedance probability of Index Location RA07.

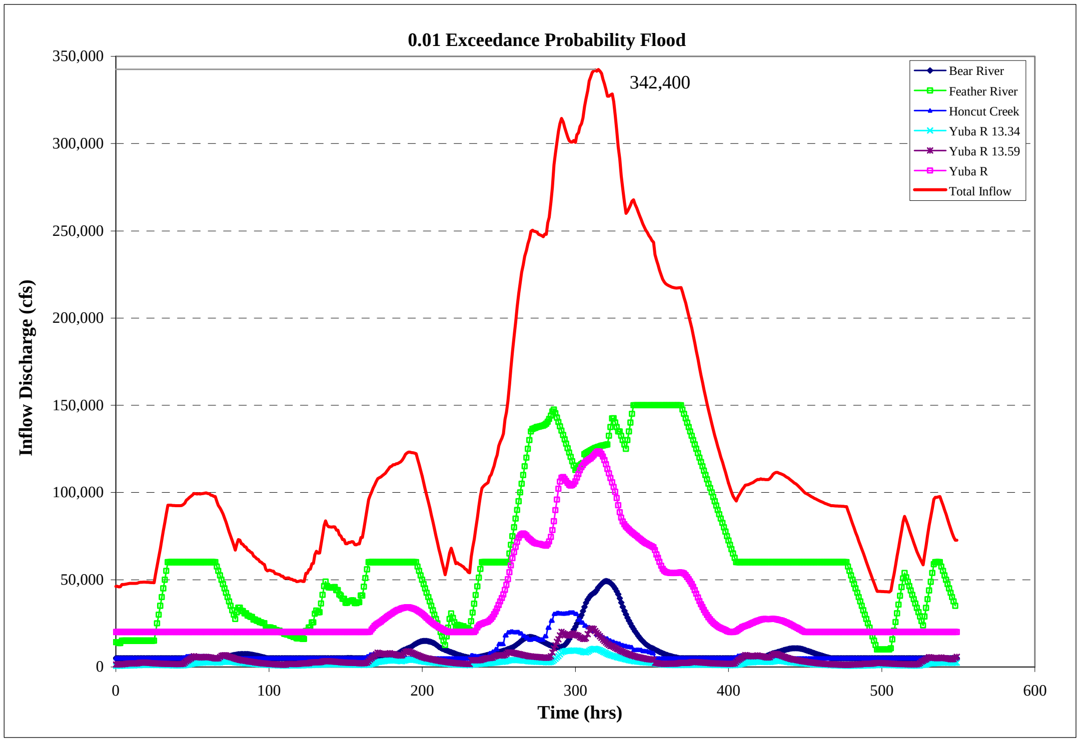


Figure B-1. Combination of Hydrographs to Determine the Inflow Discharge at Index Location RA07 for the 0.01 Exceedance Probability

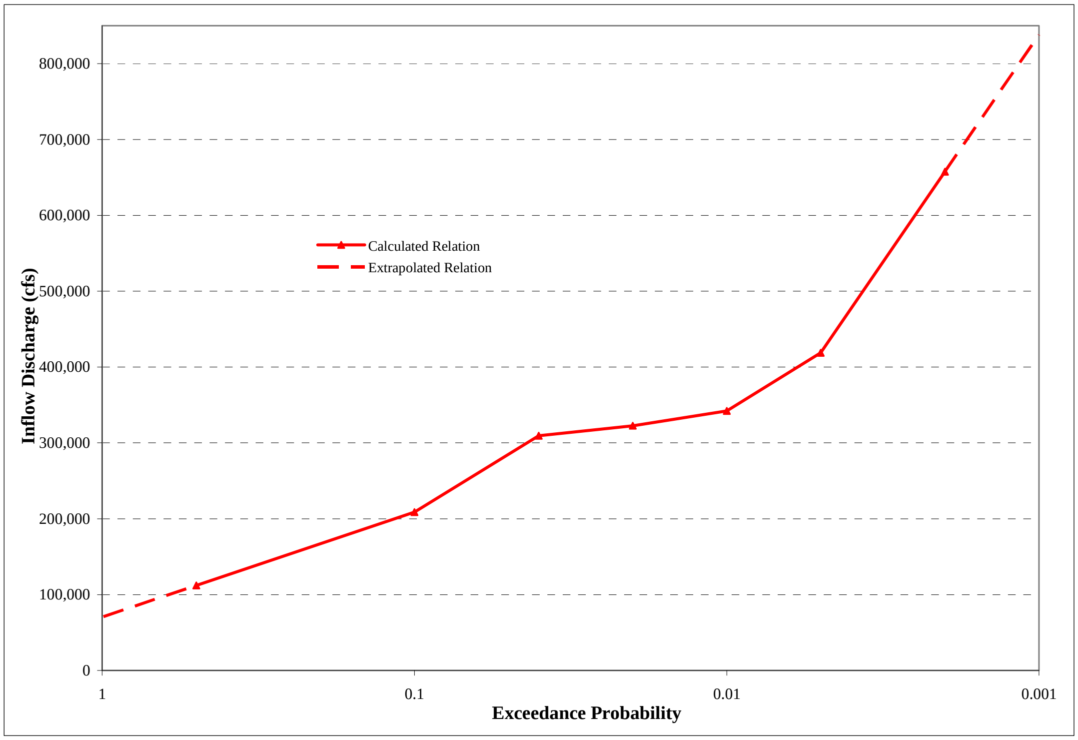


Figure B-2. Inflow Discharge versus Exceedance Probability Relationship at Index Location RA07

Table B-2. Summary of Inflow Discharge versus Exceedance Probability Relationship at Index Locations RA07 and RA17

Exceedance Probability	Index Location RA07 Inflow Discharge (cfs)	Index Location RA17 Inflow Discharge (cfs)
0.999*	70,900	166,900
0.5	112,000	224,300
0.1	208,800	359,600
0.04	309,600	525,300
0.02	322,600	551,700
0.01	342,400	666,700
0.005	419,000	939,900
0.002	657,500	1,133,400
0.001*	837,900	1,279,800

$$S = \frac{Q_{0.1} - Q_{0.5}}{Log(0.1) - Log(0.5)} = \frac{208{,}800 - 112{,}000}{Log(0.1) - Log(0.5)} = -138{,}489$$

$$Q_{0.99} = Q_{0.5} + (Log(0.5) - Log(0.99)) * S = 112{,}000 + (Log(0.5) - Log(0.99)) * -138{,}489$$
$$Q_{0.99} = 70{,}900$$

The inflow to Index Location RA17 includes: (1) upstream end of Sacramento River, (2) Sutter Bypass, (3) Feather River (Feather, Bear, Yuba, and Honcut), (4) American River, (5) Cross Canal, and (6) NEMDC. As previously mentioned, the inflow discharge for each exceedance probability is estimated based on the maximum value from the summation of all the inflow hydrographs to the point of interest. An example calculation for the 0.01 exceedance probability is shown in Figure B-3. The resulting inflow discharge versus exceedance probability relationship for Index Location RA17 is shown in Figure B-4 and summarized in Table B-2.

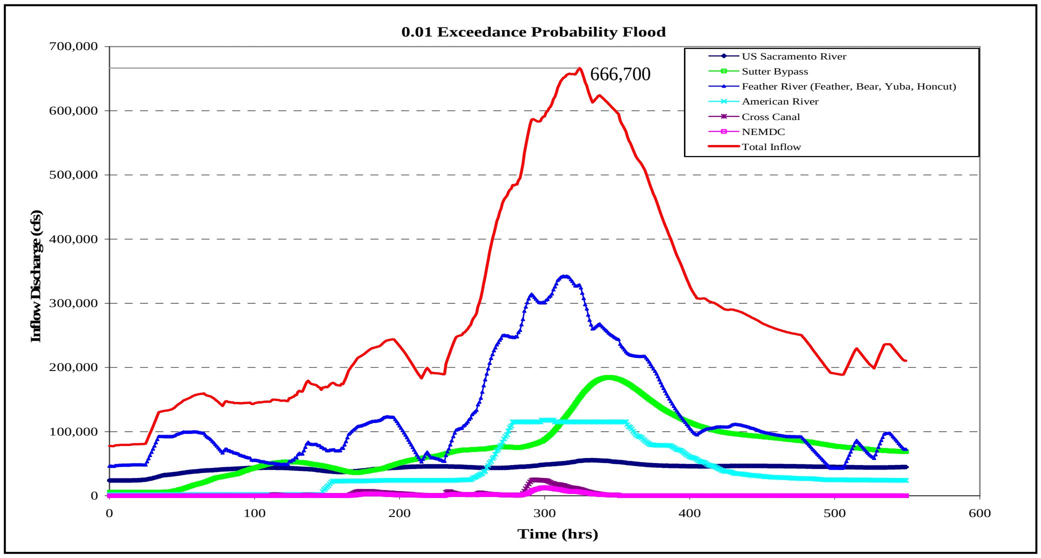


Figure B-3. Combination of Hydrographs to Determine the Inflow Discharge at Index Location RA07 for the 0.01 Exceedance Probability

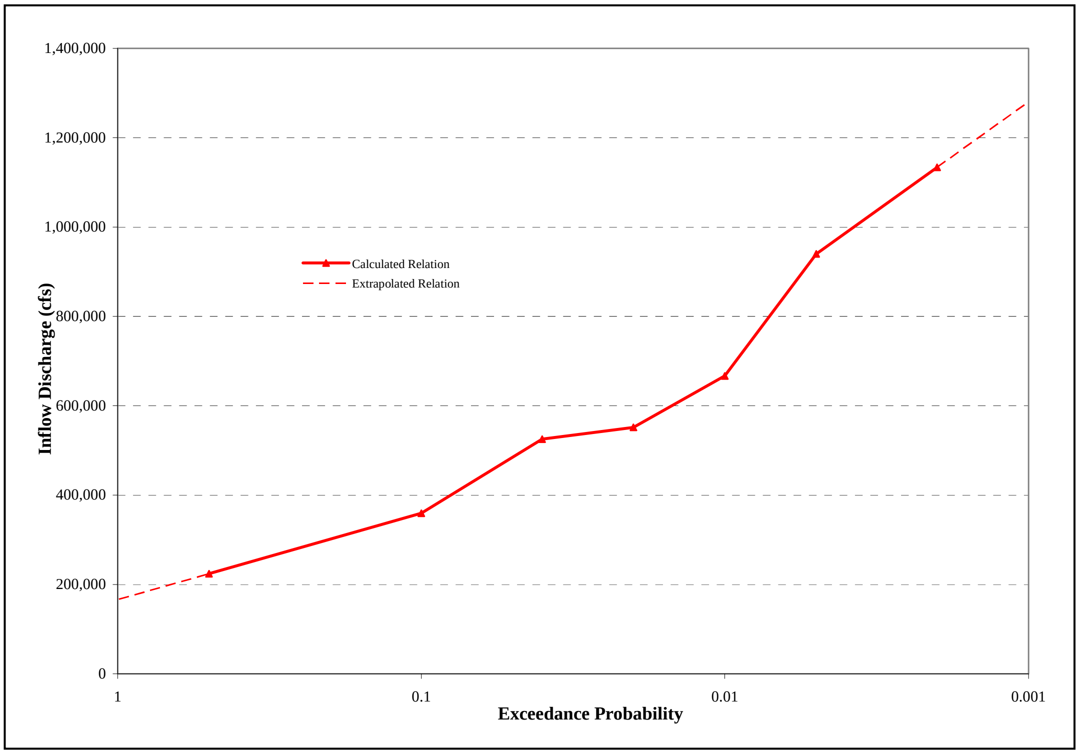


Figure B-4. Inflow Discharge versus Exceedance Probability Relationship at Index Location RA17

9.1c - Inflow-Outflow Relationship at Index Locations

The inflow-outflow relationship was defined by combining the inflow discharge versus exceedance probability and the outflow discharge versus exceedance probability relationships. The outflow discharge versus exceedance probability relationship was obtained directly from the HEC-RAS model results as shown in Figures B-5 and B-6 for the respective index locations. The outflow discharge corresponds to the flow associated with the maximum water surface elevations, and they are rounded to the same number of significant figures as inflow discharges.

Profile Output Table - Standard Table 1

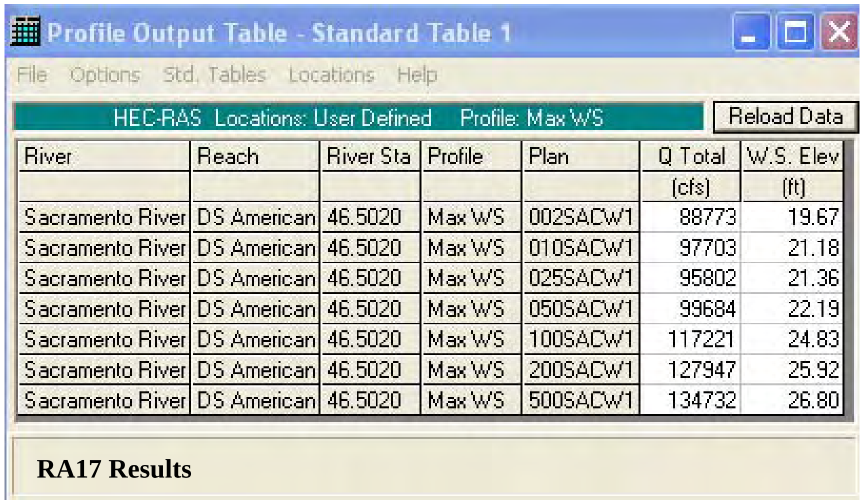
File Options Std. Tables Locations Help

HEC-RAS Locations: User Defined Profile: Max WS — Reload Data

River	Reach	River Sta	Profile	Plan	Q Total (cfs)	W.S. Elev (ft)
Feather River	Reach 35	9.00	Max WS	002SACW1	103124	40.63
Feather River	Reach 35	9.00	Max WS	010SACW1	183168	44.19
Feather River	Reach 35	9.00	Max WS	025SACW1	255408	46.97
Feather River	Reach 35	9.00	Max WS	050SACW1	289240	48.03
Feather River	Reach 35	9.00	Max WS	100SACW1	318506	49.24
Feather River	Reach 35	9.00	Max WS	200SACW1	369424	50.83
Feather River	Reach 35	9.00	Max WS	500SACW1	449488	52.34

RA07 Results

Figure B-5. HEC-RAS Results for Index Location RA07 - Baseline Condition



Profile Output Table - Standard Table 1

File Options Std. Tables Locations Help

HEC-RAS Locations: User Defined Profile: Max WS | Reload Data

River	Reach	River Sta	Profile	Plan	Q Total (cfs)	W.S. Elev (ft)
Sacramento River	DS American	46.5020	Max WS	002SACW1	88773	19.67
Sacramento River	DS American	46.5020	Max WS	010SACW1	97703	21.18
Sacramento River	DS American	46.5020	Max WS	025SACW1	95802	21.36
Sacramento River	DS American	46.5020	Max WS	050SACW1	99684	22.19
Sacramento River	DS American	46.5020	Max WS	100SACW1	117221	24.83
Sacramento River	DS American	46.5020	Max WS	200SACW1	127947	25.92
Sacramento River	DS American	46.5020	Max WS	500SACW1	134732	26.80

RA17 Results

Figure B-6. HEC-RAS Results for Index Location RA17 - Baseline Condition

Similar to the inflow discharge-exceedance probability relationship, the outflow discharge for the exceedance probabilities of 0.999 and 0.001 was estimated by linear extrapolation from the defined relationship. The unadjusted inflow-outflow relationships are summarized in Table B-3.

Table B-3. Baseline Condition Unadjusted Inflow versus Outflow Relationship at Index Location RA07 and RA17

Exceedance Probability	Inflow Discharge (cfs)	Outflow Discharge (cfs)
Index Location RA07		
0.999*	70,900	69,100
0.500	112,000	103,100
0.100	208,800	183,200
0.040	309,600	255,400
0.020	322,600	289,200
0.010	342,400	318,500
0.005	419,000	369,400
0.002	657,500	449,400
0.001*	837,900	509,900
Index Location RA17		
0.999*	166,900	85,000
0.500	224,300	88,800
0.100	359,600	97,700
0.040	525,300	95,800
0.020	551,700	99,700
0.010	666,700	117,200
0.005	939,900	127,900
0.002	1,133,400	134,400
0.001*	1,279,800	139,300

*Values estimated by linear extrapolation.

9.1d - Adjustment to Inflow-Outflow Relationship at Index Locations

HEC-FDA requires that the outflow discharge increase with increasing inflow discharge, i.e., outflow discharge must increase with decreasing exceedance probabilities. A review of the relationship for Index Location RA07 indicates that no adjustments were necessary. A review of the relationship for Index Location RA17 indicates that there is a slight reduction in outflow discharge for the 0.04 chance exceedance event. Therefore, the outflow discharge for this exceedance probability was increased slightly to be larger than the outflow discharge for the 0.10 chance exceedance event. The adjusted and unadjusted outflow discharge versus exceedance probability relationships for Index Location RA17 is shown in Figure B-7.

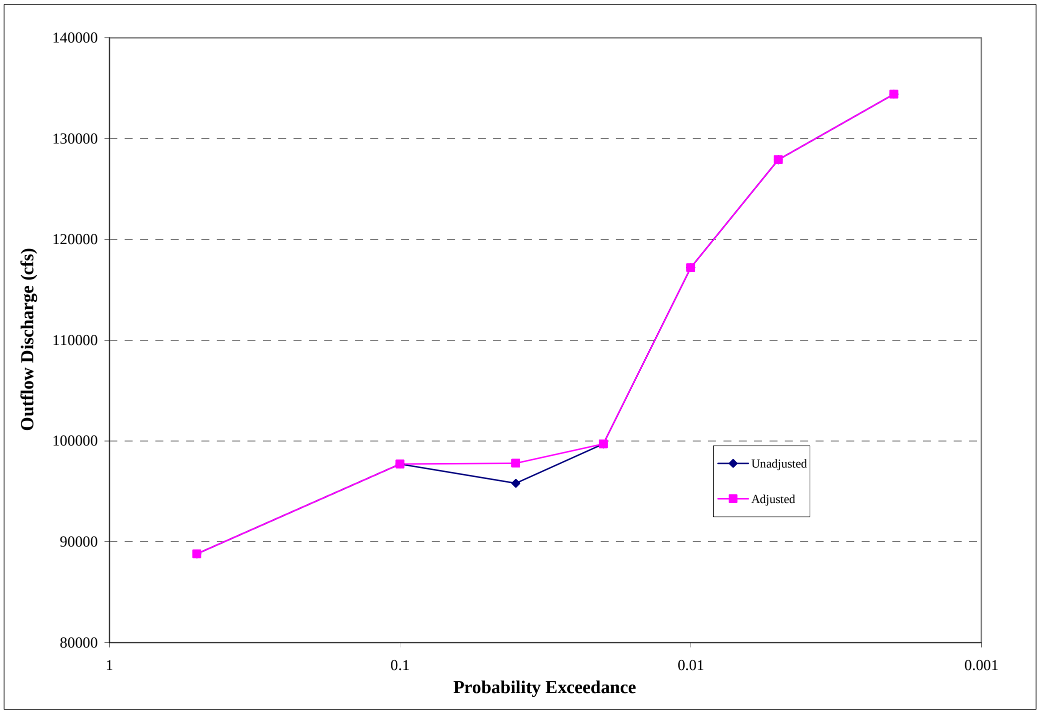


Figure B-7. Baseline Condition Outflow Discharge versus Exceedance Probability Relationship at Index Location RA17

The inflow-outflow relationship was also extended by linear extrapolation to include the maximum inflow discharge that could be sampled from the inflow versus exceedance probability relationship, i.e., upper bound of the relationship, which was obtained from the HEC-FDA program. The adopted inflow-outflow relationship is provided in Table B-4 and shown in Figure B-8.

An example calculation for the extrapolation of the inflow-outflow relationship for Index Location RA07 is provided as follows:

$$S = \frac{Qin_{0.001} - Qin_{0.002}}{Qout_{0.001} - Qout_{0.002}} = \frac{509{,}900 - 449{,}400}{837{,}900 - 657{,}500} = 0.3354$$

Table B-4. Baseline Condition Adjusted Inflow Discharge versus Outflow Discharge Relationship at Index Locations RA07 and RA17

Exceedance Probability	Inflow Discharge (cfs)	Outflow Discharge (cfs)
Index Location RA07		
0.999*	70,900	69,100
0.500	112,000	103,100
0.100	208,800	183,200
0.040	309,600	255,400
0.020	322,600	289,200
0.010	342,400	318,500
0.005	419,000	369,400
0.002	657,500	449,400
0.001*	837,900	509,900
Upper Bound of 0.001	1,527,000	741,000
Index Location RA17		
0.999*	166,900	85,000
0.500	224,300	88,800
0.100	359,600	97,700
0.040	525,300	95,800
0.020	551,700	99,700
0.010	666,700	117,200
0.005	939,900	127,900
0.002	1,133,400	134,400
0.001*	1,279,800	139,300
Upper Bound of 0.001	2,447,700	178,400

*Values estimated by linear extrapolation.

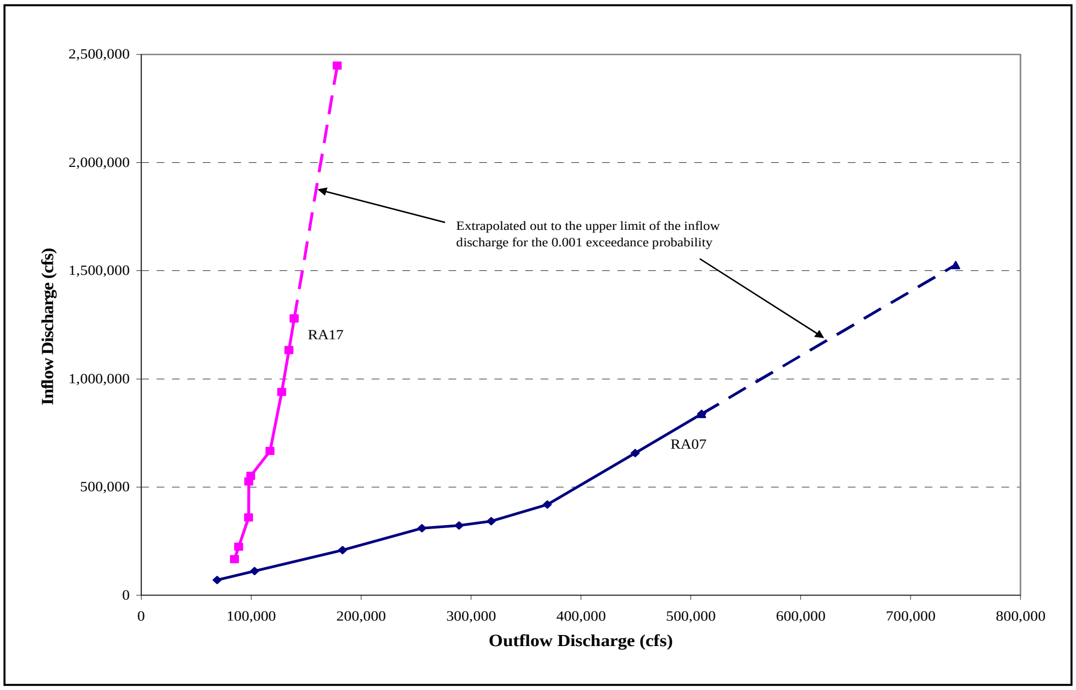


Figure B-8. Baseline Condition Inflow Discharge versus Outflow Discharge Relationship

$$Qout_{\max} = Qout_{0.001} + (Qin_{\max} - Qin_{0.001}) * S \quad = 509{,}900 + (1{,}527{,}000 - 837{,}900) * 0.3354$$
$$Qout_{\max} = 741{,}000$$

There were several index locations where the outflow discharge versus exceedance probability relationship was influenced by the attenuation effects of the upstream overbank areas associated with either levee overtopping and/or levee breaches. At Index Locations RA07 and RA17, there were no attenuation effects. To demonstrate the adjustments made to the relationships where attenuation effects occurred, the relationship at Index Location RA09 is presented. The outflow discharge versus exceedance probability relationship for Index Location RA09 is shown in Figure B-9, and the inflow-outflow relationship is shown in Figure B-10. As shown in Figure B-9., the adjustment involved using a discharge slightly greater than the discharge prior to the reduction in the relationship.

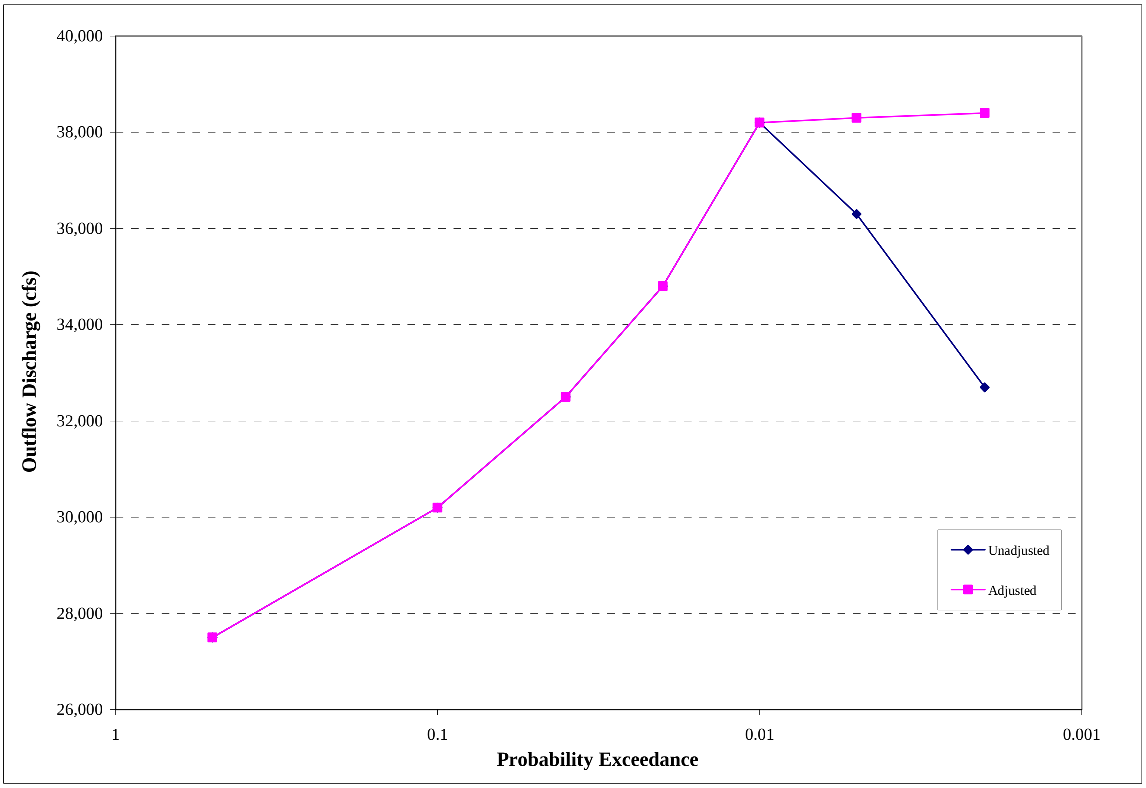


Figure B-9. Baseline Condition Outflow Discharge versus Exceedance Probability Relationship at Index Location RA09

9.1e - Estimate Stage-Outflow Discharge Relationship at Index Locations

The stage versus outflow discharge relationship was defined by combining the outflow versus exceedance probability and the stage versus exceedance probability relationships. The stage versus exceedance probability relationship was obtained directly from the HEC-RAS model results as shown in Figures B-5 and B-6 for the respective index locations. The stage corresponds to the maximum stage for the entire simulation. The stage versus outflow relationship is summarized in Table B.5. **NOTE: See Appendix A, Step 9.1e for a more appropriate method to develop the stage-outflow discharge relationship.**

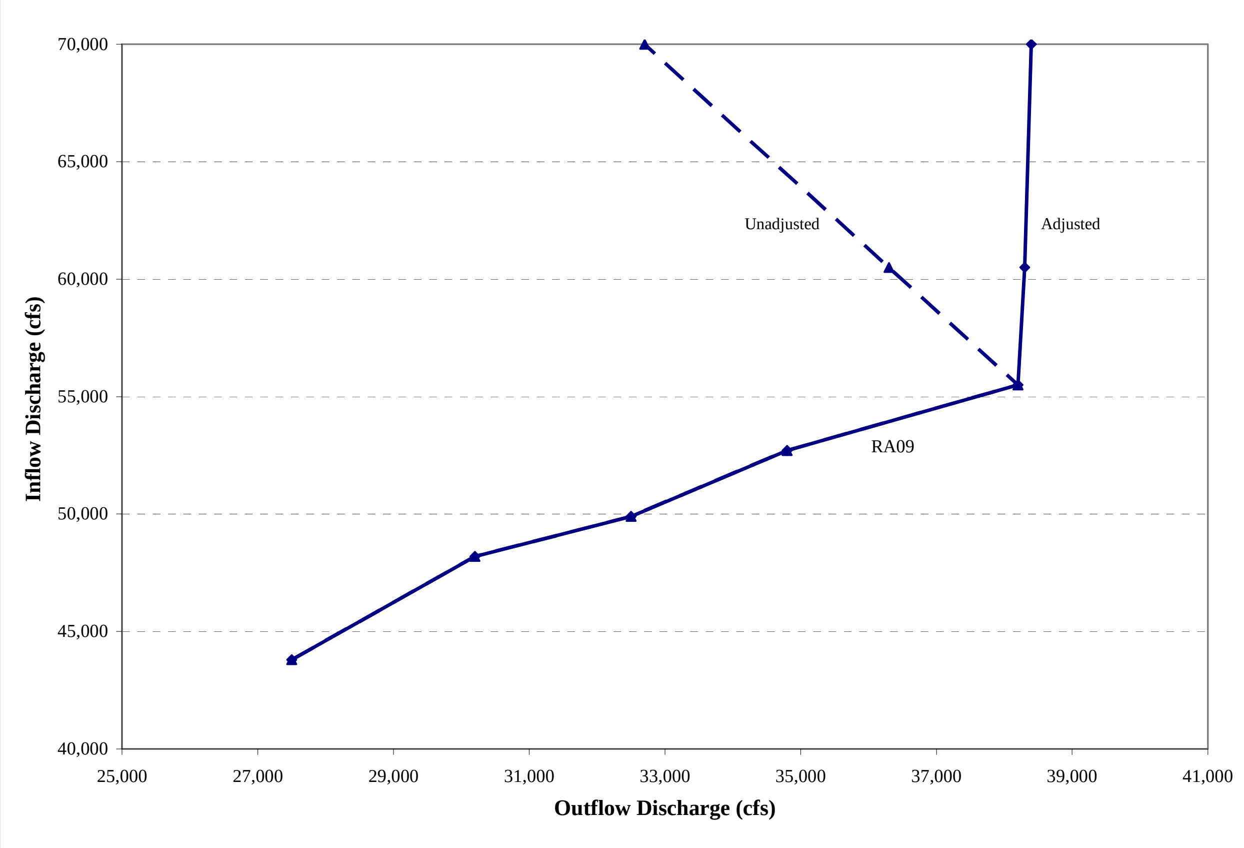


Figure B-10. Baseline Condition Inflow-Outflow Relationship at Index Location RA09

Table B-5 Baseline Condition Unadjusted Stage versus Outflow Discharge Relationship at Index Locations RA07 and RA17

Exceedance Probability	Stage (ft)	Outflow Discharge (cfs)
Index Location RA07		
0.500	40.63	103,100
0.100	44.19	183,200
0.040	46.97	255,400
0.020	48.03	289,200
0.010	49.24	318,500
0.005	50.83	369,400
0.002	52.34	449,400
Index Location RA17		
0.500	19.67	88,800
0.100	21.18	97,700
0.040	21.36	95,800
0.020	22.19	99,700
0.010	24.83	117,200
0.005	25.92	127,900
0.002	26.76	134,400

9.1f - Adjustment to Stage-Outflow Discharge Relationship at Index Locations

For both Index Locations RA07 and RA17, the stage for the 0.002 exceedance probability was below the top of levee elevation. Therefore, the relationship was adjusted by extending the relationship to be above the top of the levee elevation. The adjustment was made by linear extrapolating the relationship out to the 0.001 exceedance probability and then assuming that the stage for the maximum discharge would be two feet above the top of levee elevation. The relationship was also adjusted to include a discharge of zero. Since Index Location RA07 is not tidally influenced, a stage equal to the thalweg elevation was defined for no outflow discharge. The adjusted stage versus exceedance probability relationship at Index Location RA07 is shown in Figure B-11. The resulting stage versus outflow discharge relationship is shown in Figure B-12 and summarized in Table B-6.

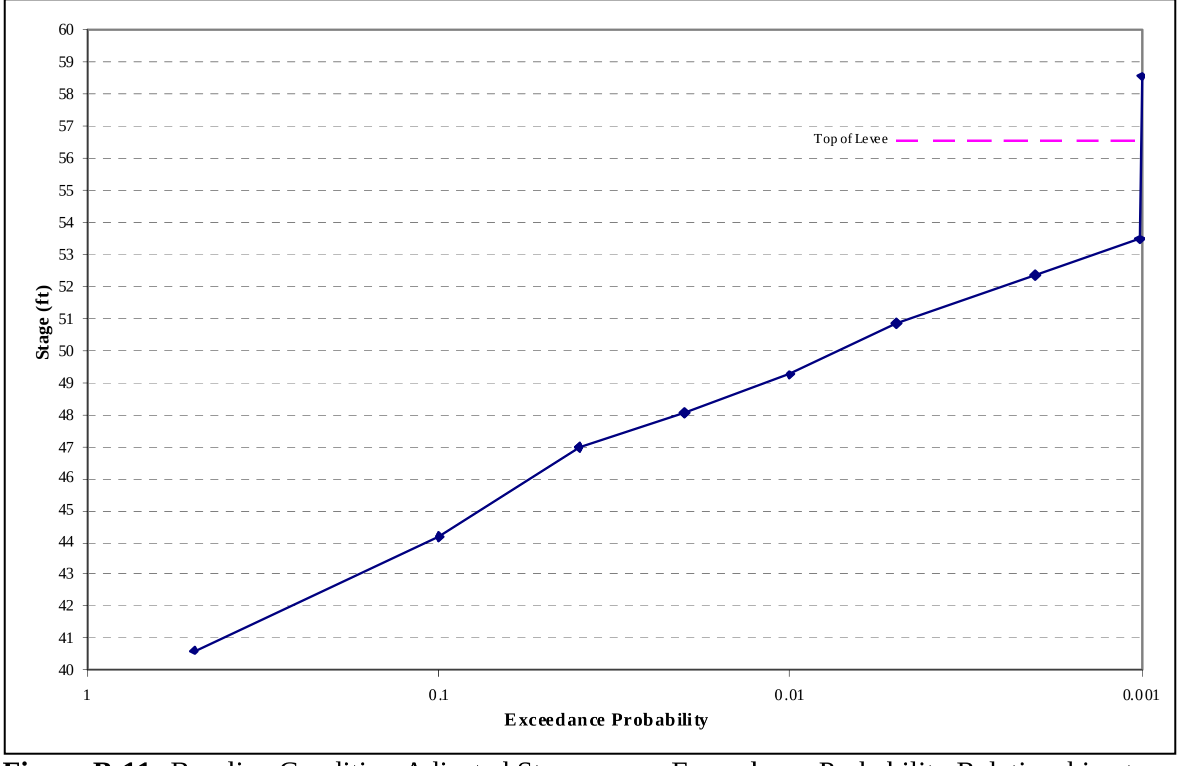


Figure B-11. Baseline Condition Adjusted Stage versus Exceedance Probability Relationship at Index Location RA07

The stage for the 0.001 exceedance probability was determined by linear extrapolation demonstrated as follows:

$$S = \frac{Stage_{0.002} - Stage_{0.005}}{Log(0.002) - Log(0.005)} = \frac{52.34 - 50.83}{Log(0.002) - Log(0.005)} = -3.7945$$

$$Stage_{0.001} = Stage_{0.002} + (Log(0.001) - Log(0.002)) * S$$

$$Stage_{0.001} = 52.34 + (Log(0.001) - Log(0.002)) * -3.7945 = 53.48$$

Table B-6. Baseline Condition Adjusted Stage versus Outflow Discharge Relationship at Index Location RA07

Exceedance Probability	Stage (ft)	Outflow Discharge (cfs)
n/a	11.12	0
0.500	40.63	103,100
0.100	44.19	183,200
0.040	46.97	255,400
0.020	48.03	289,200
0.010	49.24	318,500
0.005	50.83	369,400
0.002	52.34	449,400
0.001	53.48[a]	509,900[a]
Upper Bound of 0.001	58.55[b]	741,000[a]

[a] Values estimated by linear extrapolation.
[b] Maximum stage set at two feet above the top of levee elevation.

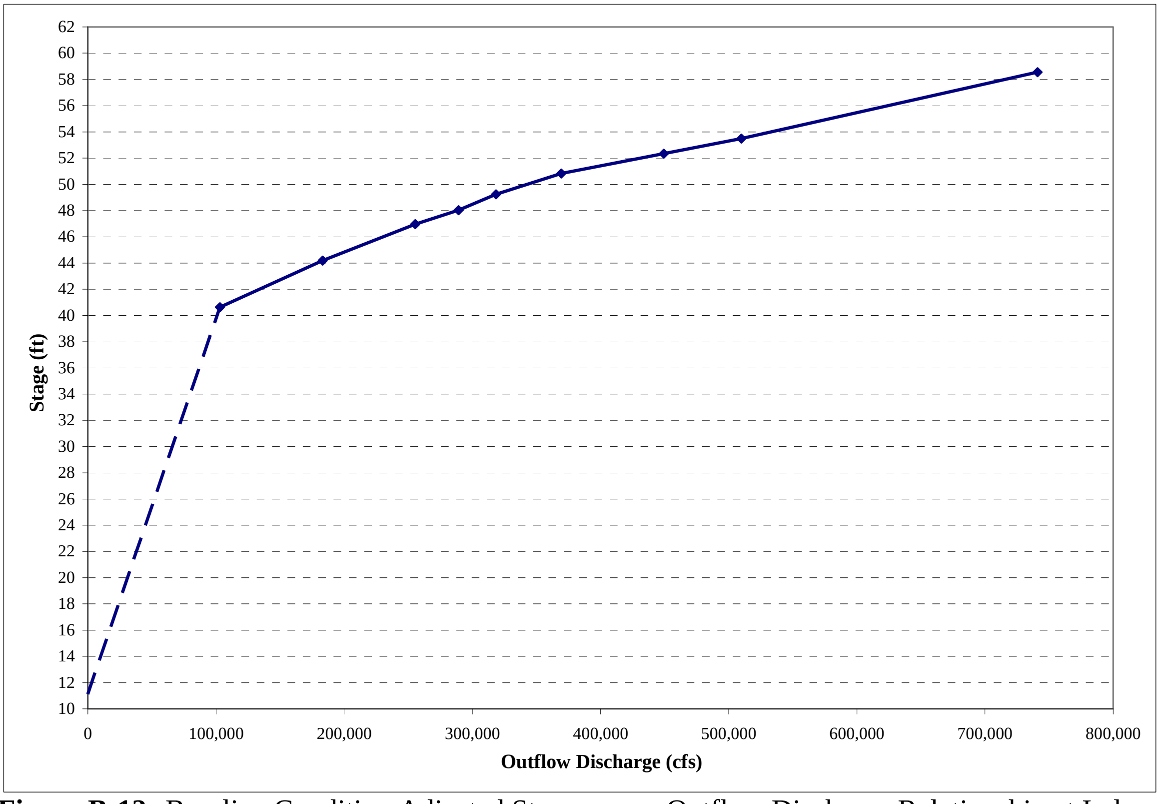


Figure B-12. Baseline Condition Adjusted Stage versus Outflow Discharge Relationship at Index Location RA07

The computation was only performed when the stage for the 0.002 exceedance probability was below the top of levee elevation.

The adjusted stage versus exceedance probability relationship at Index Location RA17 is shown in Figure B-13. The resulting stage versus outflow discharge relationship is shown in Figure B-14 and summarized in Table B-7.

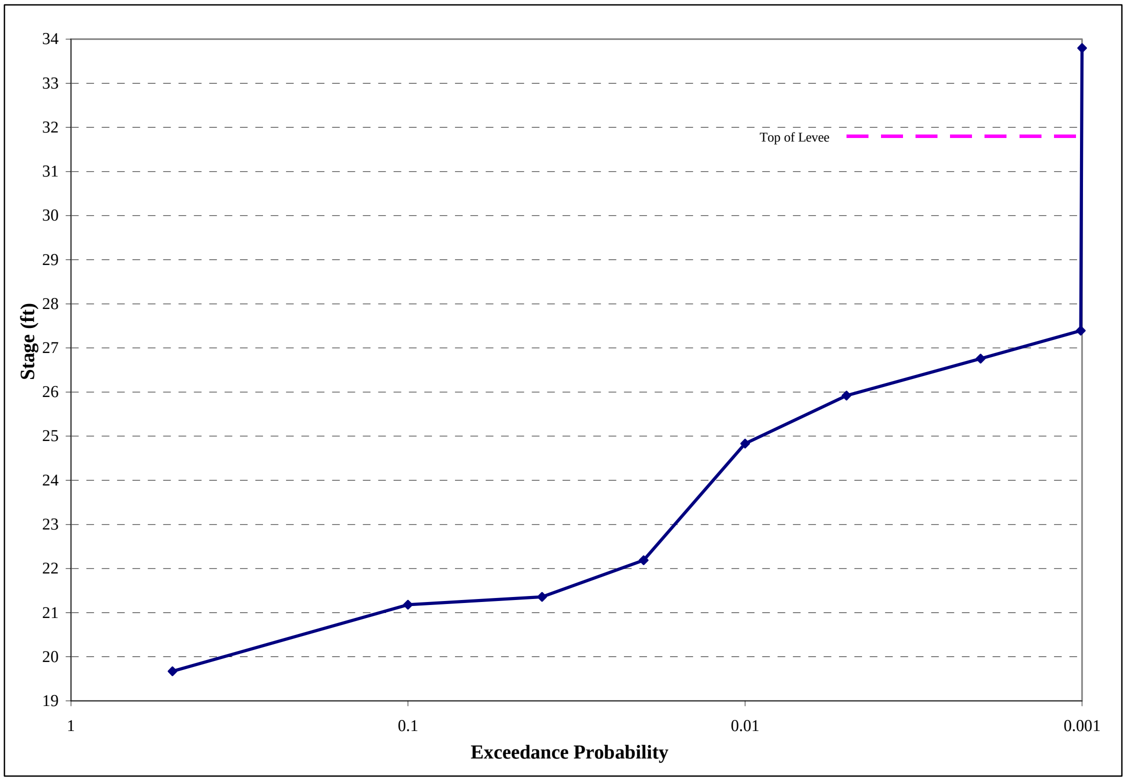


Figure B-13. Baseline Condition Adjusted Stage versus Exceedance Probability Relationship at Index Location RA17

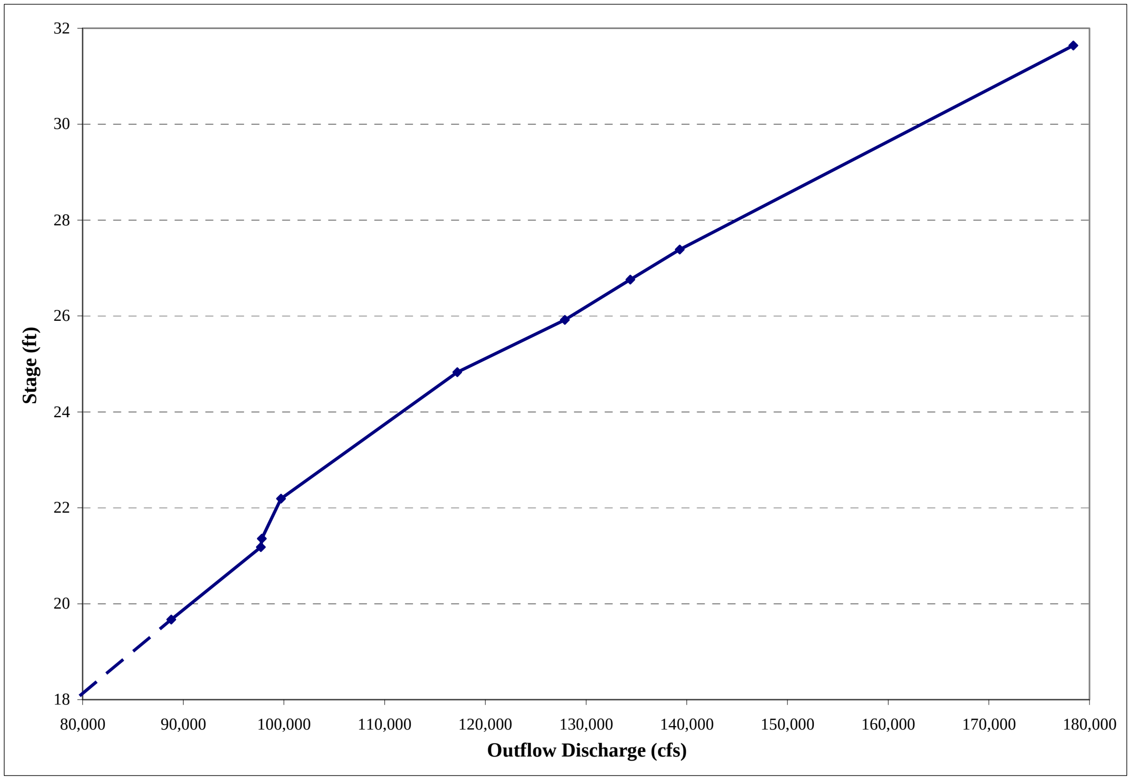


Figure B-14. Baseline Condition Adjusted Stage versus Outflow Discharge Relationship at Index Location RA17

Table B-7. Baseline Condition Adjusted Stage versus Outflow Discharge Relationship at Index Location RA17

Exceedance Probability	Stage (ft)	Outflow Discharge (cfs)
n/a.	4.14	0
0.500	19.67	88,800
0.100	21.18	97,700
0.040	21.36	95,800
0.020	22.19	99,700
0.010	24.83	117,200
0.005	25.92	127,900
0.002	26.76	134,400
0.001	27.39[a]	139,300[a]
Upper Bound of 0.001	38.25[b]	178,400[a]

[a] Values estimated by linear extrapolation.
[b] Maximum stage set at two feet above the top of levee elevation.

Step 9.2 - Evaluate Proposed Condition

The proposed condition provided for this example calculation is based on the Bear River-Feather No.1 River EIP.

9.2a - Hydrology at Inflow Locations

No changes were made to the inflow hydrology for the proposed condition. So, the same information presented in Step 9.1.a was used for the proposed condition.

9.2b - Inflow Discharge at Index Locations

No changes were made to the inflow hydrology for the proposed condition. So, the information provided in Step 9.1.b was used for the proposed condition.

9.2c - Inflow-Outflow Relationship at Index Locations

The HEC-RAS results for the proposed condition are provided in Figures B-15 and B-16, and the unadjusted inflow-outflow relationships are summarized in Table B-8.

9.2d - Adjustment to Inflow-Outflow Relationship at Index Locations

Adjustment to the inflow-outflow relationship was necessary only for Index Location RA17. The same approach for adjusting the inflow-outflow relationship for the baseline condition was used for the proposed condition. Therefore, the outflow discharge for this exceedance probability was increased to slightly larger than the outflow discharge for the 0.10 chance exceedance event. The adjusted and unadjusted outflow discharges versus exceedance probability relationships for Index Location RA17 are shown in Figure B-17.

Profile Output Table - Standard Table 1

File Options Std. Tables Locations Help

HEC-RAS Locations: User Defined Profile: Max WS | Reload Data

River	Reach	River Sta	Profile	Plan	Q Total	W.S. Elev
					(cfs)	(ft)
Feather River	Reach 35	9.00	Max WS	002SACW1	103538	40.65
Feather River	Reach 35	9.00	Max WS	010SACW1	183773	44.21
Feather River	Reach 35	9.00	Max WS	025SACW1	257266	47.01
Feather River	Reach 35	9.00	Max WS	050SACW1	291925	48.14
Feather River	Reach 35	9.00	Max WS	100SACW1	322899	49.39
Feather River	Reach 35	9.00	Max WS	200SACW1	374205	50.94
Feather River	Reach 35	9.00	Max WS	500SACW1	474704	52.96

RA07 Results

Figure B-15. HEC-RAS Results for Index Location RA07 - Proposed Condition

Profile Output Table - Standard Table 1

File Options Std. Tables Locations Help

HEC-RAS Locations: User Defined Profile: Max WS | Reload Data

River	Reach	River Sta	Profile	Plan	Q Total	W.S. Elev
					(cfs)	(ft)
Sacramento River	DS American	46.5020	Max WS	002SACW1	88669	19.65
Sacramento River	DS American	46.5020	Max WS	010SACW1	97715	21.18
Sacramento River	DS American	46.5020	Max WS	025SACW1	95683	21.34
Sacramento River	DS American	46.5020	Max WS	050SACW1	99899	22.23
Sacramento River	DS American	46.5020	Max WS	100SACW1	117334	24.85
Sacramento River	DS American	46.5020	Max WS	200SACW1	127826	25.89
Sacramento River	DS American	46.5020	Max WS	500SACW1	134668	26.78

RA17 Results

Figure B-16. HEC-RAS Results for Index Location RA17 - Proposed Condition

The maximum outflow was assumed to be the same outflow as that estimated for the baseline condition. The adopted inflow-outflow relationship is provided in Table B-9 and shown in Figure B-18.

9.2e - Estimate Stage-Outflow Discharge Relationship at Index Locations

The stage versus outflow discharge relationship for the proposed condition was defined using the same approach used for the baseline condition. The HEC-RAS model results used to develop the relationship are displayed in Figures B-15 and B-16, and the stage versus outflow discharge relationship is summarized in Table B-10.

Table B-8. Proposed Condition Unadjusted Inflow versus Outflow Discharge Relationship at Index Locations RA07 and RA17

Exceedance Probability	Inflow Discharge (cfs)	Outflow Discharge (cfs)
Index Location RA07		
0.999*	70,900	69,400
0.500	112,000	103,500
0.100	208,800	183,800
0.040	309,600	257,300
0.020	322,600	291,900
0.010	342,400	322,900
0.005	419,000	374,200
0.002	657,500	474,700
0.001*	837,900	550,700
Index Location RA17		
0.999*	166,900	84,900
0.500	224,300	88,700
0.100	359,600	97,700
0.040	525,300	95,700
0.020	551,700	99,900
0.010	666,700	117,300
0.005	939,900	127,800
0.002	1,133,400	134,700
0.001*	1,279,800	139,900

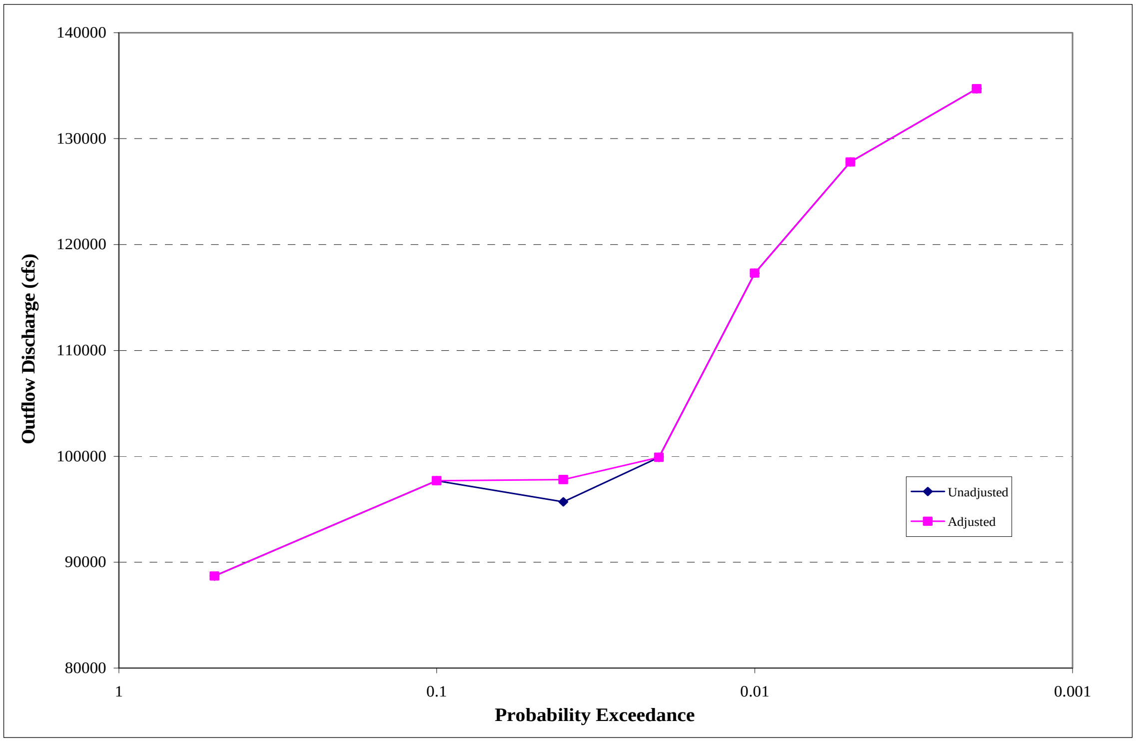


Figure B-17. Proposed Condition Outflow Discharge versus Exceedance Probability Relationship at Index Location RA17

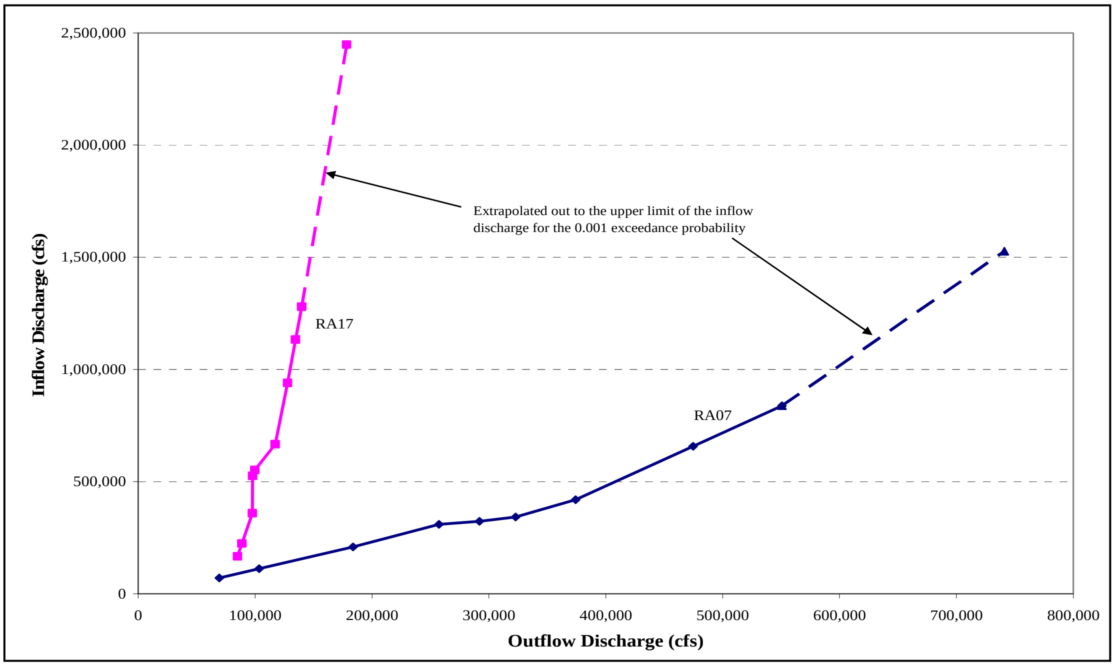


Figure B-18. Proposed Condition Inflow Discharge versus Outflow Discharge Relationship

Table B-9. Proposed Condition Adjusted Inflow versus Outflow Discharge Relationship at Index Locations RA07 and RA17

Exceedance Probability	Inflow Discharge (cfs)	Outflow Discharge (cfs)
	RA07	
0.999	70,900[a]	69,400[a]
0.500	112,000	103,500
0.100	208,800	183,800
0.040	309,600	257,300
0.020	322,600	291,900
0.010	342,400	322,900
0.005	419,000	374,200
0.002	657,500	474,700
0.001	837,900[a]	550,700[a]
Upper Bound of 0.001	1,527,000	741,000[b]
	RA17	
0.999	166,900[a]	84,900[a]
0.500	224,300	88,700
0.100	359,600	97,700
0.040	525,300	97,800
0.020	551,700	99,900
0.010	666,700	117,300
0.005	939,900	127,800
0.002	1,133,400	134,700
0.001	1,279,800[a]	139,900[a]
Upper Bound of 0.001	2,447,700	178,400[b]

[a]Values estimated by linear extrapolation.
[b]Maximum outflow was assumed to be the same as that estimated for the baseline condition.

Table B-10. Proposed Condition Unadjusted Stage versus Outflow Discharge Relationship at Index Locations RA07 and RA17

Exceedance Probability	Stage (ft)	Outflow Discharge (cfs)
Index Location RA07		
0.500	40.65	103,500
0.100	44.21	183,800
0.040	47.01	257,300
0.020	48.14	291,900
0.010	49.39	322,900
0.005	50.94	374,200
0.002	52.96	474,700
Index Location RA17		
0.500	19.65	88,700
0.100	21.18	97,700
0.040	21.34	97,800
0.020	22.23	99,900
0.010	24.85	117,300
0.005	25.89	127,800
0.002	26.78	134,700

9.2f - Adjustment to Stage-Outflow Discharge Relationship at Index Locations

The stage-outflow discharge relationships for Index Locations RA07 and RA17 were adjusted using the same assumptions considered for the baseline condition. The adjusted stage versus exceedance probability relationship at Index Location RA07 is shown in Figure B-19, and the resulting stage versus outflow discharge relationship is shown in Figure B-20. The adjusted

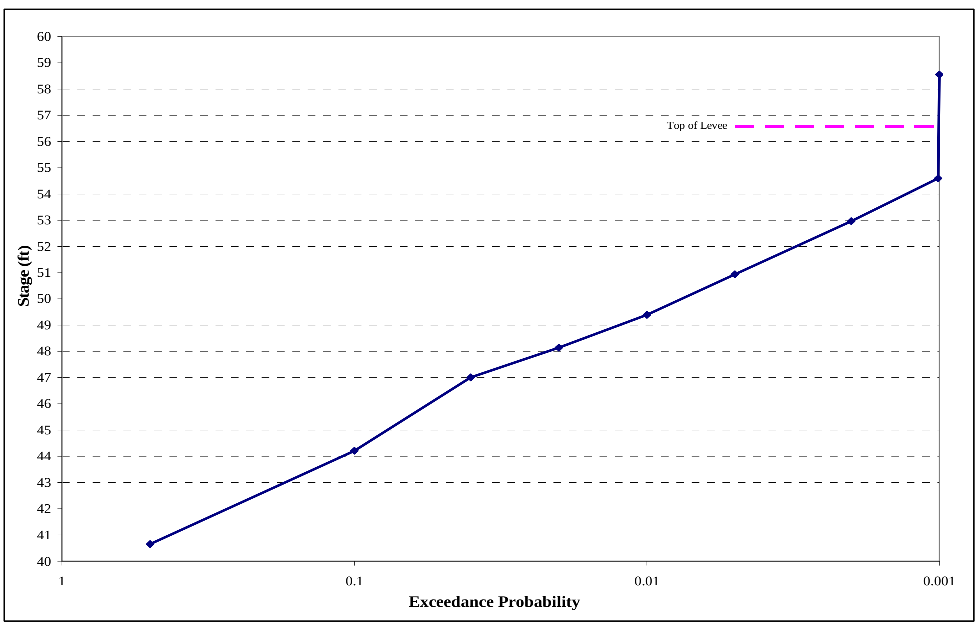


Figure B-19. Proposed Condition Adjusted Stage versus Exceedance Probability Relationship at Index Location RA07

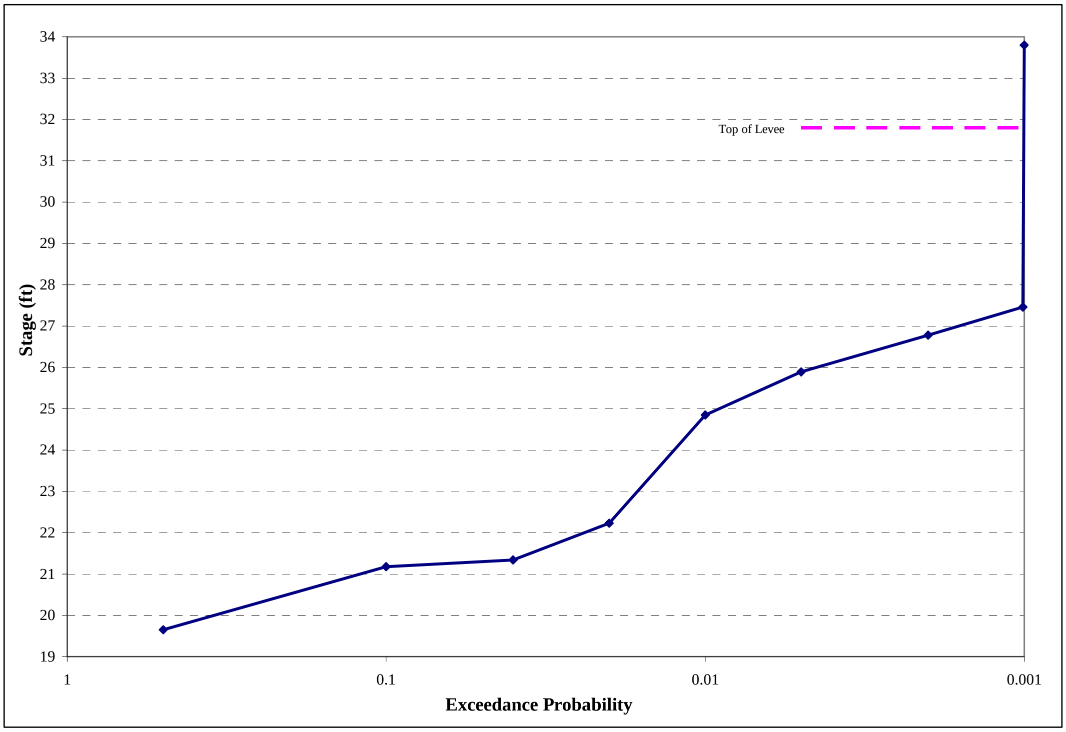


Figure B-20. Proposed Condition Adjusted Stage versus Outflow Discharge Relationship at Index Location RA07

stage versus exceedance probability relationship at Index Location RA17 is shown in Figure B-21 and the resulting stage versus outflow discharge relationship are shown in Figure B-22. Both relationships are summarized in Table B-11.

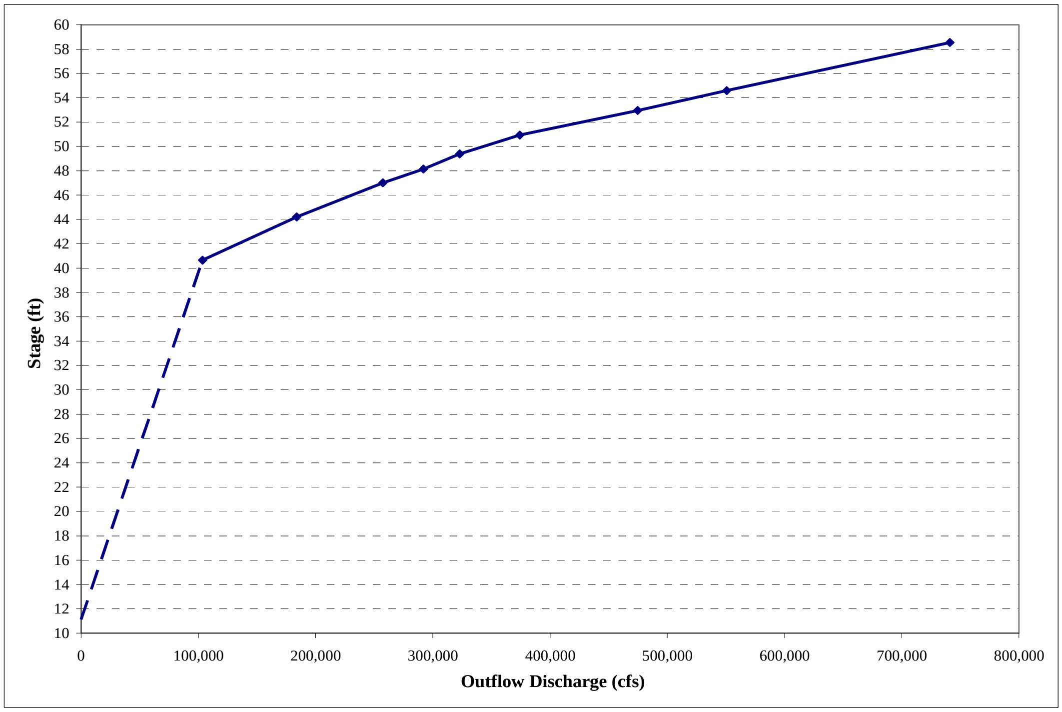


Figure B-21. Proposed Condition Adjusted Stage versus Exceedance Probability Relationship at Index Location RA17

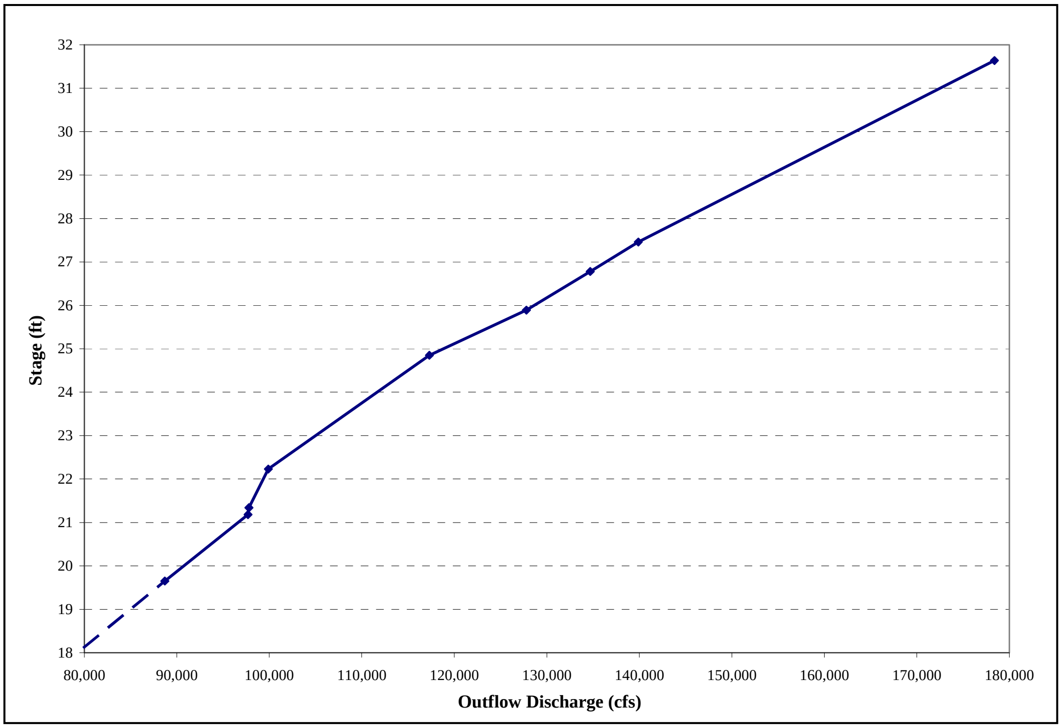


Figure B-22. Proposed Condition Adjusted Stage versus Outflow Discharge Relationship at Index Location RA17

Step 10.1 - Uncertainty for Baseline Condition

10.1a - Uncertainty at Inflow Discharge Locations

Information about how the uncertainty in the inflow discharge versus exceedance probability relationship at all of the inflow locations was estimated is presented in Section 3.1.10 of this report. Briefly, the uncertainty was estimated using the Equivalent Years of Record (EYR) for combining the uncertainty of the unregulated and regulated flow conditions. The uncertainty for the unregulated flow was estimated using the direct analytical approach documented in Bulletin 17B (USGS, 1982) and information provided in the Comprehensive Study (USACE, 2002). The uncertainty for the regulated flow conditions was estimated assuming that the 95% confidence boundaries are defined as ±10% of the median value. An example calculation for the Upstream Sacramento is provided as follows:

A. Obtain Log-Pearson Type III statistics for the inflow location (based on Sacramento River at Ord Ferry).

Component	Based on Five-Day Relationship
Mean (M)	4.866
Standard Deviation (S)	0.279
Skew (G)	-0.100
Years of Record (N)	76.000

Table B-11. Proposed Condition Adjusted Stage versus Outflow Discharge Relationship at Index Locations RA07 and RA17

Exceedance Probability	Stage (ft)	Outflow Discharge (cfs)
Index Location RA07		
-	11.12	0
0.500	40.65	103,500
0.100	44.21	183,800
0.040	47.01	257,300
0.020	48.14	291,900
0.010	49.39	322,900
0.005	50.94	374,200
0.002	52.96	474,700
0.001	54.59[a]	550,700
Upper Bound of 0.001	58.55[b]	741,000
Index Location RA17		
-	4.14	0
0.500	19.65	88,700
0.100	21.18	97,700
0.040	21.34	97,800
0.020	22.23	99,900
0.010	24.85	117,300
0.005	25.89	127,800
0.002	26.78	134,700
0.001	27.46[a]	139,900
Upper Bound of 0.001	31.64[b]	178,400

[a] Values estimated by linear extrapolation.
[b] Maximum stage set at two feet above the top of levee elevation.

B. Determine confidence limits (CL) and standard deviation for the unregulated flow conditions.

Component	Equation\Comment	Value
Exceedance Probability (p)	None	0.01
Standard Normal Deviate (Kn)	Calculate as NORMSINV (1-P) in Excel®	2.326
K value	K value can be estimated using Equation 3-1 provided in Bulletin 17B $K = \frac{2}{G}\left[\left((K_n - \frac{G}{6})\frac{G}{6}+1\right)^3 - 1\right]$	2.253000
Standard Normal Deviate for Confidence Limits (Zc)	Calculate as NORMSINV (0.975) function in Excel®	1.959964
Equation 9-5 ("a") in Bulletin 17B	$a = 1 - \frac{Z_c^2}{1(N-1)}$	0.974000
Equation 9-6 ("b") in Bulletin 17B	$b = K_n^2 - \frac{Z_x^2}{N}$	5.024200

Component	Equation\Comment	Value
Equation 9-4b ("K_L") in Bulletin 17B	$K_L = \frac{K_n - \sqrt{K_n^2 - (a)(b)}}{a}$	1.877000
Equation 9-4a ("K_U") in Bulletin 17B	$K_U = \frac{K_n + \sqrt{K_n^2 - (a)(b)}}{a}$	2.746000
2.5% CL (log space)	2.5% CL = M + K_L(S)	5.390000
97.5% CL (log space)	97.5% CL= M + K_U(S)	5.632000
Standard deviation of uncertainty for unregulated flow conditions	SD = (97.5% CL -2.5% CL)/4	0.061000

C. Determine confidence limits (CL) and standard deviation for the regulated flow conditions.

Component	Equation/Comment	Value
Regulated Flow (QR)	Obtained from Comprehensive Study (CEPSK, 2002)	55,472
Low Flow (QR_L)	QR_L = 0.9*QR	49,925
High Flow (QR_U)	QR_U = 1.1*QR	61,019
Low Log Flow	Log(QR_L)	4.698320
High Log Flow	Log(QR_U)	4.785470
Standard deviation of uncertainty for regulated flow conditions	SD = (Log(QR_U) - Log(QR_L))/4	0.021788

D. Determine standard deviation for combined flow conditions.

Component	Equation/Comment	Value
Standard deviation of uncertainty for combined flow conditions	$SD_{combine} = \sqrt{SD_{reg}^2 + SD_{unreg}^2}$	0.064000

E. Determine equivalent years of record (EYR) using a trial-and-error procedure.

Component	Equation/Comment	Value
Assumed EYR	Change the EYR until the value below equals the value in Step D.	68.000000
Standard Normal Deviate for Confidence Limits (Zc)	Calculate as NORMSINV (0.975) function in Excel®	1.959964
Equation 9-5 ("a") in Bulletin 17B	Same equation provided in B.5.	0.971000
Equation 9-6 ("b") in Bulletin 17B	$b = K_n^2 - \frac{Z_x^2}{N}$	5.018000
Equation 9-4b ("K_L") in Bulletin 17B	$K_L = \frac{K_n - \sqrt{K_n^2 - (a)(b)}}{a}$	1.858000
Equation 9-4a ("K_U") in Bulletin 17B	$K_U = \frac{K_n + \sqrt{K_n^2 - (a)(b)}}{a}$	2.780000

Component	Equation/Comment	Value
2.5% CL (log space)	2.5% CL = M + K_L(S)	5.384
97.5% CL (log space)	97.5% CL= M + K_U(S)	5.642
Standard deviation of uncertainty	SD = (97.5% CL -2.5% CL)/4	0.064

The EYR at all of the inflow locations is summarized in Table B-12.

Table B-12. Equivalent Years of Record (EYR) at Handoff Locations.

Location	Type	Method	Number of Years	Equivalent Years of Record (EYR)
Upstream Sacramento	Regulated	Order statistics using FDA	76	68
Upstream Feather River	Regulated	Order statistics using FDA	96	89
Yuba River	Regulated	Order statistics using FDA	94	88
Bear River	Regulated	Order statistics using FDA	93	85
American River	Regulated	Order statistics using FDA	93	87
Putah Creek	Regulated	Order statistics using FDA	68	62
Cache Creek	Regulated	Order statistics using FDA	73	66
Local Inflows				
NEMDC at RS6.425	Unregulated	Order statistics using FDA	--	25
NEMDC at RS6.425	Unregulated	Order statistics using FDA	--	25
Sutter Bypass	Diversion	Order statistics using FDA	--	55
Yuba River at RS 13.59 (Deer Creek)	Regulated	Order statistics using FDA	62	56
Yuba River at RS 13.34 (Dry Creek)	Regulated	Order statistics using FDA	--	56
Tributaries to Cross Canal	Unregulated	Order statistics using FDA	--	25
Honcut Creek (Local inflow to SA Robinson)	Unregulated	Order statistics using FDA	--	48

10.1b - Uncertainty of the Inflow Discharge at Index Locations

The uncertainty of the inflow discharge at the index locations was estimated using a discharge weighted EYR. The calculation for the adopted EYR for Index Location RA07 is provided in Table B-13, and the calculation for the adopted EYR for Index Location RA07 is provided in Table B-14.

The uncertainty of the inflow discharge versus exceedance probability relationship calculated by the HEC-FDA program for Index Locations RA07 and RA17 is shown in Figures B-23 and
B-24, respectively.

10.1c - Estimate Uncertainty in Inflow-Outflow Relationships

The uncertainty in the outflow discharge relationship was estimated from the results of sensitivity analysis that included the roughness coefficients, weir coefficients, downstream boundary, and breach characteristics. With a high and low uncertainty band defined for n-values, weir coefficients, and downstream boundary conditions, eight separate sensitivity analysis plans were constructed in the HEC-RAS model:

Table B-13. Equivalent Years of Record (EYR) for Index Location RA07.

System	EYR (years)	Peak Discharge (cfs)	EYR*Q
Bear River	85	49,200	4,182,000
Feather River	92	150,000	13,800,000
Honcut Creek	48	31,250	1,500,000
Yuba River	88	123,600	10,876,800
Yuba River Inflow	56	22,100	1,237,600
Yuba River Local Inflow	56	10,400	582,400
	Summation	386,550	32,178,800
Adopted EYR (∑(EYR*Q)/∑Q = 32,178,800/386,550)		**83**	

Table B-14. Equivalent Years of Record (EYR) for Index Location RA17.

System	EYR (years)	Peak Discharge (cfs)	EYR*Q
American River	87	117,900	10,257,300
Bear River	85	49,200	4,182,000
Cross Canal	25	25,100	627,500
Feather River	92	150,000	13,800,000
Honcut Creek	48	31,250	1,500,000
NEMDC Local Inflow	25	4,200	105,000
NEMDC Inflow	25	9,100	227,500
Sutter Bypass	55	184,500	10,147,500
Yuba River	88	123,600	10,876,800
Yuba River Inflow	56	22,100	1,237,600
Yuba River Local Inflow	56	10,400	582,400
	Summation	727,350	53,543,600
Adopted EYR (∑(EYR*Q)/∑Q = 32,178,800/386,550)		**73**	

Exceedance Probability	Discharge (cfs)	Confidence Limit Curves Discharge (cfs)			
		-2 SD	-1 SD	+1 SD	+2 SD
0.9990	70,899.96	65,548.84	68,171.88	73,737.22	76,687.93
0.9900	79,383.76	73,854.70	76,569.38	82,301.57	85,326.73
0.9500	87,805.84	82,080.48	84,894.91	90,816.59	93,930.56
0.9000	92,654.90	87,642.77	90,114.05	95,267.40	97,953.66
0.8000	98,886.55	94,449.30	96,642.46	101,182.74	103,532.26
0.7000	103,638.59	99,346.88	101,469.99	105,853.55	108,115.71
0.5000	112,000.04	102,343.17	107,062.73	117,165.05	122,568.11
0.3000	144,513.94	125,770.38	134,816.81	154,908.55	166,050.84
0.2000	168,604.48	144,961.59	156,336.66	181,834.97	196,103.45
0.1000	208,799.89	162,889.67	184,421.66	236,400.64	267,649.84
0.0400	309,599.94	221,689.97	261,983.20	365,871.25	432,370.13
0.0200	322,599.81	228,695.30	271,619.19	383,149.13	455,062.50
0.0100	342,400.19	239,176.42	286,171.22	409,677.41	490,173.22
0.0040	469,417.56	302,140.78	376,603.50	585,105.69	729,305.19
0.0020	657,500.19	386,085.31	503,836.44	858,029.44	1,119,717.63
0.0010	837,899.69	459,799.06	620,697.56	1,131,107.75	1,526,918.88

Figure B-23. Uncertainty of Inflow Discharge versus Exceedance Probability Relationship at Index Location RA07

Exceedance Probability	Discharge (cfs)	Confidence Limit Curves Discharge (cfs)			
		-2 SD	-1 SD	+1 SD	+2 SD
0.9990	166,900.05	158,625.56	162,710.22	171,197.77	175,606.16
0.9900	179,551.69	171,221.27	175,337.02	183,867.67	188,287.41
0.9500	191,646.02	183,223.41	187,387.39	196,001.42	200,455.81
0.9000	198,422.84	190,971.55	194,661.66	202,256.72	206,164.89
0.8000	206,950.72	200,470.33	203,684.75	210,269.06	213,640.59
0.7000	213,326.50	207,173.30	210,227.27	216,471.42	219,662.47
0.5000	224,299.92	208,779.27	216,400.61	232,487.58	240,974.39
0.3000	272,088.09	243,089.14	257,180.36	287,860.00	304,546.44
0.2000	305,809.34	270,229.72	287,469.59	325,319.09	346,073.50
0.1000	359,599.84	283,683.22	319,393.69	404,867.28	455,832.59
0.0400	525,300.13	373,205.09	442,769.09	623,214.69	739,379.50
0.0200	551,700.06	385,933.16	461,431.59	659,627.50	788,667.56
0.0100	666,699.69	438,277.72	540,554.63	822,282.31	1,014,170.88
0.0040	985,334.50	565,725.69	746,612.13	1,300,386.13	1,716,174.50
0.0020	1,133,400.13	619,062.13	837,642.13	1,533,585.63	2,075,068.00
0.0010	1,279,799.63	669,147.63	925,405.25	1,769,913.25	2,447,721.50

Figure B-24. Uncertainty of Inflow Discharge versus Exceedance Probability Relationship at Index Location RA17

(1) High n-value, high weir coefficient, high downstream stage
(2) High n-value, high weir coefficient, low downstream stage
(3) High n-value, low weir coefficient, high downstream stage
(4) High n-value, low weir coefficient, low downstream stage
(5) Low n-value, high weir coefficient, high downstream stage
(6) Low n-value, high weir coefficient, low downstream stage
(7) Low n-value, low weir coefficient, high downstream stage
(8) Low n-value, low weir coefficient, low downstream stage

The eight models were considered for the various combinations associated with the breach characteristics:

(1) Lower breach criteria with lower breach dimension
(2) Lower breach criteria with median breach dimension
(3) Lower breach criteria with higher breach dimension
(4) Median breach criteria with lower breach dimension
(5) Median breach criteria with median breach dimension
(6) Median breach criteria with higher breach dimension
(7) Higher breach criteria with lower breach dimension
(8) Higher breach criteria with median breach dimension
(9) Higher breach criteria with higher breach dimension

The HEC-RAS flow results for all the plans were imported into an Excel® spreadsheet and the standard deviation of error in flow was estimated by dividing the difference between the minimum and maximum values obtained from the model by four. A summary of this calculation for the 0.1 exceedance chance event is provided in Table B-15.

Table B-15. Summary Calculation of Uncertainty in the Outflow Discharge for the 0.01 Exceedance Probability Event.

	Index Location RA07	Index Location RA17
Minimum Discharge (cfs)	305,916	101,085
Controlling Breach Condition	Lower breach criteria with median breach width	Lower breach criteria with median breach width
Controlling Sensitivity Combination	High n, High weir, and High d/s boundary	High n, Low weir, and High d/s boundary
Maximum Discharge (cfs)	327,929	138,732
Controlling Breach Condition	All	Several
Controlling Sensitivity Combination	Low n, High weir, and Low d/s boundary	Low n, Low weir, and High d/s boundary
Difference (cfs)	22,013	37,647
Standard Deviation	5,500	9,410

10.1d - Estimate Uncertainty of Stage-Outflow Discharge Relationship at Index Locations

The sensitivity results were also used to estimate the uncertainty in stage-outflow discharge relationship. The HEC-RAS stage results for all the plans were imported into an Excel® spreadsheet and the standard deviation of error in flow was estimated by dividing the difference between the minimum and maximum values obtained from the model by four. The resulting standard deviation of error in stage was used if it was greater than the minimum standard deviation of 0.7 feet selected from the information provided in EM 1110-2-1619 (USACE, 1996), otherwise the minimum recommended value was used. A summary of this calculation for the 0.1 exceedance chance event is provided in Table B-16.

Table B-16. Summary Calculation of Uncertainty in the Stage for 0.01 Exceedance Probability Event

	Index Location RA07	Index Location RA17
Minimum Stage (ft)	47.43	23.56
Controlling Breach Condition	All	All
Controlling Sensitivity Combination	Low n, High weir, and High/Low d/s boundary	Low n, High weir, and Low d/s boundary
Maximum Stage (ft)	50.85	25.68
Controlling Breach Condition	High breach criteria with High breach width	High breach criteria with Low breach width
Controlling Sensitivity Combination	High n, Low weir, and High d/s boundary	High n, Low weir, and High d/s boundary
Difference (ft)	3.42	2.12
Standard Deviation	0.9	0.5 (0.7)*

*The value in the parenthesis corresponds to the adopted standard deviation, which is based on the minimum standard deviation of 0.7 selected using the information provided in EM 1110-2-1619 (USACE, 1996).

Step 10.2 - Uncertainty for Proposed Condition

The sensitivity analysis was conducted only for the baseline condition, and it was assumed that the proposed condition would not significantly change the uncertainty in the various relationships.

Step 11 - Risk Analysis

11a - Develop HEC-FDA Model for Baseline Condition

Develop the HEC-FDA model using the following steps:

A. Start HEC-FDA by double-click the **HEC-FDA** icon on your desktop, or from the taskbar click **Start**, point to **Programs**, point to **HEC**, point to **HEC-FDA**, and then click **HEC-FDA**. The main window of FDA will appear and you are now ready to start using HEC-FDA.

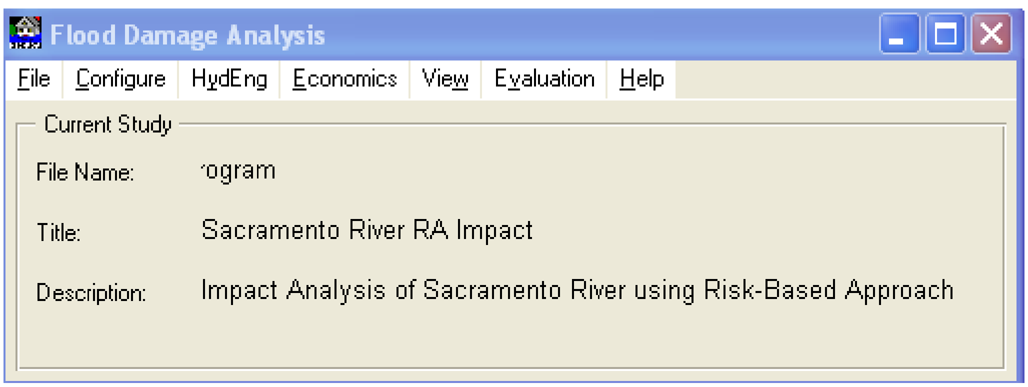


Figure B-25. HEC-FDA Main Window

B. To create a new study, from the **File** menu, click **New Study**, the **Create New Study** browser will open (Figure B-26). The **Create New Study** browser has a default study filename extension (*.sty), directories and drive (c:\Program Files\hec\fda). Enter a filename for the study - *SacRAimpact*, click **Save**.

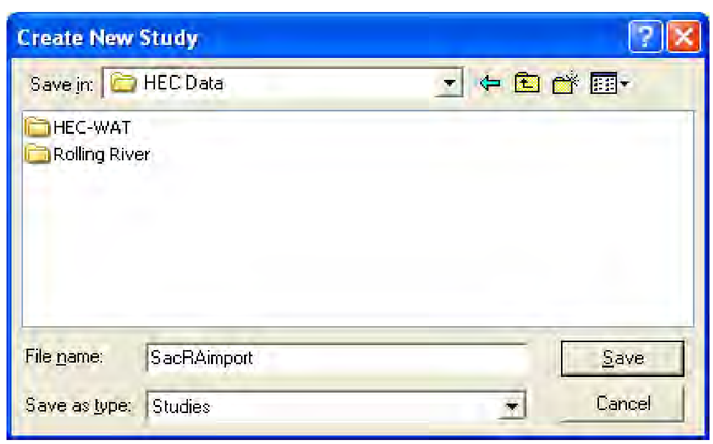


Figure B-26. HEC-FDA Create New Study Browser

The **Study Information** dialog box will open (Figure B-27). From dialog box, provide information about the study including: a title; a description; notes about the study; and price index information. The information is used on various dialog boxes

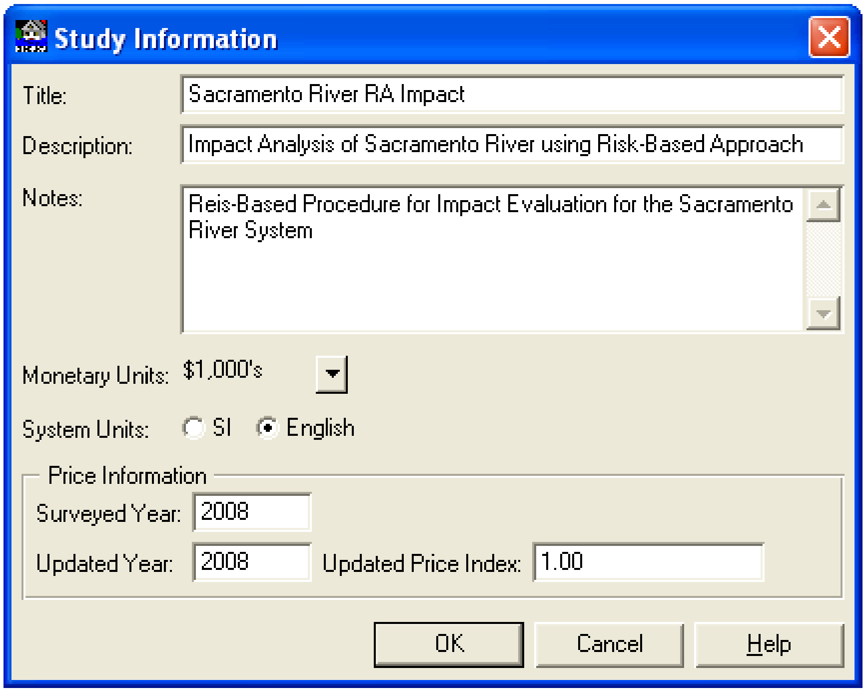


Figure B-27. HEC-FDA Study Information Dialog Box

and reports throughout the program. Select monetary and system units to be used for all study data entry and output reports. Click **OK**, the HEC-FDA main window will now have information about the new study displayed (Figure B-25).

C. Create the different watercourses where the index locations will be located. From the **Configure** menu, click **Study Streams**. The **Study Streams** dialog box will open (Figure B-28) enter the name of a stream (i.e., American River, Bear River, Feather River, etc.), click **Add**, the stream is added. Enter as many additional streams as needed for the study. When finished entering streams, from the **Study Streams** dialog box, from the **File** menu, click **Close**.

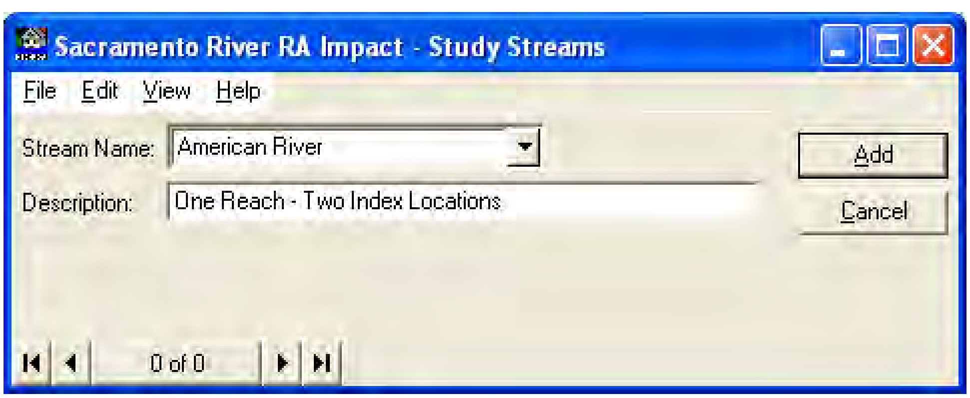


Figure B-28. HEC-FDA Study Streams Dialog Box

D. Define the damage reaches for each of the index locations, from the **Configure** menu click **Study Damage Reaches**. The **Study Damage Reaches** dialog box will open (Figure B-29), select a stream, enter the name of a damage reach (i.e., RA15, RA03,

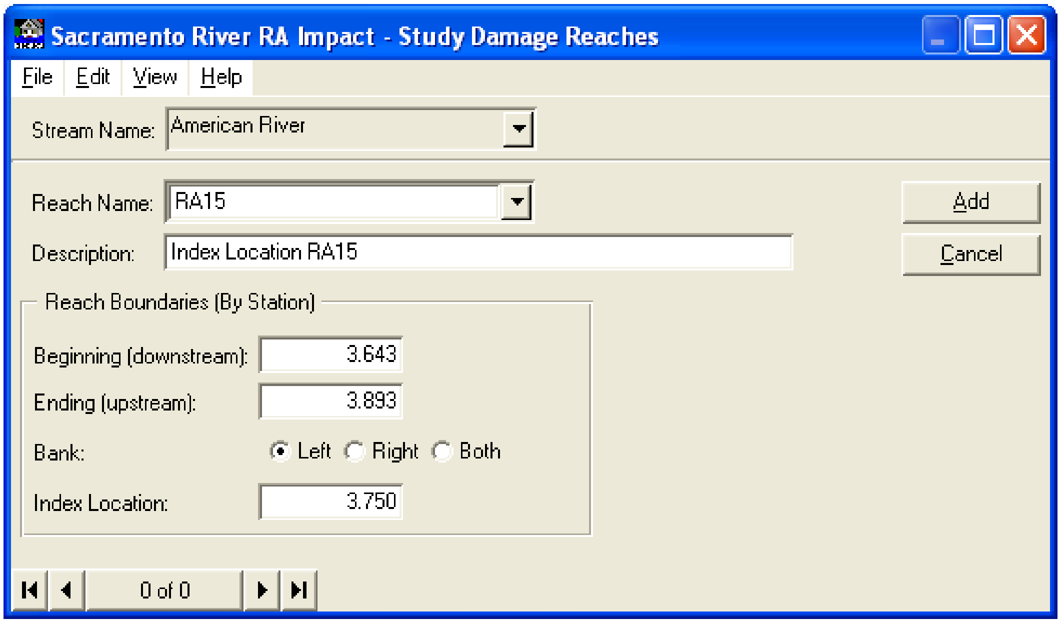


Figure B-29. HEC-FDA Study Damage Reaches Dialog Box

RA12, etc.), click **Add**, the damage reach is added. Enter damage reaches for each stream in the study. When finished entering damage reaches, from the **Study Damage Reaches** dialog box, from the **File** menu, click **Close**.

E. Enter the **Base Year** and the **Most Likely Future** year for the study. From the **Configure** menu, click **Study Analysis Years**. The **Study Analysis Years** dialog box will open (Figure B-30), enter the **Base Year** and the **Most Likely Future**, click **OK**.

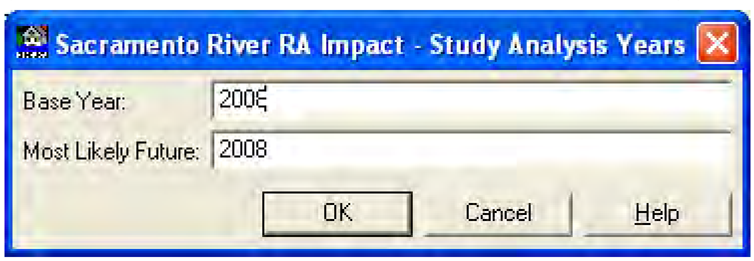


Figure B-30. HEC-FDA Study Analysis Years Dialog Box

F. The Baseline Condition is the default plan provided by HEC-FDA - **Without** and does not need to be defined (Figure B-31).

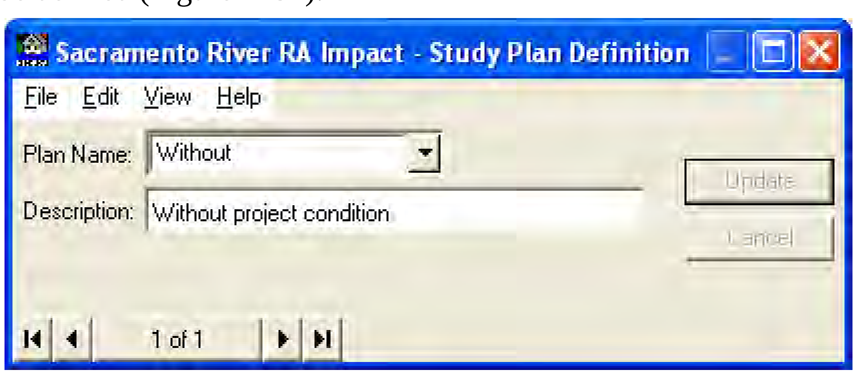


Figure B-31. HEC-FDA Study Plan Definition Dialog Box

G. Define the inflow discharge-exceedance probability relationship (graphical) for each combination of plan, analysis year, stream, and damage reach, from the **HydEng** menu; click **Exceedance Probability Functions with Uncertainty**. The **Exceedance Probability Functions with Uncertainty** dialog box will open (Figure B-32), click **Graphical**.

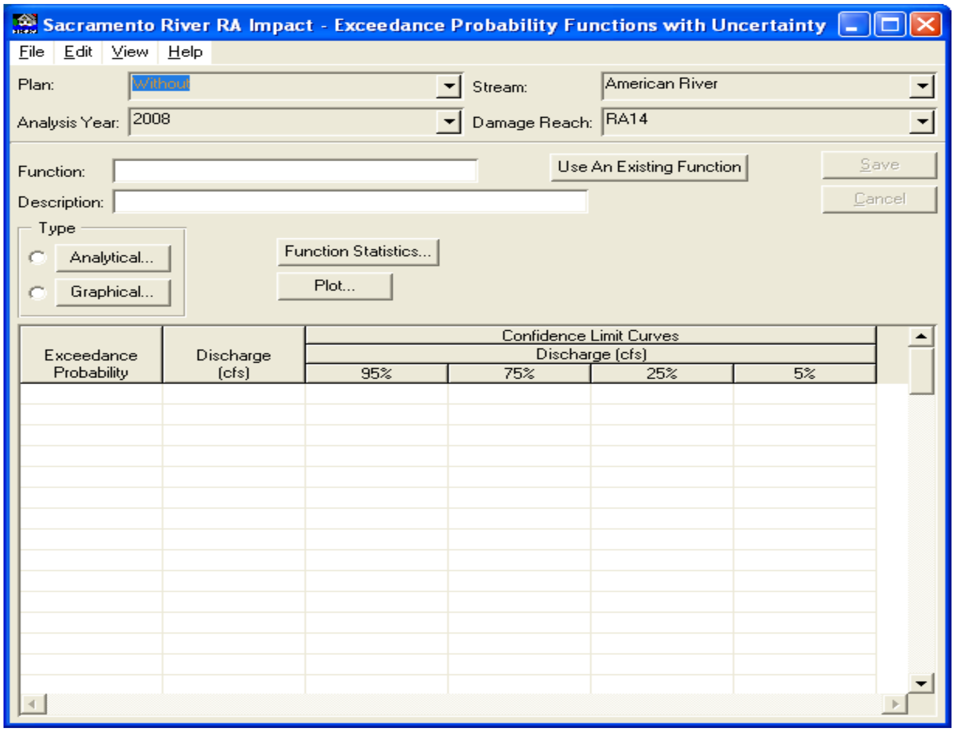


Figure B-32. HEC-FDA Exceedance Probability Functions with Uncertainty Dialog Box

The **Probability Function - Type Graphical** dialog box will open (Figure B-33), enter the function ordinates. Be sure to include the Equivalent Years of Record (EYR) for calculating the uncertainty of the relationship (**Equivalent Record Length (N)**). If an inflow-outflow relationship is required for the exceedance probability function, proceed to Step H.

Click **Save**, the **Probability Function - Type Graphical** dialog box will close. Now enter a name (**Function**) and a description for the inflow

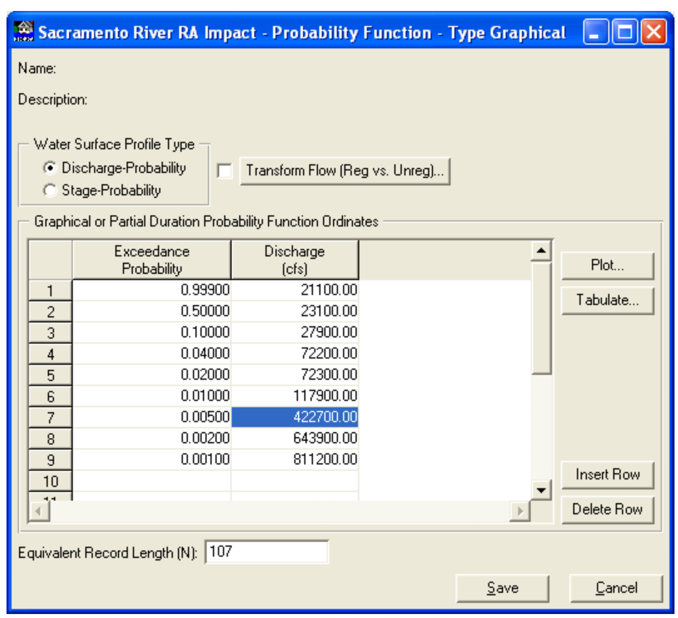
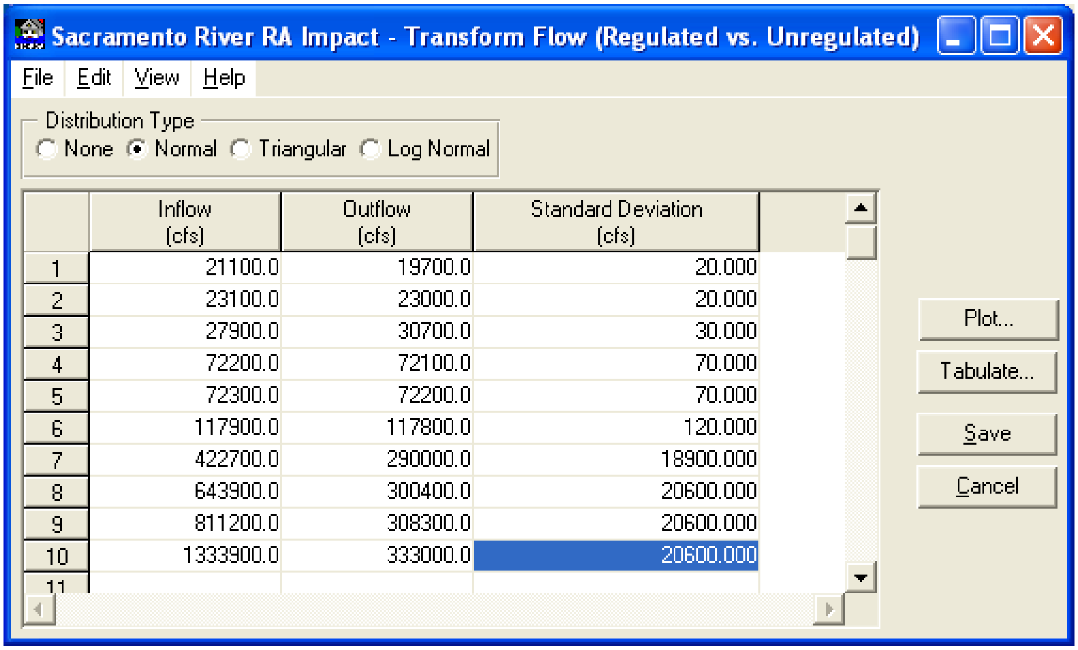


Figure B-33. HEC-FDA Probability Function - Type Graphical Dialog Box discharge-exceedance probability relationship. Since HEC-FDA only allows sixteen characters for the name, be sure to provide details in the description, click **Save**.

H. If you need to define an inflow-outflow relationship for each discharge-exceedance probability relationship, from the **Probability Function - Type Graphical** dialog box, click **Transform Flow (reg vs. unreg)**. The **Transform Flow (Regulated vs. Unregulated)** dialog box will open (Figure B-34).



	Inflow (cfs)	Outflow (cfs)	Standard Deviation (cfs)
1	21100.0	19700.0	20.000
2	23100.0	23000.0	20.000
3	27900.0	30700.0	30.000
4	72200.0	72100.0	70.000
5	72300.0	72200.0	70.000
6	117900.0	117800.0	120.000
7	422700.0	290000.0	18900.000
8	643900.0	300400.0	20600.000
9	811200.0	308300.0	20600.000
10	1333900.0	333000.0	20600.000
11			

Figure B-34. HEC-FDA Transform Flow (Regulated vs. Unregulated) Dialog Box

If there is uncertainty about the inflow-outflow relationships, from the **Distribution Type** box, select the appropriate type. Enter the inflow-outflow relationship including the uncertainty. Click **Save**, the **Transform Flow (Regulated vs. Unregulated)** dialog box will close.

I. Define the stage-outflow discharge relationship (i.e., rating curve, stage-discharge) and uncertainty values for each combination of plan, analysis year, stream, and damage reach, from the **HydEng** menu; click **Stage-Discharge Function with Uncertainty**, the **Stage-Discharge Function with Uncertainty dialog** box will open (Figure B-35). If there is uncertainty about the stage-outflow discharge relationship, from the **Distribution Type** box, select the appropriate type. Enter the stage-outflow discharge relationship including the uncertainty. Now enter a name (**Function**) and a description for the defined stage-outflow discharge relationship. Since HEC-FDA only allows sixteen characters for the name, be sure to provide details in the description, click **Save**.

J. Define the target stage for the basis of the risk analysis for each combination of plan, analysis year, stream, and damage reach, from the **HydEng** menu, click Levee Features, the Levee Features dialog box will open (Figure B-36). Enter a name (**Levee Name**), description, and **Top of Levee Stage**, click **Save**.

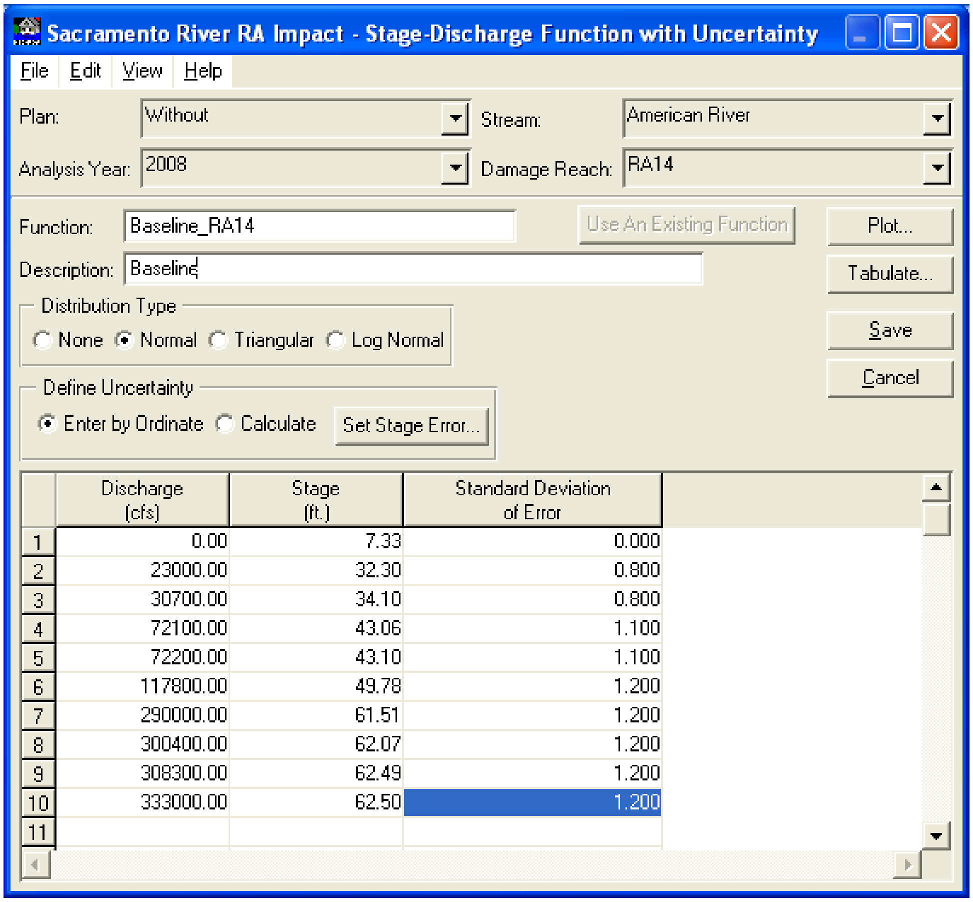


Figure B-35. HEC-FDA Stage-Discharge Function with Uncertainty Dialog Box

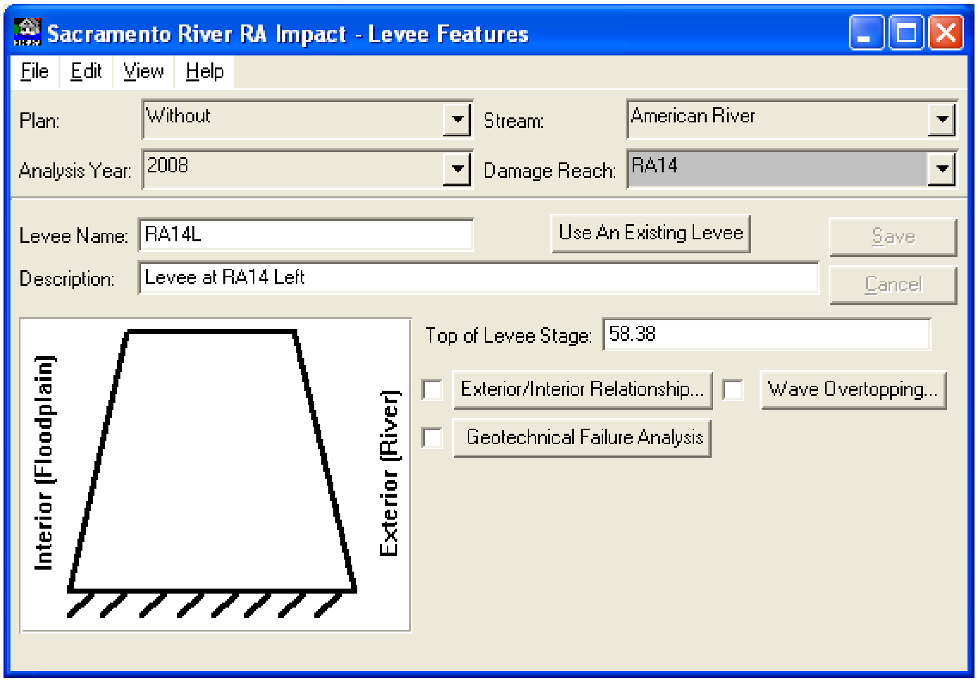


Figure B-36. HEC-FDA Levee Features Dialog Box

K. To define an artificial set of economic data first you must define a damage category. From the **Economics** menu, click **Study Damage Categories**, the **Study Damage Categories** dialog box will open (Figure B-37) and create a dummy damage category (e.g., APT).

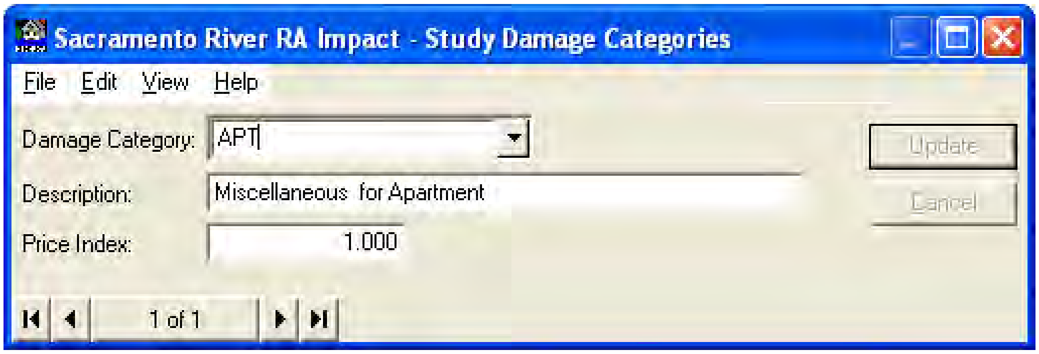


Figure B-37. HEC-FDA Study Damage Categories Dialog Box

Once the damage category is created now define the stage-damage functions for each combination of plan, analysis year, damage category, stream, and damage reach, from the **Economics** menu, click **Enter/Edit/View Reach Stage-Damage Function with Uncertainty**, the **Stage-Damage Function at Index Location with Uncertainty** dialog box will open (Figure B-38). Enter the stage-damage relationship including the uncertainty. Now enter a name (**Function**) and a description for the defined stage-

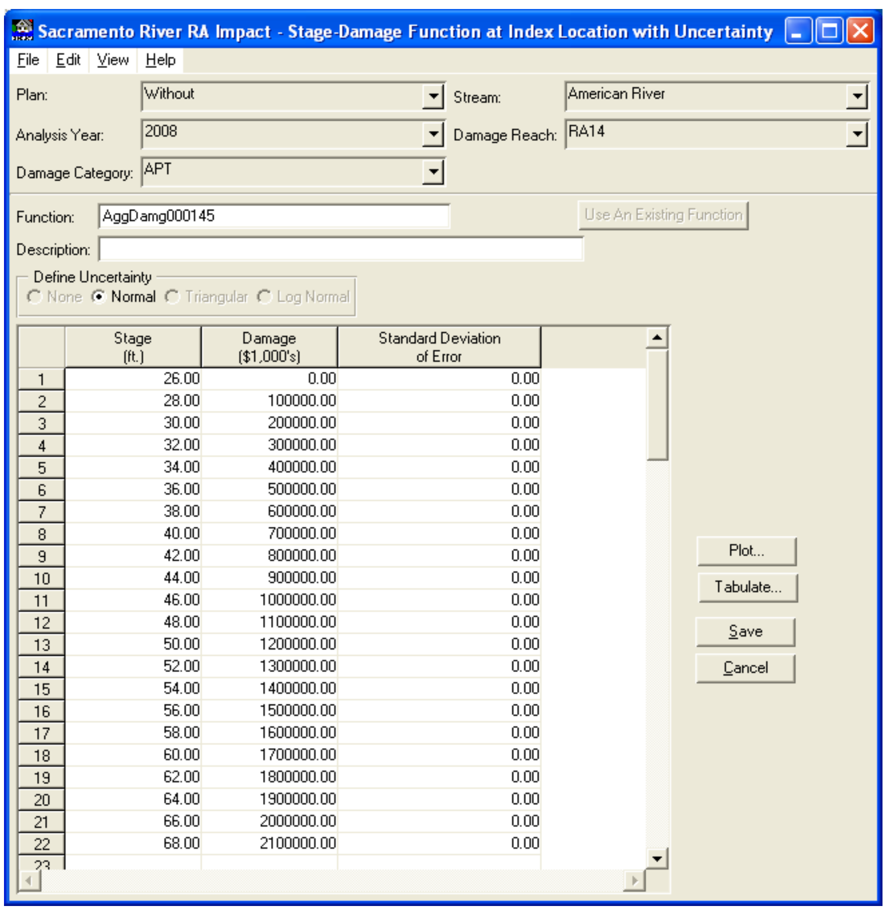
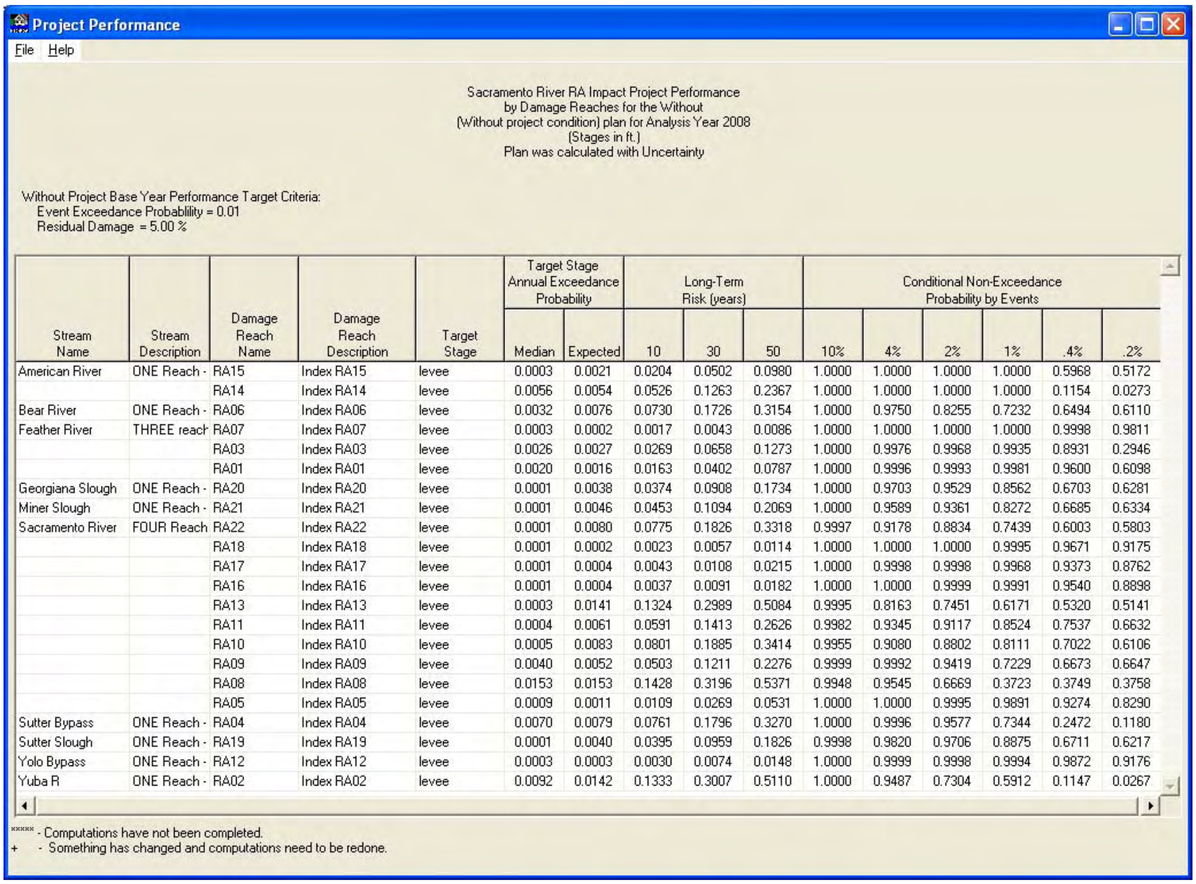


Figure B-38. HEC-FDA Stage-Damage Function at Index Location with Uncertainty Dialog Box damage relationship. Since HEC-FDA only allows sixteen characters for the name, be sure to provide details in the description, click **Save**. The stage-damage was developed by assuming the relationship increases linearly at a slope of $100,000 of damage per a stage increase of one or two feet.

11b - Evaluate HEC-FDA Results for the Baseline Condition

Once the data has been entered, check to make sure all the data required is available for calculation. From the **Evaluation** menu, click **Study Status Report** and review the report to make sure all the data that is required has been entered. Now that the check has been made, from the **Evaluation** menu, click **Evaluation of Plans by Analysis Year**. From the **Evaluation of Plans by Analysis Year** dialog box, highlight the **Without** plan for both analysis years, click **Compute**. The **EAD Computation Status** dialog box will open, & the EAD calculation will proceed.



Project Performance

File Help

Sacramento River RA Impact Project Performance
by Damage Reaches for the Without
(Without project condition) plan for Analysis Year 2008
(Stages in ft.)
Plan was calculated with Uncertainty

Without Project Base Year Performance Target Criteria:
Event Exceedance Probablility = 0.01
Residual Damage = 5.00 %

Stream Name	Stream Description	Damage Reach Name	Damage Reach Description	Target Stage	Target Stage Annual Exceedance Probability		Long-Term Risk (years)			Conditional Non-Exceedance Probability by Events					
					Median	Expected	10	30	50	10%	4%	2%	1%	.4%	.2%
American River	ONE Reach -	RA15	Index RA15	levee	0.0003	0.0021	0.0204	0.0502	0.0980	1.0000	1.0000	1.0000	1.0000	0.5968	0.5172
		RA14	Index RA14	levee	0.0056	0.0054	0.0526	0.1263	0.2367	1.0000	1.0000	1.0000	1.0000	0.1154	0.0273
Bear River	ONE Reach -	RA06	Index RA06	levee	0.0032	0.0076	0.0730	0.1726	0.3154	1.0000	0.9750	0.8255	0.7232	0.6494	0.6110
Feather River	THREE reach	RA07	Index RA07	levee	0.0003	0.0002	0.0017	0.0043	0.0086	1.0000	1.0000	1.0000	1.0000	0.9998	0.9811
		RA03	Index RA03	levee	0.0026	0.0027	0.0269	0.0658	0.1273	1.0000	0.9976	0.9968	0.9935	0.8931	0.2946
		RA01	Index RA01	levee	0.0020	0.0016	0.0163	0.0402	0.0787	1.0000	0.9996	0.9993	0.9981	0.9600	0.6098
Georgiana Slough	ONE Reach -	RA20	Index RA20	levee	0.0001	0.0038	0.0374	0.0908	0.1734	1.0000	0.9703	0.9529	0.8562	0.6703	0.6281
Miner Slough	ONE Reach -	RA21	Index RA21	levee	0.0001	0.0046	0.0453	0.1094	0.2069	1.0000	0.9589	0.9361	0.8272	0.6685	0.6334
Sacramento River	FOUR Reach	RA22	Index RA22	levee	0.0001	0.0080	0.0775	0.1826	0.3318	0.9997	0.9178	0.8834	0.7439	0.6003	0.5803
		RA18	Index RA18	levee	0.0001	0.0002	0.0023	0.0057	0.0114	1.0000	1.0000	1.0000	0.9995	0.9671	0.9175
		RA17	Index RA17	levee	0.0001	0.0004	0.0043	0.0108	0.0215	1.0000	0.9998	0.9998	0.9968	0.9373	0.8762
		RA16	Index RA16	levee	0.0001	0.0004	0.0037	0.0091	0.0182	1.0000	1.0000	0.9999	0.9991	0.9540	0.8898
		RA13	Index RA13	levee	0.0003	0.0141	0.1324	0.2989	0.5084	0.9995	0.8163	0.7451	0.6171	0.5320	0.5141
		RA11	Index RA11	levee	0.0004	0.0061	0.0591	0.1413	0.2626	0.9982	0.9345	0.9117	0.8524	0.7537	0.6632
		RA10	Index RA10	levee	0.0005	0.0083	0.0801	0.1885	0.3414	0.9955	0.9080	0.8802	0.8111	0.7022	0.6106
		RA09	Index RA09	levee	0.0040	0.0052	0.0503	0.1211	0.2276	0.9999	0.9992	0.9419	0.7229	0.6673	0.6647
		RA08	Index RA08	levee	0.0153	0.0153	0.1428	0.3196	0.5371	0.9948	0.9545	0.6669	0.3723	0.3749	0.3758
		RA05	Index RA05	levee	0.0009	0.0011	0.0109	0.0269	0.0531	1.0000	1.0000	0.9995	0.9891	0.9274	0.8290
Sutter Bypass	ONE Reach -	RA04	Index RA04	levee	0.0070	0.0079	0.0761	0.1796	0.3270	1.0000	0.9996	0.9577	0.7344	0.2472	0.1180
Sutter Slough	ONE Reach -	RA19	Index RA19	levee	0.0001	0.0040	0.0395	0.0959	0.1826	0.9998	0.9820	0.9706	0.8875	0.6711	0.6217
Yolo Bypass	ONE Reach -	RA12	Index RA12	levee	0.0003	0.0003	0.0030	0.0074	0.0148	1.0000	0.9999	0.9998	0.9994	0.9872	0.9176
Yuba R	ONE Reach -	RA02	Index RA02	levee	0.0092	0.0142	0.1333	0.3007	0.5110	1.0000	0.9487	0.7304	0.5912	0.1147	0.0267

***** - Computations have not been completed.
+ - Something has changed and computations need to be redone.

Figure B-39. HEC-FDA Project Performance by Damage Reaches Report

The above HEC-FDA results (Figure B-39) should be manually entered in Excel® for evaluating locations of potential impact. The return interval for 90% assurance of containment can be estimated from the assurance (CNP) results as demonstrated in the following calculations for RA17.

$$S = \frac{(CNP > 0.9) - (CNP < 0.9)}{Log(Exceedance\,P_{CNP>0.9}) - Log(Exceedance\,P_{CNP<0.9})}$$

$$S = \frac{0.9373 - 0.8762}{Log(0.004) - Log(0.002)} \quad = \quad 0.20297$$

$$Exceedance\,P_{0.9CNP} = 10^{\left(Log(Exceedance P_{CNP<0.9}) + \frac{(0.9 - CNP<0.9)}{S}\right)}$$

$$Exceedance\;P_{0.9CNP} = 10^{\left(Log(0.002) + \frac{(0.9 - 0.8762)}{0.20297}\right)} = 0.00262$$

$$RI = \frac{1}{Exceedance\,P_{0.9CNP}} = 382\;years$$

11c - Develop HEC-FDA Model for the Proposed Condition

Now develop the proposed conditions for the study following the approach in Step 11a for each proposed condition.

11d - Evaluate HEC-FDA Results for the Proposed Condition

Now evaluate HEC-FDA results for each proposed condition as described in Step 11b.

Step 12 - Identification of Potential Impacts

Potential impacts can be identified as an increase in the AEP, reduction in assurance (CNP), or reduction in the return interval for 90% assurance of containment. Changes in the risk results and identification of potential impact at Index Locations RA07 and RA17 are presented in Table B-17.

Table B-17. Identification of Potential Impacts for Index Locations RA07 and RA17.

Condition	AEP		Assurance (CNP)			
	Median	Expected	0.01 Exceedance Probability Event	0.004 Exceedance Probability Event	0.002 Exceedance Probability Event	Return Interval for 90% Containment
Index Location RA07						
Baseline	0.0003	0.0002	1.0000	0.9998	0.9811	> 500
Proposed	0.0003	0.0003	1.0000	0.9989	0.9583	> 500
Change	0.0000	0.0001	0.0000	-0.0009	-0.0228	-
% Change	-	-	-	-0.1000	-2.3000	-
Potential Impact	No	Yes	No	Yes	Yes	No
Index Location RA17						
Baseline	0.0001	0.0004	0.9968	0.9373	0.8762	382
Proposed	0.0001	0.0005	0.9968	0.9350	0.8723	368
Change	0.0000	0.0001	0.0000	-0.0023	-0.0039	-14.0
% Change	-	-	-	-0.2000	-0.4000	-3.7
Potential Impact	No	Yes	No	Yes	Yes	Yes

Appendix C

Hydrologic Engineering Center's Flood Damage Reduction Analysis (HEC-FDA) Input Data

Appendix C

Hydrologic Engineering Center's Flood Damage Reduction Analysis (HEC-FDA) Input Data

Table C-1. HEC-FDA Input – Information about Index Locations

Index Location No.	System	River Mile (RM)	Bank	Top of Levee Elevation (feet)		
				Baseline	Bear EIP	Natomas EIP
RA01	Feather River	42.24	Left	89.39	--	--
RA02	Yuba River	7.00	Right	90.58	--	--
RA03	Feather River	29.00	Right	83.23	--	--
RA04	Sutter Bypass	88.79	Right	59.15	--	--
RA05	Sacramento River	119.75	Right	54.50	--	--
RA06	Bear River	1.75	Right	56.33	58.50	--
RA07	Feather River	9.00	Right	56.55	--	--
RA08	Sacramento River	90.00	Right	40.65	--	--
RA09	Sacramento River	86.50	Left	41.13	--	--
RA10	Sacramento River	79.21	Left	41.79	--	45.93
RA11	Sacramento River	76.25	Left	40.91	--	44.12
RA12	Yolo Bypass	48.84	Right	34.45	--	--
RA13	Sacramento River	63.82	Right	35.66	--	--
RA14	American River	11.00	Left	58.38	--	--
RA15	American River	3.75	Right	44.49	--	--
RA16	Sacramento River	59.75	Right	36.25	--	--
RA17	Sacramento River	46.50	Right	29.64	--	--
RA18	Sacramento River	36.50	Left	23.09	--	--
RA19	Sutter Slough	25.23	Right	21.45	--	--
RA20	Georgiana Slough	12.36	Left	19.31	--	--
RA21	Miner Slough	19.11	Right	18.20	--	--
RA22	Sacramento River	14.75	Right	22.40	--	--

Table C-2. HEC-FDA Input – Inflow Relationships

Index Location ID	1.01-yr[a] (0.99)	2-yr (0.5)	10-yr (0.1)	25-yr (0.04)	50-yr (0.02)	100-yr (0.01)	200-yr (0.005)	500-yr (0.002)	1,000-yr[a] (0.001)	2,000-yr[e] (qmax)	Equivalent Years of Record
RA01	73,600	73,600	111,800	168,000	170,400	178,000	188,000[c]	327,900	327,900	888,400	84
RA02	28,600	28,600	77,700	115,200	141,300	153,500	205,800	281,000	281,000	573,400	81
RA03	73,600	73,600	111,800	168,000	170,400	178,000	188,000[c]	395,000[c]	395,000	888,400	84
RA04	57,500	57,500	102,200	126,400	155,300	184,500	228,600	327,400	327,400	588,500	55
RA05	43,800	43,800	48,200	49,900	52,700	55,500	60,500[d]	70,000[d]	70,000	83,800	68
RA06	26,200	26,200[b]	26,300	35,800	43,000	49,200	54,700	62,000	62,000	142,000	85
RA07	112,000	112,000	208,800	309,600	322,600	342,400	419,000	657,500	657,500	1,527,000	83
RA08	43,800	43,800	48,200	49,900	52,700	55,500	60,500[d]	70,000[d]	70,000	82,400	68
RA09	43,800	43,800	48,200	49,900	52,700	55,500	60,500[d]	70,000[d]	70,000	82,400	68
RA10	197,300	197,300	328,800	448,700	475,700	545,800	635,700	911,400	911,400	1,952,700	71
RA11	197,300	197,300	328,800	448,700	475,700	545,800	635,700	911,400	911,400	1,952,700	71
RA12	200,100	200,100	343,600	458,700	492,200	552,000	646,600	928,700	928,700	1,907,200	72
RA13	197,300	197,300	328,800	448,700	475,700	545,800	635,700	911,400	911,400	1,952,700	71
RA14	23,100	23,100	27,900	72,200	72,200	117,900	422,700	643,900	643,900	**1,333,900**[f]	106[g]
RA15	23,100	23,100	27,900	72,200	72,200	117,900	422,700	643,900	643,900	**1,333,900**[f]	106[g]
RA16	224,300	224,300	359,600	525,300	551,700	666,700	939,900	1,133,400	1,133,400	2,447,700	73
RA17	224,300	224,300	359,600	525,300	551,700	666,700	939,900	1,133,400	1,133,400	2,447,700	73
RA18	224,300	224,300	359,600	525,300	551,700	666,700	939,900	1,133,400	1,133,400	2,447,700	73
RA19	224,300	224,300	359,600	525,300	551,700	666,700	939,900	1,133,400	1,133,400	2,447,700	73
RA20	224,300	224,300	359,600	525,300	551,700	666,700	939,900	1,133,400	1,133,400	2,447,700	73
RA21	224,300	224,300	359,600	525,300	551,700	666,700	939,900	1,133,400	1,133,400	2,447,700	73
RA22	224,300	224,300	359,600	525,300	551,700	666,700	939,900	1,133,400	1,133,400	2,447,700	73

Notes:

[a] Interpolated values (interpolated with linear flow) (yellow).

[b] Initial value in HEC-RAS model is based on a ten-year flow; this was intentional per conversation with CESPK. Value was reduced slightly to provide an increase in discharge (light blue).

[c] Initial value 169,600 was less than 100-yr because of constant releases from Oroville Dam. Thus, adopted value determined by ratio of flows for Honcut (SA Robinson) (green).

Oroville	Delta 100-yr	100-yr Honcut	200-yr Honcut	Est. Delta 200-yr	Adopted 200-yr	Adopted 500-yr
15,0000	28,000	31,250	37,268	38,000	188,000	395,000 (increased to account for Yuba River
				33,400	183,400	Initial

[d] Increased to account for added inflow from storage areas (purple).

	Initial	Revised
RA05	59,300	70,000
RA08	60,500	70,000
RA09	60,500	70,000

[e] Upper limit of the inflow discharge as determined by HEC-FDA (dark blue).

[f] Changed to account for large uncertainty at lower frequency events (orange).

[g] At Index RA14/RA15 locations, the uncertainty calculated for the initial EYR was significantly greater than the uncertainty for the unregulated discharges (the upper bound of the 0.002 exceedance probability discharge was calculated to be fifteen times the median value). For all other index locations, the upper bound of the 0.002 exceedance probability discharge was 1.1 to 2.0 times the median value. Therefore, the EYR at these locations was increased to provide a more reasonable upper and lower bound of the relationship.

Table C-3. HEC-FDA Input – Outflow Relationships - Baseline

Index Location ID	Adopted Values									Initial Values						
	1.01-yr (0.99)	2-yr (0.5)	10-yr (0.1)	25-yr (0.04)	50-yr (0.02)	100-yr (0.01)	200-yr (0.005)	500-yr (0.002)	1,000-yr[a] (0.001)	2-yr (0.5)	10-yr (0.1)	25-yr (0.04)	50-yr (0.02)	100-yr (0.01)	200-yr (0.005)	500-yr (0.002)
RA14	19,700[a]	23,000	30,700	72,100	72,200[c]	117,800	290,000	300,400	308,300	22,979	30,728	72,092	72,095	117,847	290,004	300,434
RA15	20,400[a]	22,600	27,700	71,100	71,200[c]	115,000	209,400	209,500[c]	209,600	22,559	27,735	71,074	70,370	114,975	209,378	182,698
RA06	25,200[b]	25,300	25,400[c]	32,500	37,300	40,700	40,800[c]	40,900[c]	41,000	25,282	25,114	32,451	37,316	40,683	38,633	31,322
RA01	35,700[a]	56,500	105,600	156,500	156,600[c]	162,200	162,300[c]	285,300	378,300	56,531	105,567	156,505	149,488	162,159	159,314	285,304
RA03	33,700[a]	55,000	105,200	121,100[d]	133,100	140,100	169,900	242,700	297,800	55,044	105,162	155,879	133,104	140,111	169,873	242,662
RA07	69,100[a]	103,100	183,200	255,400	289,200	318,500	369,400	449,400	509,900	103,124	183,168	255,408	289,240	318,506	369,424	449,413
RA20	14,100[a]	14,700	16,100	17,000	17,900	21,200	22,000	22,100[c]	22,200	14,725	16,074	16,993	17,899	21,209	22,040	22,030
RA21	2,600[b]	2,700[b]	2,800[b]	2,900	3,400	6,200	6,300[c]	6,400[c]	6,500	9,130	4,662	2,918	3,405	6,172	6,093	5,858
RA05	47,400[a]	47,500	47,700	49,300	51,900	54,600	57,600	67,700	75,300	47,470	47,724	49,317	51,857	54,571	57,571	67,735
RA08	30,400[a]	30,400[b]	30,500	32,800	35,900	38,700	38,800[c]	38,900[c]	39,000	38,697	30,483	32,781	35,871	38,660	37,147	35,118
RA09	26,400[a]	27,500	30,200	32,500	34,800	38,200	38,300[c]	38,400[c]	38,500	27,522	30,234	32,500	34,813	38,163	36,294	32,734
RA10	64,700[a]	71,300	86,900	99,500	103,600	104,500	110,800	114,100	116,600	71,276	86,931	99,526	103,593	104,503	110,785	114,070
RA11	67,300[a]	71,000	79,700	99,500	103,600	104,400	110,600	114,000	116,600	70,970	79,664	99,526	103,592	104,444	110,621	114,000
RA13	62,800[a]	64,300	67,900[d]	69,900	75,800	104,400	104,500[c]	104,600[c]	104,700	64,295	78,964	69,935	75,818	104,402	79,328	74,763
RA16	85,400[a]	89,100	97,900	99,900	101,100	117,400	130,500	142,100	150,900	89,077	97,939	99,937	101,092	117,351	130,543	142,117
RA17	85,000[a]	88,800	97,700	97,800[c]	99,700	117,200	127,900	134,400	139,300	88,773	97,703	95,802	99,684	117,221	127,947	134,435
RA18	84,900[a]	88,700	97,600	97,700[c]	99,600	117,200	124,600	133,600	140,400	88,736	97,615	95,786	99,633	117,165	124,594	133,559
RA22	17,400[a]	20,000	26,200	27,800	27,800	33,300	33,400[c]	33,500[c]	33,600	19,997	26,190	27,782	27,805	33,255	29,648	26,842
RA04	38,500[a]	57,400	102,000	126,100	154,900	184,000	216,400	319,100	396,800	57,430	101,993	126,131	154,882	183,983	216,410	319,085
RA19	25,100[a]	25,100	25,200[c]	25,300[c]	25,400[c]	29,700	33,700	33,800[c]	33,900	25,121	24,775	22,686	23,791	29,681	33,709	28,536
RA12	79,400[a]	126,300	236,700	339,400	382,300	439,700	448,700	494,700	529,500	126,319	236,744	339,371	382,342	439,723	448,677	494,687
RA02	4,200[a]	26,100	77,600	115,100	140,800	152,500	185,100	228,300	261,000	26,082	77,609	115,106	140,759	152,528	185,056	228,349

[a]Extrapolated values (magenta).
[b]A value slightly less than the next lower probability of exceedance probability event (blue).
[c]A value slightly greater than the next higher probability of exceedance probability event (yellow).
[d]Interpolated values (green).

Table C-4. HEC-FDA Input – Outflow Relationships – Bear River EIP

Index Location ID	Adopted Values 1.01-yr (0.99)	2-yr (0.5)	10-yr (0.1)	25-yr (0.04)	50-yr (0.02)	100-yr (0.01)	200-yr (0.005)	500-yr (0.002)	1,000-yr[a] (0.001)	Initial Values 2-yr (0.5)	10-yr (0.1)	25-yr (0.04)	50-yr (0.02)	100-yr (0.01)	200-yr (0.005)	500-yr (0.002)
RA14	19,700[a]	23,000	30,700	72,100	72,200[c]	117,800	290,000	300,000	307,600	22,978	30,728	72,095	72,095	117,846	289,957	299,970
RA15	20,300[a]	22,500	27,700	71,600	71,700[c]	115,000	209,300	209,400[c]	209,500	22,539	27,733	71,586	70,339	114,970	209,334	176,627
RA06	26,100[b]	26,200	26,300[c]	33,900	39,500	44,200	44,300[c]	44,400[c]	44,500	26,156	26,066	33,896	39,547	44,196	38,918	37,259
RA01	35,700[a]	56,500	105,600	156,500	156,600[c]	162,100	162,200[c]	285,200	378,200	56,480	105,566	156,505	149,480	162,119	159,311	285,184
RA03	33,700[a]	55,000	105,200	121,100[d]	133,100	140,100	169,800	242,700	297,800	54,992	105,159	155,894	133,140	140,150	169,823	242,661
RA07	69,700[a]	103,800	184,100	256,800	290,000	321,100	372,200	456,000	519,400	103,819	184,139	256,785	290,015	321,148	372,172	456,023
RA20	14,100[a]	14,700	16,100	17,000	17,900	21,200	22,100	22,200[c]	22,300	14,725	16,074	16,974	17,903	21,198	22,062	22,057
RA21	2,700[b]	2,800[b]	2,900[b]	3,000	3,300	5,800	5,900[c]	6,000[c]	6,100	9,127	4,662	3,002	3,334	5,811	5,846	5,854
RA05	47,400[a]	47,500	47,700	49,300	51,900	54,600	57,600	67,700	75,300	47,476	47,734	49,337	51,910	54,628	57,557	67,736
RA08	30,400[a]	30,400[b]	30,500	32,800	35,700	38,600	38,700[c]	38,800[c]	38,900	38,699	30,455	32,760	35,733	38,558	37,062	34,991
RA09	26,400[a]	27,500	30,200	32,500	34,600	38,000	38,100[c]	38,200[c]	38,300	27,509	30,196	32,481	34,593	37,968	36,153	32,320
RA10	64,800[a]	71,400	87,000	99,500	103,700	104,800	110,800	114,200	116,800	71,358	86,967	99,503	103,744	104,793	110,789	114,247
RA11	67,400[a]	71,100	79,700	99,500	103,700	104,700	110,600	114,200	116,900	71,071	79,691	99,503	103,742	104,729	110,626	114,220
RA13	62,800[a]	64,300	67,900[d]	69,900	75,800	104,700	104,800[c]	104,900[c]	105,000	64,338	78,978	69,921	75,781	104,667	79,174	74,480
RA16	85,400[a]	89,100	97,900	99,900	101,200	117,500	130,500	142,800	152,100	89,071	97,947	99,932	101,232	117,538	130,465	142,758
RA17	85,000[a]	88,800	97,700	97,800[c]	99,800	117,300	127,900	134,700	139,800	88,765	97,705	95,692	99,829	117,298	127,907	134,692
RA18	84,900[a]	88,700	97,600	97,700[c]	99,800	117,300	124,600	133,800	140,800	88,729	97,610	95,680	99,772	117,276	124,594	133,823
RA22	17,500[a]	20,100	26,200	27,700	27,800	33,300	33,400[c]	33,500[c]	33,600	20,066	26,193	27,709	27,827	33,267	29,627	28,667
RA04	38,500[a]	57,400	102,000	126,100	154,900	184,000	216,400	316,000	391,300	57,430	101,993	126,137	154,898	184,017	216,367	319,307
RA19	25,100[a]	25,100	25,200[c]	25,300[c]	25,400[c]	29,700	33,700	33,800[c]	33,900	25,117	24,773	22,631	23,808	29,743	33,727	28,532
RA12	80,200[a]	126,900	237,000	339,200	383,600	441,400	449,500	495,700	530,600	126,869	237,041	339,158	383,640	441,357	449,479	495,733
RA02	4,200[a]	26,100	77,600	115,100	140,800	152,500	185,100	228,400	261,200	26,147	77,609	115,106	140,767	152,520	185,098	228,356

[a]Extrapolated values (magenta).
[b]A value slightly less than the next lower probability of exceedance probability event (blue).
[c]A value slightly greater than the next higher probability of exceedance probability event (yellow).
[d]Interpolated values (green).

Table C-5. HEC-FDA Input – Outflow Relationships – Feather River No. 1 EIP

Index Location ID	Adopted Values									Initial Values						
	1.01-yr (0.99)	2-yr (0.5)	10-yr (0.1)	25-yr (0.04)	50-yr (0.02)	100-yr (0.01)	200-yr (0.005)	500-yr (0.002)	1,000-yr[a] (0.001)	2-yr (0.5)	10-yr (0.1)	25-yr (0.04)	50-yr (0.02)	100-yr (0.01)	200-yr (0.005)	500-yr (0.002)
RA14	19,700[a]	23,000	30,700	72,100	72,200[c]	117,800	290,000	300,200	307,900	22,977	30,728	72,091	72,097	117,846	290,003	300,228
RA15	20,300[a]	22,500	27,700	71,100	71,200[c]	115,000	209,400	209,500[c]	209,600	22,530	27,735	71,110	70,309	114,972	209,401	176,647
RA06	25,200[b]	25,300	25,400[c]	32,400	37,300	40,600	40,700[c]	40,800[c]	40,900	25,280	26,071	32,405	37,279	40,615	38,503	28,172
RA01	35,700[a]	56,500	105,600	156,600	156,700[c]	162,700	162,800[c]	285,700	378,700	56,528	105,559	156,604	149,404	162,737	159,531	285,698
RA03	33,900[a]	55,100	105,100	121,400[d]	133,800	141,200	171,300	256,400	320,800	55,071	105,139	155,998	133,767	141,215	171,252	256,367
RA07	68,300[a]	102,800	184,100	256,000	290,700	320,400	371,500	462,900	532,000	102,824	184,100	255,967	290,719	320,433	371,501	462,857
RA20	14,400[a]	14,700	15,500	17,000	17,900	21,200	22,200	22,300[c]	22,400	14,710	15,510	17,004	17,915	21,208	22,158	22,039
RA21	2,600[b]	2,700[b]	2,800[b]	2,900	3,400	6,200	6,300[c]	6,400[c]	6,500	9,131	4,881	2,834	3,215	6,109	5,973	5,092
RA05	47,400[a]	47,500	47,700	49,300	51,900	54,600	57,600	67,700	75,300	47,465	47,734	49,308	51,881	54,600	57,556	67,710
RA08	30,300[a]	30,300[b]	30,400	32,800	35,800	38,600	38,700[c]	38,800[c]	38,900	38,701	30,445	32,794	35,844	38,621	37,064	34,811
RA09	26,500[a]	27,600	30,200	32,500	34,800	38,100	38,200[c]	38,300[c]	38,400	27,561	30,185	32,514	34,808	38,099	36,167	31,250
RA10	65,600[a]	71,500	85,300	99,600	103,700	104,700	110,800	114,900	118,000	71,460	85,318	99,622	103,740	104,667	110,790	114,852
RA11	65,200[a]	71,200	85,300	99,600	103,700	104,600	110,600	114,800	118,000	71,154	85,314	99,621	103,738	104,610	110,622	114,836
RA13	62,900[a]	64,300	67,700[d]	69,700	75,500	104,600	104,700[c]	104,800[c]	104,900	64,250	78,981	69,717	75,496	104,572	79,040	74,408
RA16	85,200[a]	89,000	97,900	100,000	101,200	117,400	130,400	142,700	152,000	88,987	97,930	99,987	101,172	117,440	130,404	142,709
RA17	84,900[a]	88,700	97,700	97,800[c]	99,800	117,300	127,900	134,700	139,800	88,676	97,685	95,794	99,759	117,264	127,856	134,688
RA18	84,800[a]	88,600	97,600	97,700[c]	99,700	117,200	124,400	133,900	141,100	88,641	97,593	95,780	99,703	117,234	124,417	133,852
RA22	17,100[a]	20,000	26,900	27,800	27,900	33,300	33,400[c]	33,500[c]	33,600	19,997	26,890	27,768	27,923	33,256	29,654	28,596
RA04	38,500[a]	57,400	102,000	126,100	154,900	184,000	216,300	319,700	397,900	57,430	101,992	126,128	154,893	184,000	216,292	319,713
RA19	25,100[a]	25,100	25,200[c]	25,300[c]	25,400[c]	29,700	33,700	33,800[c]	33,900	25,086	25,961	22,713	23,802	29,698	33,672	26,765
RA12	78,800[a]	126,400	238,600	340,000	383,600	440,600	449,400	496,100	531,400	126,378	238,550	340,031	383,556	440,635	449,367	496,147
RA02	4,200[a]	26,100	77,600	115,100	140,800	152,500	185,100	228,500	261,300	26,133	77,602	115,107	140,769	152,529	185,111	228,516

[a]Extrapolated values (magenta).
[b]A value slightly less than the next lower probability of exceedance probability event (blue).
[c]A value slightly greater than the next higher probability of exceedance probability event (yellow).
[d]Interpolated values (green).

Table C-6. HEC-FDA Input – Outflow Relationships – Bear-Feather River No. 1 EIP

Index Location ID	Adopted Values 1.01-yr (0.99)	2-yr (0.5)	10-yr (0.1)	25-yr (0.04)	50-yr (0.02)	100-yr (0.01)	200-yr (0.005)	500-yr (0.002)	1,000-yr[a] (0.001)	Initial Values 2-yr (0.5)	10-yr (0.1)	25-yr (0.04)	50-yr (0.02)	100-yr (0.01)	200-yr (0.005)	500-yr (0.002)
RA14	19,700[a]	23,000	30,700	72,100	72,200[c]	117,800	290,000	300,200	307,900	22,977	30,728	72,096	72,098	117,846	289,979	300,159
RA15	20,300[a]	22,500	27,700	71,600	71,700[c]	115,000	209,400	209,500[c]	209,600	22,511	27,732	71,602	70,277	114,970	209,367	176,613
RA06	26,100[b]	26,200	26,300[c]	33,800	39,600	44,100	44,200[c]	44,300[c]	44,400	26,157	26,026	33,794	39,628	44,111	38,700	34,366
RA01	35,700[a]	56,500	105,600	156,600	156,700[c]	162,700	162,800[c]	285,600	378,500	56,480	105,572	156,612	149,413	162,738	159,529	285,641
RA03	33,700[a]	55,000	105,200	121,400[d]	133,700	141,200	171,200	256,400	320,900	55,023	105,216	156,011	133,734	141,250	171,227	256,389
RA07	69,400[a]	103,500	183,800	257,300	291,900	322,900	374,200	474,700	550,700	103,538	183,773	257,266	291,925	322,899	374,205	474,704
RA20	14,500[a]	14,700	15,100	17,000	17,900	21,200	22,200	22,300[c]	22,400	14,711	15,110	16,983	17,916	21,236	22,165	22,036
RA21	2,600[b]	2,700[b]	2,800[b]	2,900	3,600	6,100	6,200[c]	6,300[c]	6,400	9,130	4,668	2,945	3,628	6,150	5,972	5,160
RA05	47,400[a]	47,500	47,700	49,300	51,900	54,700	57,500	67,700	75,400	47,476	47,723	49,327	51,931	54,654	57,525	67,738
RA08	30,400[a]	30,400[b]	30,500	32,800	35,700	38,500	38,600[c]	38,700[c]	38,800	38,699	30,487	32,778	35,714	38,519	36,967	34,647
RA09	26,400[a]	27,500	30,200	32,500	34,600	37,900	38,000[c]	38,100[c]	38,200	27,543	30,235	32,496	34,610	37,915	36,028	30,417
RA10	64,900[a]	71,500	87,000	99,600	103,900	105,000	110,800	115,200	118,500	71,525	87,011	99,599	103,898	104,954	110,781	115,206
RA11	67,700[a]	71,300	79,800	99,600	103,900	104,900	110,600	115,200	118,700	71,253	79,762	99,599	103,895	104,891	110,612	115,188
RA13	62,900[a]	64,300	67,700[d]	69,700	75,500	104,800	104,900[c]	105,000[c]	105,100	64,290	79,053	69,701	75,458	104,844	78,901	74,336
RA16	85,200[a]	89,000	97,900	100,000	101,300	117,600	130,400	142,700	152,000	88,979	97,938	99,982	101,303	117,610	130,358	142,665
RA17	84,900[a]	88,700	97,700	97,800[c]	99,900	117,300	127,800	134,700	139,900	88,669	97,715	95,683	99,899	117,334	127,826	134,668
RA18	84,700[a]	88,600	97,700	97,800[c]	99,800	117,300	124,400	133,800	140,900	88,632	97,653	94,144	99,841	117,309	124,380	133,834
RA22	17,500[a]	20,100	26,200	27,700	27,800	33,200	33,300[c]	33,400[c]	33,500	20,066	26,217	27,743	27,901	33,247	29,649	32,111
RA04	38,500[a]	57,400	102,000	126,100	154,900	184,000	216,200	319,200	397,100	57,430	101,995	126,133	154,907	184,038	216,190	319,157
RA19	25,100[a]	25,100	25,200[c]	25,300[c]	25,400[c]	29,700	33,700	33,800[c]	33,900	25,081	24,771	22,649	23,763	29,718	33,664	28,542
RA12	80,000[a]	126,900	237,300	339,800	384,900	442,300	450,100	497,600	533,500	126,905	237,255	339,808	384,889	442,348	450,103	497,611
RA02	4,500[a]	26,300	77,600	115,100	140,800	152,500	185,100	228,500	261,300	26,252	77,609	115,110	140,769	152,532	185,111	228,521

[a]Extrapolated values (magenta).
[b]A value slightly less than the next lower probability of exceedance probability event (blue).
[c]A value slightly greater than the next higher probability of exceedance probability event (yellow).
[d]Interpolated values (green).

Table C-7. HEC-FDA Input – Outflow Relationships – Feather River No. 2 (Star Bend) EIP

Index Location ID	Adopted Values									Initial Values						
	1.01-yr (0.99)	2-yr (0.5)	10-yr (0.1)	25-yr (0.04)	50-yr (0.02)	100-yr (0.01)	200-yr (0.005)	500-yr (0.002)	1,000-yr[a] (0.001)	2-yr (0.5)	10-yr (0.1)	25-yr (0.04)	50-yr (0.02)	100-yr (0.01)	200-yr (0.005)	500-yr (0.002)
RA14	19,700[a]	23,000	30,700	72,100	72,200[c]	117,800	290,000	300,400	308,300	22,979	30,728	72,095	72,095	117,843	290,004	300,440
RA15	20,300[a]	22,500	27,700	71,600	71,700[c]	115,000	209,400	209,500[c]	209,600	22,549	27,741	71,599	70,370	114,974	209,394	176,662
RA06	25,200[b]	25,300	25,400[c]	32,500	37,300	40,700	40,800[c]	40,900[c]	41,000	25,282	25,110	32,450	37,316	40,677	38,616	31,332
RA01	35,700[a]	56,500	105,600	156,500	156,600[c]	162,100	162,200[c]	285,300	378,400	56,536	105,555	156,505	149,479	162,118	159,319	285,305
RA03	33,700[a]	55,000	105,100	121,000[d]	133,100	140,100	169,900	242,700	297,800	55,047	105,125	155,906	133,105	140,136	169,892	242,710
RA07	69,100[a]	103,100	183,100	255,400	289,100	318,500	369,400	449,300	509,700	103,121	183,091	255,355	289,143	318,511	369,391	449,346
RA20	14,400[a]	14,700	15,500	17,000	17,900	21,200	22,000	22,100[c]	22,200	14,723	15,480	16,985	17,899	21,173	22,034	22,059
RA21	2,600[b]	2,700[b]	2,800[b]	2,900	3,400	6,100	6,200[c]	6,300[c]	6,400	9,132	4,881	2,911	3,399	6,121	5,958	5,972
RA05	47,400[a]	47,500	47,700	49,300	51,900	54,600	57,600	67,700	75,300	47,476	47,724	49,316	51,856	54,568	57,585	67,735
RA08	30,400[a]	30,400[b]	30,500	32,800	35,900	38,700	38,800[c]	38,900[c]	39,000	38,698	30,481	32,782	35,878	38,662	37,149	35,116
RA09	26,400[a]	27,500	30,200	32,500	34,800	38,200	38,300[c]	38,400[c]	38,500	27,527	30,225	32,504	34,834	38,162	36,295	32,724
RA10	65,400[a]	71,300	85,300	99,600	103,600	104,500	110,800	114,100	116,600	71,296	85,286	99,566	103,602	104,508	110,792	114,076
RA11	64,900[a]	71,000	85,300	99,600	103,600	104,500	110,600	114,000	116,600	70,981	85,282	99,566	103,601	104,453	110,631	114,005
RA13	62,800[a]	64,300	67,900[d]	69,900	75,800	104,400	104,500[c]	104,600[c]	104,700	64,290	78,981	69,925	75,798	104,406	79,313	74,529
RA16	85,400[a]	89,100	97,900	99,900	101,100	117,400	130,500	142,800	152,100	89,065	97,928	99,933	101,091	117,365	130,543	142,794
RA17	85,000[a]	88,800	97,700	97,800[c]	99,700	117,200	127,900	134,700	139,800	88,763	97,688	95,625	99,683	117,238	127,930	134,730
RA18	84,900[a]	88,700	97,600	97,700[c]	99,600	117,200	124,500	133,800	140,800	88,728	97,607	94,099	99,633	117,192	124,545	133,844
RA22	17,000[a]	20,000	27,000	27,700	27,800	33,200	33,300[c]	33,400[c]	33,500	19,997	26,971	27,750	27,801	33,213	29,648	26,890
RA04	38,500[a]	57,400	102,000	126,100	154,900	184,000	216,400	319,100	396,800	57,429	101,992	126,129	154,885	183,981	216,409	319,082
RA19	25,100[a]	25,100	25,200[c]	25,300[c]	25,400[c]	29,700	33,700	33,800[c]	33,900	25,118	25,940	22,647	23,785	29,688	33,704	28,533
RA12	78,800[a]	126,300	238,300	339,400	382,400	439,800	448,700	494,600	529,300	126,327	238,277	339,358	382,404	439,764	448,709	494,618
RA02	4,200[a]	26,100	77,600	115,100	140,800	152,500	185,100	228,300	261,000	26,082	77,602	115,106	140,766	152,521	185,053	228,350

[a]Extrapolated values (magenta).
[b]A value slightly less than the next lower probability of exceedance probability event (blue).
[c]A value slightly greater than the next higher probability of exceedance probability event (yellow).
[d]Interpolated values (green).

Table C-8. HEC-FDA Input – Outflow Relationships – Bear-Feather River No. 1-SB EIP

Index Location ID	Adopted Values									Initial Values						
	1.01-yr (0.99)	2-yr (0.5)	10-yr (0.1)	25-yr (0.04)	50-yr (0.02)	100-yr (0.01)	200-yr (0.005)	500-yr (0.002)	1,000-yr[a] (0.001)	2-yr (0.5)	10-yr (0.1)	25-yr (0.04)	50-yr (0.02)	100-yr (0.01)	200-yr (0.005)	500-yr (0.002)
RA14	19,700[a]	23,000	30,700	72,100	72,200[c]	117,800	290,000	300,000	307,600	22,977	30,728	72,096	72,098	117,846	289,981	299,972
RA15	20,300[a]	22,500	27,700	71,600	71,700[c]	115,000	209,400	209,500[c]	209,600	22,510	27,732	71,605	70,268	114,969	209,367	176,619
RA06	26,100[b]	26,200	26,300[c]	33,800	39,600	44,100	44,200[c]	44,300[c]	44,400	26,145	26,014	33,773	39,625	44,105	38,686	34,288
RA01	35,700[a]	56,500	105,600	156,600	156,700[c]	162,700	162,800[c]	285,700	378,700	56,480	105,573	156,613	149,413	162,740	159,536	285,659
RA03	33,700[a]	55,000	105,200	121,400[d]	133,700	141,200	171,200	256,400	320,900	55,025	105,230	156,026	133,743	141,247	171,224	256,416
RA07	69,500[a]	103,500	183,700	257,200	291,900	322,900	374,200	474,600	550,500	103,502	183,715	257,174	291,881	322,932	374,156	474,605
RA20	14,500[a]	14,700	15,100	17,000	17,900	21,200	22,200	22,300[c]	22,400	14,709	15,109	16,984	17,921	21,237	22,162	22,034
RA21	2,600[b]	2,700[b]	2,800[b]	2,900	3,600	6,200	6,300[c]	6,400[c]	6,500	9,130	4,668	2,935	3,630	6,164	6,082	5,090
RA05	47,400[a]	47,500	47,700	49,300	51,900	54,700	57,500	67,700	75,400	47,476	47,721	49,326	51,931	54,654	57,530	67,738
RA08	30,400[a]	30,400[b]	30,500	32,800	35,700	38,500	38,600[c]	38,700[c]	38,800	38,699	30,491	32,780	35,718	38,528	36,970	34,648
RA09	26,400[a]	27,500	30,200	32,500	34,600	37,900	38,000[c]	38,100[c]	38,200	27,548	30,237	32,496	34,613	37,922	36,030	30,413
RA10	64,900[a]	71,500	87,000	99,600	103,900	105,000	110,800	115,200	118,500	71,525	87,011	99,602	103,904	104,959	110,785	115,219
RA11	67,700[a]	71,300	79,800	99,600	103,900	104,900	110,600	115,200	118,700	71,259	79,767	99,601	103,901	104,896	110,620	115,200
RA13	62,900[a]	64,300	67,700[4]	69,700	75,400	104,800	104,900[c]	105,000[c]	105,100	64,303	79,059	69,688	75,434	104,850	78,871	74,317
RA16	85,200[a]	89,000	97,900	100,000	101,300	117,600	130,400	142,700	152,000	88,975	97,938	99,977	101,302	117,611	130,351	142,655
RA17	84,900[a]	88,700	97,700	97,800[c]	99,900	117,300	127,800	134,700	139,900	88,664	97,716	95,678	99,897	117,337	127,820	134,665
RA18	84,700[a]	88,600	97,700	97,800[c]	99,800	117,300	124,400	133,800	140,900	88,627	97,657	94,142	99,839	117,312	124,359	133,833
RA22	17,500[a]	20,100	26,200	27,800	27,900	33,200	33,300[c]	33,400[c]	33,500	20,066	26,215	27,753	27,949	33,244	29,649	32,107
RA04	38,500[a]	57,400	102,000	126,100	154,900	184,000	216,200	318,900	396,600	57,429	101,993	126,133	154,908	184,039	216,189	319,150
RA19	25,100[a]	25,100	25,200[c]	25,300[c]	25,400[c]	29,700	33,700	33,800[c]	33,900	25,080	24,772	22,650	23,762	29,722	33,648	28,537
RA12	80,100[a]	126,900	237,200	339,800	384,900	442,400	450,200	497,600	533,500	126,885	237,247	339,805	384,928	442,389	450,178	497,579
RA02	4,500[a]	26,300	77,600	115,100	140,800	152,500	185,100	228,500	261,300	26,252	77,609	115,107	140,769	152,535	185,111	228,518

[a]Extrapolated values (magenta).
[b]A value slightly less than the next lower probability of exceedance probability event (blue).
[c]A value slightly greater than the next higher probability of exceedance probability event (yellow).
[d]Interpolated values (green).

Table C-9. HEC-FDA Input – Outflow Relationships – Natomas EIP

Index Location ID	Adopted Values									Initial Values						
	1.01-yr (0.99)	2-yr (0.5)	10-yr (0.1)	25-yr (0.04)	50-yr (0.02)	100-yr (0.01)	200-yr (0.005)	500-yr (0.002)	1,000-yr[a] (0.001)	2-yr (0.5)	10-yr (0.1)	25-yr (0.04)	50-yr (0.02)	100-yr (0.01)	200-yr (0.005)	500-yr (0.002)
RA14	19,700[a]	23,000	30,700	72,100	72,200[c]	117,800	290,000	300,400	308,300	22,979	30,728	72,100	72,100	117,848	290,003	300,431
RA15	20,400[a]	22,600	27,700	71,600	71,700[c]	115,000	209,400	209,500[c]	209,600	22,559	27,735	71,599	70,572	114,971	209,393	175,258
RA06	25,200[b]	25,300	25,400[c]	32,500	37,300	40,700	40,800[c]	40,900[c]	41,000	25,282	25,114	32,451	37,312	40,684	38,611	31,255
RA01	35,700[a]	56,500	105,600	156,500	156,600[c]	162,100	162,200[c]	285,300	378,400	56,518	105,566	156,513	149,488	162,128	159,318	285,304
RA03	33,700[a]	55,000	105,200	121,000[d]	133,000	140,100	169,900	242,700	297,800	55,031	105,162	155,894	133,037	140,137	169,886	242,658
RA07	69,100[a]	103,100	183,200	255,400	289,200	318,500	368,700	448,800	509,400	103,114	183,176	255,409	289,218	318,464	368,665	448,780
RA20	14,100[a]	14,700	16,100	17,000	17,800	21,200	22,000	22,100[c]	22,200	14,725	16,073	16,963	17,837	21,194	22,036	22,929
RA21	2,500[b]	2,600[b]	2,700[b]	2,800	3,500	6,100	6,200[c]	6,300[c]	6,400	9,130	4,662	2,773	3,465	6,097	6,019	9,868
RA05	47,400[a]	47,500	47,700	49,300	51,900	54,600	57,500	67,700	75,400	47,478	47,724	49,317	51,857	54,588	57,472	67,729
RA08	30,400[a]	30,400[b]	30,500	32,800	35,900	38,600	38,700[c]	38,800[c]	38,900	38,698	30,486	32,780	35,873	38,598	36,241	33,659
RA09	26,400[a]	27,500	30,200	32,500	34,800	38,100	38,200[c]	38,300[c]	38,400	27,522	30,232	32,496	34,811	38,099	34,613	27,258
RA10	64,700[a]	71,300	86,900	99,600	103,700	105,100	113,400	119,800	124,600	71,281	86,930	99,613	103,704	105,108	113,412	119,786
RA11	67,300[a]	71,000	79,700	99,600	103,700	105,100	113,400	119,200	123,600	70,969	79,664	99,613	103,702	105,059	113,390	119,248
RA13	62,800[a]	64,300	67,900[d]	69,900	75,800	105,000	105,100[c]	105,200[c]	105,300	64,295	78,964	69,941	75,844	105,027	79,349	75,149
RA16	85,400[a]	89,100	97,900	100,000	100,600	117,200	130,500	144,600	155,300	89,072	97,939	99,951	100,624	117,212	130,524	144,643
RA17	85,000[a]	88,800	97,700	97,800[c]	99,300	117,000	127,900	135,400	141,100	88,771	97,703	95,399	99,268	117,050	127,938	135,415
RA18	84,900[a]	88,700	97,600	97,700[c]	99,200	117,000	124,600	134,700	142,300	88,736	97,615	93,926	99,213	117,009	124,566	134,688
RA22	17,400[a]	20,000	26,200	27,700	27,900	33,200	33,300[c]	33,400[c]	33,500	19,997	26,190	27,708	27,851	33,249	29,698	24,619
RA04	38,500[a]	57,400	102,000	126,100	154,900	184,000	216,300	319,100	396,900	57,430	101,991	126,130	154,882	183,990	216,255	319,117
RA19	25,100[a]	25,100	25,200[c]	25,300[c]	25,400[c]	29,600	33,700	33,800[c]	33,900	25,122	24,775	22,623	22,779	29,611	33,699	32,549
RA12	79,400[a]	126,300	236,700	339,300	382,200	441,600	450,600	485,900	512,600	126,305	236,744	339,265	382,203	441,553	450,598	485,937
RA02	4,200[a]	26,100	77,600	115,100	140,800	152,500	185,100	228,400	261,200	26,069	77,609	115,106	140,759	152,527	185,053	228,359

[a]Extrapolated values (magenta).
[b]A value slightly less than the next lower probability of exceedance probability event (blue).
[c]A value slightly greater than the next higher probability of exceedance probability event (yellow).
[d]Interpolated values (green).

Table C-10. HEC-FDA Input – Outflow Relationships – Bear-Feather River No. 1-SB-Natomas EIP

Index Location ID	Adopted Values									Initial Values						
	1.01-yr (0.99)	2-yr (0.5)	10-yr (0.1)	25-yr (0.04)	50-yr (0.02)	100-yr (0.01)	200-yr (0.005)	500-yr (0.002)	1,000-yr[a] (0.001)	2-yr (0.5)	10-yr (0.1)	25-yr (0.04)	50-yr (0.02)	100-yr (0.01)	200-yr (0.005)	500-yr (0.002)
RA14	19,700[a]	23,000	30,700	72,100	72,200[c]	117,800	290,000	300,200	307,900	22,977	30,728	72,095	72,098	117,846	289,981	300,156
RA15	20,300[a]	22,500	27,700	71,600	71,700[c]	115,000	209,400	209,500[c]	209,600	22,516	27,739	71,605	70,277	114,967	209,404	175,268
RA06	26,100[b]	26,200	26,300[c]	33,800	39,600	44,100	44,200[c]	44,300[c]	44,400	26,155	26,010	33,773	39,625	44,112	38,633	34,198
RA01	35,700[a]	56,500	105,600	156,600	156,700[c]	162,800	162,900[c]	285,700	378,600	56,539	105,564	156,608	149,404	162,768	159,532	285,652
RA03	33,800[a]	55,100	105,200	121,400[d]	133,700	141,200	171,200	256,400	320,900	55,076	105,218	156,012	133,743	141,247	171,235	256,412
RA07	69,600[a]	103,600	183,700	257,200	291,900	322,800	373,500	473,900	549,800	103,562	183,664	257,174	291,881	322,800	373,515	473,883
RA20	14,400[a]	14,700	15,500	17,000	17,900	21,300	22,200	22,300[c]	22,400	14,709	15,486	16,984	17,921	21,267	22,171	23,010
RA21	2,600[b]	2,700[b]	2,800[b]	2,900	3,600	6,200	6,300[c]	6,400[c]	6,500	9,126	4,882	2,933	3,628	6,165	6,091	9,744
RA05	47,400[a]	47,500	47,700	49,300	51,900	54,700	57,400	67,700	75,500	47,474	47,719	49,325	51,931	54,668	57,401	67,734
RA08	30,400[a]	30,400[b]	30,500	32,800	35,700	38,400	38,500[c]	38,600[c]	38,700	38,695	30,489	32,775	35,715	38,450	36,040	33,185
RA09	26,400[a]	27,500	30,200	32,500	34,600	37,800	37,900[c]	38,000[c]	38,100	27,546	30,225	32,496	34,618	37,844	34,163	21,554
RA10	65,600[a]	71,500	85,400	99,600	103,900	105,500	113,700	125,500	134,400	71,536	85,364	99,602	103,908	105,480	113,703	125,500
RA11	65,300[a]	71,300	85,400	99,600	103,900	105,400	113,700	124,400	132,500	71,265	85,360	99,601	103,905	105,432	113,675	124,423
RA13	62,900[a]	64,300	67,700[d]	69,700	75,400	105,400	105,500[c]	105,600[c]	105,700	64,282	79,062	69,688	75,434	105,397	78,872	74,874
RA16	85,200[a]	89,000	97,900	100,000	101,300	117,800	130,300	144,500	155,200	88,986	97,930	99,977	101,300	117,822	130,350	144,474
RA17	84,900[a]	88,700	97,700	97,800[c]	99,900	117,500	127,800	135,400	141,100	88,674	97,699	95,678	99,901	117,484	127,820	135,395
RA18	84,800[a]	88,600	97,600	97,700[c]	99,800	117,400	124,400	134,600	142,300	88,638	97,641	94,139	99,840	117,444	124,366	134,622
RA22	17,000[a]	20,000	27,000	27,800	27,900	33,300	33,400[c]	33,500[c]	33,600	19,997	26,982	27,754	27,949	33,297	29,719	24,741
RA04	38,500[a]	57,400	102,000	126,100	154,900	184,000	216,000	318,900	396,700	57,430	101,995	126,133	154,909	184,050	216,045	318,877
RA19	25,100[a]	25,100	25,200[c]	25,300[c]	25,400[c]	29,700	33,700	33,800[c]	33,900	25,084	25,939	22,650	23,762	29,734	33,650	32,565
RA12	79,600[a]	127,000	238,700	339,800	384,900	444,200	452,200	501,000	537,900	126,955	238,749	339,811	384,943	444,244	452,195	500,975
RA02	4,200[a]	26,100	77,600	115,100	140,800	152,500	185,100	228,500	261,300	26,133	77,602	115,107	140,769	152,535	185,118	228,518

[a]Extrapolated values (magenta).
[b]A value slightly less than the next lower probability of exceedance probability event (blue).
[c]A value slightly greater than the next higher probability of exceedance probability event (yellow).
[d]Interpolated values (green).

Table C-11. HEC-FDA Input – Inflow vs. Outflow Relationships with Standard Deviations (SD) - Baseline

	RA01			RA02			RA03			RA04			RA05		
Event	Inflow	Outflow	SD	Inflow	Outflow	SD	Inflow	Outflow	SD	Inflow	Outflow	SD	Inflow	Outflow	SD
1.1-yr	57,400	35,700	50	7,800	4,200	25	57,400	33,700	50	38,500	38,500	10	47,900	47,400	50
2-yr	73,600	56,500	50	28,600	26,100	25	73,600	55,000	50	57,500	57,400	10	48,000	47,500	50
10-yr	111,800	105,600	110	77,700	77,600	70	111,800	105,200	180	102,200	102,000	40	48,200	47,700	50
25-yr	168,000	156,500	700	115,200	115,100	105	168,000	121,100	1,260	126,400	126,100	80	49,900	49,300	90
50-yr	170,400	156,600	800	141,300	140,800	130	170,400	133,100	1,300	155,300	154,900	90	52,700	51,900	100
100-yr	178,000	162,200	880	153,500	152,500	290	178,000	140,100	1,500	184,500	184,000	1,180	55,500	54,600	330
200-yr	188,000	162,300	990	205,800	185,100	6,150	188,000	169,900	3,920	228,600	216,400	1,200	60,500	57,600	640
500-yr	327,900	285,300	9,900	281,000	228,300	7,740	395,000	242,700	16,100	327,400	319,100	6,950	70,000	67,700	3,590
1000-yr	433,700	378,300	9,900	337,900	261,000	7,740	551,600	297,800	16,100	402,100	396,800	6,950	78,200	75,300	3,590
Max	888,400	778,000	9,900	573,400	396,300	7,740	888,400	416,300	16,100	588,500	588,500	6,950	83,800	80,500	3,590

	RA06			RA07			RA08			RA09			RA10		
Event	Inflow	Outflow	SD	Inflow	Outflow	SD	Inflow	Outflow	SD	Inflow	Outflow	SD	Inflow	Outflow	SD
1.1-yr	26,200	25,200	310	70,900	69,100	60	41,900	30,300	100	41,900	26,400	100	141,500	64,700	1,090
2-yr	26,200	25,300	310	112,000	103,100	60	43,800	30,400	100	43,800	27,500	100	197,300	71,300	1,090
10-yr	26,300	25,400	370	208,800	183,200	1,570	48,200	30,500	880	48,200	30,200	820	328,800	86,900	9,310
25-yr	35,800	32,500	670	309,600	255,400	4,440	49,900	32,800	950	49,900	32,500	890	448,700	99,500	12,800
50-yr	43,000	37,300	780	322,600	289,200	4,500	52,700	35,900	1,320	52,700	34,800	1,610	475,700	103,600	13,200
100-yr	49,200	40,700	2,190	342,400	318,500	5,500	55,500	38,700	2,910	55,500	38,200	3,250	545,800	104,500	14,200
200-yr	54,700	40,800	3,110	419,000	369,400	6,720	60,500	38,800	6,600	60,500	38,300	4,790	635,700	110,800	14,300
500-yr	62,000	40,900	4,300	657,500	449,400	31,900	70,000	38,900	7,240	70,000	38,400	4,850	911,400	114,100	16,300
1000-yr	67,500	41,000	4,300	837,900	509,900	31,900	77,200	39,000	7,240	77,200	38,500	4,850	1,120,000	116,600	16,300
Max	142,000	42,400	4,300	1,527,000	741,000	31,900	82,400	39,100	7,240	82,400	38,600	4,850	1,952,700	126,600	16,300

	RA11			RA12			RA13			RA14			RA15		
Event	Inflow	Outflow	SD	Inflow	Outflow	SD	Inflow	Outflow	SD	Inflow	Outflow	SD	Inflow	Outflow	SD
1.1-yr	141,500	71,000	1,070	139,200	79,400	1,370	141,500	62,800	1,050	21,100	19,700	20	21,100	20,400	20
2-yr	197,300	71,000	1,070	200,100	126,300	1,370	197,300	64,300	1,050	23,100	23,000	20	23,100	22,600	20
10-yr	328,800	85,400	9,310	343,600	237,000	7,510	328,800	67,900	9,310	27,900	30,700	30	27,900	27,700	130
25-yr	448,700	99,500	12,800	458,700	339,400	8,600	448,700	69,900	12,800	72,200	72,100	70	72,200	71,100	320
50-yr	475,700	103,600	13,200	492,200	382,300	8,900	475,700	103,500	13,100	72,300	72,200	70	72,300	71,200	350
100-yr	545,800	104,400	14,200	552,000	439,700	21,700	545,800	104,400	14,100	117,900	117,800	120	117,900	115,000	550
200-yr	635,700	110,600	14,300	646,600	448,700	36,100	635,700	104,500	14,200	422,700	290,000	18,900	422,700	209,400	20,000
500-yr	911,400	114,000	16,300	928,700	494,700	59,000	911,400	104,600	16,200	643,900	300,400	20,600	643,900	209,500	23,700
1000-yr	1,120,000	116,600	16,300	1,142,100	529,500	59,000	1,120,000	104,700	16,200	811,200	308,300	20,600	811,200	209,600	23,700
Max	1,952,700	127,000	16,300	1,907,200	654,300	59,000	1,952,700	105,100	16,200	1,333,900	333,000	20,600	1,333,900	209,900	23,700

Table C-11. HEC-FDA Input – Inflow vs. Outflow Relationships with Standard Deviations (SD) - Baseline (continued)

	RA16			RA17			RA18			RA19			RA20		
Event	**Inflow**	**Outflow**	**SD**	**Inflow**	**Outflow**	**SD**	**Inflow**	**Outflow**	**SD**	**Inflow**	**Outflow**	**SD**	**Inflow**	**Outflow**	**SD**
1.1-yr	166,900	85,400	500	166,900	85,000	500	166,900	84,900	500	166,900	25,000	140	166,900	14,100	90
2-yr	224,300	89,100	500	224,300	88,800	500	224,300	88,700	500	224,300	25,100	140	224,300	14,700	90
10-yr	359,600	97,900	7,890	359,600	97,700	7,845	359,600	97,600	7,990	359,600	25,200	2,800	359,600	16,100	1,000
25-yr	525,300	98,000	8,050	525,300	97,800	7,850	525,300	97,700	7,995	525,300	25,300	2,810	525,300	17,000	1,120
50-yr	551,700	101,100	8,145	551,700	99,700	8,000	551,700	99,600	8,150	551,700	25,400	2,880	551,700	17,900	1,200
100-yr	666,700	117,400	9,460	666,700	117,200	9,410	666,700	117,200	9,590	666,700	29,700	3,360	666,700	21,200	1,700
200-yr	939,900	130,500	12,200	939,900	127,900	12,600	939,900	124,600	12,700	939,900	33,700	3,700	939,900	22,000	2,130
500-yr	1,133,400	142,100	13,900	1,133,400	134,400	14,200	1,133,400	133,600	14,800	1,133,400	33,800	5,390	1,133,400	22,100	3,340
1000-yr	1,279,800	150,900	13,900	1,279,800	139,300	14,200	1,279,800	140,400	14,800	1,279,800	33,900	5,390	1,279,800	22,200	3,340
Max	2,447,700	221,100	13,900	2,447,700	178,400	14,200	2,447,700	194,600	14,800	2,447,700	34,700	5,390	2,447,700	23,000	3,340

	RA21			RA22		
Event	**Inflow**	**Outflow**	**SD**	**Inflow**	**Outflow**	**SD**
1.1-yr	166,900	2,600	600	166,900	17,400	190
2-yr	224,300	2,700	600	224,300	20,000	190
10-yr	359,600	2,800	625	359,600	26,200	2,350
25-yr	525,300	2,900	645	525,300	27,800	2,560
50-yr	551,700	3,400	755	551,700	27,900	2,960
100-yr	666,700	6,200	1,380	666,700	33,300	4,370
200-yr	939,900	6,300	1,930	939,900	33,400	5,950
500-yr	1,133,400	6,400	2,240	1,133,400	33,500	7,190
1000-yr	1,279,800	6,500	2,240	1,279,800	33,600	7,190
Max	2,447,700	7,300	2,240	2,447,700	34,400	7,190

Table C-12. HEC-FDA Input – Inflow vs. Outflow Relationships with Standard Deviations (SD) - Bear River EIP

	RA01			RA02			RA03			RA04			RA05		
Event	Inflow	Outflow	SD	Inflow	Outflow	SD	Inflow	Outflow	SD	Inflow	Outflow	SD	Inflow	Outflow	SD
1.1-yr	57,400	35,700	50	7,800	4,200	25	57,400	33,700	50	38,500	38,500	10	47,900	47,400	50
2-yr	73,600	56,500	50	28,600	26,100	25	73,600	55,000	50	57,500	57,400	10	48,000	47,500	50
10-yr	111,800	105,600	110	77,700	77,600	70	111,800	105,200	180	102,200	102,000	40	48,200	47,700	50
25-yr	168,000	156,500	700	115,200	115,100	105	168,000	121,100	1,260	126,400	126,100	80	49,900	49,300	90
50-yr	170,400	156,600	800	141,300	140,800	130	170,400	133,100	1,300	155,300	154,900	90	52,700	51,900	100
100-yr	178,000	162,100	880	153,500	152,500	290	178,000	140,100	1,500	184,500	184,000	1,180	55,500	54,600	330
200-yr	188,000	162,200	990	205,800	185,100	6,150	188,000	169,800	3,920	228,600	216,400	1,200	60,500	57,600	640
500-yr	327,900	285,200	9,900	281,000	228,400	7,740	395,000	242,700	16,100	327,400	319,100	6,950	70,000	67,700	3,590
1000-yr	433,700	378,200	9,900	337,900	261,200	7,740	551,600	297,800	16,100	402,100	391,300	6,950	78,200	75,300	3,590
Max	888,400	778,000	9,900	573,400	396,300	7,740	888,400	416,300	16,100	588,500	588,500	6,950	83,800	80,500	3,590

	RA06			RA07			RA08			RA09			RA10		
Event	Inflow	Outflow	SD	Inflow	Outflow	SD	Inflow	Outflow	SD	Inflow	Outflow	SD	Inflow	Outflow	SD
1.1-yr	26,200	26,100	310	70,900	69,700	60	41,900	30,300	100	41,900	26,400	100	141,500	64,800	1,090
2-yr	26,200	26,200	310	112,000	103,800	60	43,800	30,400	100	43,800	27,500	100	197,300	71,400	1,090
10-yr	26,300	26,300	370	208,800	184,100	1,570	48,200	30,500	880	48,200	30,200	820	328,800	87,000	9,310
25-yr	35,800	33,900	670	309,600	256,800	4,440	49,900	32,800	950	49,900	32,500	890	448,700	99,500	12,800
50-yr	43,000	39,500	780	322,600	290,000	4,500	52,700	35,700	1,320	52,700	34,600	1,610	475,700	103,700	13,200
100-yr	49,200	44,200	2,190	342,400	321,100	5,500	55,500	38,600	2,910	55,500	38,000	3,250	545,800	104,800	14,200
200-yr	54,700	44,300	3,110	419,000	372,200	6,720	60,500	38,700	6,600	60,500	38,100	4,790	635,700	110,800	14,300
500-yr	62,000	44,400	4,300	657,500	456,000	31,900	70,000	38,800	7,240	70,000	38,200	4,850	911,400	114,200	16,300
1000-yr	67,500	44,500	4,300	837,900	519,400	31,900	77,200	38,900	7,240	77,200	38,300	4,850	1,120,000	116,600	16,300
Max	142,000	45,900	4,300	1,527,000	741,000	31,900	82,400	39,000	7,240	82,400	38,400	4,850	1,952,700	126,600	16,300

	RA11			RA12			RA13			RA14			RA15		
Event	Inflow	Outflow	SD	Inflow	Outflow	SD	Inflow	Outflow	SD	Inflow	Outflow	SD	Inflow	Outflow	SD
1.1-yr	141,500	71,100	1,070	139,200	80,200	1,370	141,500	62,800	1,050	21,100	19,700	20	21,100	20,300	20
2-yr	197,300	71,100	1,070	200,100	126,900	1,370	197,300	64,300	1,050	23,100	23,000	20	23,100	22,500	20
10-yr	328,800	85,400	9,310	343,600	237,000	7,510	328,800	67,900	9,310	27,900	30,700	30	27,900	27,700	130
25-yr	448,700	99,500	12,800	458,700	339,200	8,600	448,700	69,900	12,800	72,200	72,100	70	72,200	71,600	320
50-yr	475,700	103,700	13,200	492,200	383,600	8,900	475,700	103,500	13,100	72,300	72,200	70	72,300	71,700	350
100-yr	545,800	104,700	14,200	552,000	441,400	21,700	545,800	104,700	14,100	117,900	117,800	120	117,900	115,000	550
200-yr	635,700	110,600	14,300	646,600	449,500	36,100	635,700	104,800	14,200	422,700	290,000	18,900	422,700	209,300	20,000
500-yr	911,400	114,200	16,300	928,700	495,700	59,000	911,400	104,900	16,200	643,900	300,000	20,600	643,900	209,400	23,700
1000-yr	1,120,000	116,600	16,300	1,142,100	530,600	59,000	1,120,000	105,000	16,200	811,200	307,600	20,600	811,200	209,500	23,700
Max	1,952,700	127,000	16,300	1,907,200	654,300	59,000	1,952,700	105,400	16,200	1,333,900	333,000	20,600	1,333,900	209,900	23,700

Table C-12. HEC-FDA Input – Inflow vs. Outflow Relationships with Standard Deviations (SD) - Bear River EIP (continued)

	RA16			RA17			RA18			RA19			RA20		
Event	**Inflow**	**Outflow**	**SD**	**Inflow**	**Outflow**	**SD**	**Inflow**	**Outflow**	**SD**	**Inflow**	**Outflow**	**SD**	**Inflow**	**Outflow**	**SD**
1.1-yr	166,900	85,400	500	166,900	85,000	500	166,900	84,900	500	166,900	25,000	140	166,900	14,100	90
2-yr	224,300	89,100	500	224,300	88,800	500	224,300	88,700	500	224,300	25,100	140	224,300	14,700	90
10-yr	359,600	97,900	7,890	359,600	97,700	7,845	359,600	97,600	7,990	359,600	25,200	2,800	359,600	16,100	1,000
25-yr	525,300	98,000	8,050	525,300	97,800	7,850	525,300	97,700	7,995	525,300	25,300	2,810	525,300	17,000	1,120
50-yr	551,700	101,200	8,145	551,700	99,800	8,000	551,700	99,800	8,150	551,700	25,400	2,880	551,700	17,900	1,200
100-yr	666,700	117,500	9,460	666,700	117,300	9,410	666,700	117,300	9,590	666,700	29,700	3,360	666,700	21,200	1,700
200-yr	939,900	130,500	12,200	939,900	127,900	12,600	939,900	124,600	12,700	939,900	33,700	3,700	939,900	22,100	2,130
500-yr	1,133,400	142,800	13,900	1,133,400	134,700	14,200	1,133,400	133,800	14,800	1,133,400	33,800	5,390	1,133,400	22,200	3,340
1000-yr	1,279,800	152,100	13,900	1,279,800	139,800	14,200	1,279,800	140,800	14,800	1,279,800	33,900	5,390	1,279,800	22,300	3,340
Max	2,447,700	221,100	13,900	2,447,700	178,400	14,200	2,447,700	194,600	14,800	2,447,700	34,700	5,390	2,447,700	23,000	3,340

	RA21			RA22		
Event	**Inflow**	**Outflow**	**SD**	**Inflow**	**Outflow**	**SD**
1.1-yr	166,900	2,600	600	166,900	17,500	190
2-yr	224,300	2,700	600	224,300	20,100	190
10-yr	359,600	2,800	625	359,600	26,200	2,350
25-yr	525,300	2,900	645	525,300	27,700	2,560
50-yr	551,700	3,300	755	551,700	27,800	2,960
100-yr	666,700	6,200	1,380	666,700	33,300	4,370
200-yr	939,900	6,300	1,930	939,900	33,400	5,950
500-yr	1,133,400	6,400	2,240	1,133,400	33,500	7,190
1000-yr	1,279,800	6,500	2,240	1,279,800	33,600	7,190
Max	2,447,700	7,300	2,240	2,447,700	34,400	7,190

Table C-13. HEC-FDA Input – Inflow vs. Outflow Relationships with Standard Deviations (SD) - Feather River No. 1 EIP

	RA01			RA02			RA03			RA04			RA05		
Event	**Inflow**	**Outflow**	**SD**	**Inflow**	**Outflow**	**SD**	**Inflow**	**Outflow**	**SD**	**Inflow**	**Outflow**	**SD**	**Inflow**	**Outflow**	**SD**
1.1-yr	57,400	35,700	50	7,800	4,200	25	57,400	33,900	50	38,500	38,500	10	47,900	47,400	50
2-yr	73,600	56,500	50	28,600	26,100	25	73,600	55,100	50	57,500	57,400	10	48,000	47,500	50
10-yr	111,800	105,600	110	77,700	77,600	70	111,800	105,100	180	102,200	102,000	40	48,200	47,700	50
25-yr	168,000	156,600	700	115,200	115,100	105	168,000	121,400	1,260	126,400	126,100	80	49,900	49,300	90
50-yr	170,400	156,700	800	141,300	140,800	130	170,400	133,800	1,300	155,300	154,900	90	52,700	51,900	100
100-yr	178,000	162,700	880	153,500	152,500	290	178,000	141,200	1,500	184,500	184,000	1,180	55,500	54,600	330
200-yr	188,000	162,800	990	205,800	185,100	6,150	188,000	171,300	3,920	228,600	216,300	1,200	60,500	57,600	640
500-yr	327,900	285,700	9,900	281,000	228,500	7,740	395,000	256,400	16,100	327,400	319,700	6,950	70,000	67,700	3,590
1000-yr	433,700	378,700	9,900	337,900	261,300	7,740	551,600	320,800	16,100	402,100	397,900	6,950	78,200	75,300	3,590
Max	888,400	778,000	9,900	573,400	396,300	7,740	888,400	416,300	16,100	588,500	588,500	6,950	83,800	80,500	3,590

	RA06			RA07			RA08			RA09			RA10		
Event	**Inflow**	**Outflow**	**SD**	**Inflow**	**Outflow**	**SD**	**Inflow**	**Outflow**	**SD**	**Inflow**	**Outflow**	**SD**	**Inflow**	**Outflow**	**SD**
1.1-yr	26,200	25,200	310	70,900	68,300	60	41,900	30,300	100	41,900	26,500	100	141,500	71,500	1,090
2-yr	26,200	25,300	310	112,000	102,800	60	43,800	30,400	100	43,800	27,600	100	197,300	71,500	1,090
10-yr	26,300	25,400	370	208,800	184,100	1,570	48,200	30,500	880	48,200	30,200	820	328,800	86,900	9,310
25-yr	35,800	32,400	670	309,600	256,000	4,440	49,900	32,800	950	49,900	32,500	890	448,700	99,600	12,800
50-yr	43,000	37,300	780	322,600	290,700	4,500	52,700	35,800	1,320	52,700	34,800	1,610	475,700	103,700	13,200
100-yr	49,200	40,600	2,190	342,400	320,400	5,500	55,500	38,600	2,910	55,500	38,100	3,250	545,800	104,700	14,200
200-yr	54,700	40,700	3,110	419,000	371,500	6,720	60,500	38,700	6,600	60,500	38,200	4,790	635,700	110,800	14,300
500-yr	62,000	40,800	4,300	657,500	462,900	31,900	70,000	38,800	7,240	70,000	38,300	4,850	911,400	114,900	16,300
1000-yr	67,500	40,900	4,300	837,900	532,000	31,900	77,200	38,900	7,240	77,200	38,400	4,850	1,120,000	118,000	16,300
Max	142,000	42,400	4,300	1,527,000	741,000	31,900	82,400	39,000	7,240	82,400	38,500	4,850	1,952,700	126,600	16,300

	RA11			RA12			RA13			RA14			RA15		
Event	**Inflow**	**Outflow**	**SD**	**Inflow**	**Outflow**	**SD**	**Inflow**	**Outflow**	**SD**	**Inflow**	**Outflow**	**SD**	**Inflow**	**Outflow**	**SD**
1.1-yr	141,500	71,200	1,070	139,200	78,800	1,370	141,500	62,900	1,050	21,100	19,700	20	21,100	20,300	20
2-yr	197,300	71,200	1,070	200,100	126,400	1,370	197,300	64,300	1,050	23,100	23,000	20	23,100	22,500	20
10-yr	328,800	85,400	9,310	343,600	238,600	7,510	328,800	67,700	9,310	27,900	30,700	30	27,900	27,700	130
25-yr	448,700	99,600	12,800	458,700	340,000	8,600	448,700	69,700	12,800	72,200	72,100	70	72,200	71,100	320
50-yr	475,700	103,700	13,200	492,200	383,600	8,900	475,700	103,500	13,100	72,300	72,200	70	72,300	71,200	350
100-yr	545,800	104,600	14,200	552,000	440,600	21,700	545,800	104,600	14,100	117,900	117,800	120	117,900	115,000	550
200-yr	635,700	110,600	14,300	646,600	449,400	36,100	635,700	104,700	14,200	422,700	290,000	18,900	422,700	209,400	20,000
500-yr	911,400	114,800	16,300	928,700	496,100	59,000	911,400	104,800	16,200	643,900	300,200	20,600	643,900	209,500	23,700
1000-yr	1,120,000	118,000	16,300	1,142,100	531,400	59,000	1,120,000	104,900	16,200	811,200	307,900	20,600	811,200	209,600	23,700
Max	1,952,700	127,000	16,300	1,907,200	654,300	59,000	1,952,700	105,300	16,200	1,333,900	333,000	20,600	1,333,900	209,900	23,700

Table C-13. HEC-FDA Input – Inflow vs. Outflow Relationships with Standard Deviations (SD) - Feather River No. 1 EIP (continued)

	RA16			RA17			RA18			RA19			RA20		
Event	Inflow	Outflow	SD	Inflow	Outflow	SD	Inflow	Outflow	SD	Inflow	Outflow	SD	Inflow	Outflow	SD
1.1-yr	166,900	85,200	500	166,900	84,900	500	166,900	84,800	500	166,900	25,000	140	166,900	14,400	90
2-yr	224,300	89,000	500	224,300	88,700	500	224,300	88,600	500	224,300	25,100	140	224,300	14,700	90
10-yr	359,600	97,900	7,890	359,600	97,700	7,845	359,600	97,600	7,990	359,600	25,200	2,800	359,600	16,100	1,000
25-yr	525,300	98,000	8,050	525,300	97,800	7,850	525,300	97,700	7,995	525,300	25,300	2,810	525,300	17,000	1,120
50-yr	551,700	101,200	8,145	551,700	99,800	8,000	551,700	99,700	8,150	551,700	25,400	2,880	551,700	17,900	1,200
100-yr	666,700	117,400	9,460	666,700	117,300	9,410	666,700	117,200	9,590	666,700	29,700	3,360	666,700	21,200	1,700
200-yr	939,900	130,400	12,200	939,900	127,900	12,600	939,900	124,400	12,700	939,900	33,700	3,700	939,900	22,200	2,130
500-yr	1,133,400	142,700	13,900	1,133,400	134,700	14,200	1,133,400	133,900	14,800	1,133,400	33,800	5,390	1,133,400	22,300	3,340
1000-yr	1,279,800	152,000	13,900	1,279,800	139,800	14,200	1,279,800	141,100	14,800	1,279,800	33,900	5,390	1,279,800	22,400	3,340
Max	2,447,700	221,100	13,900	2,447,700	178,400	14,200	2,447,700	194,600	14,800	2,447,700	34,700	5,390	2,447,700	23,000	3,340

	RA21			RA22		
Event	Inflow	Outflow	SD	Inflow	Outflow	SD
1.1-yr	166,900	2,600	600	166,900	17,100	190
2-yr	224,300	2,700	600	224,300	20,000	190
10-yr	359,600	2,800	625	359,600	26,200	2,350
25-yr	525,300	2,900	645	525,300	27,800	2,560
50-yr	551,700	3,400	755	551,700	27,900	2,960
100-yr	666,700	6,200	1,380	666,700	33,300	4,370
200-yr	939,900	6,300	1,930	939,900	33,400	5,950
500-yr	1,133,400	6,400	2,240	1,133,400	33,500	7,190
1000-yr	1,279,800	6,500	2,240	1,279,800	33,600	7,190
Max	2,447,700	7,300	2,240	2,447,700	34,400	7,190

Table C-14. HEC-FDA Input – Inflow vs. Outflow Relationships with Standard Deviations (SD) - Bear-Feather No. 1 EIP

	RA01			RA02			RA03			RA04			RA05		
Event	Inflow	Outflow	SD	Inflow	Outflow	SD	Inflow	Outflow	SD	Inflow	Outflow	SD	Inflow	Outflow	SD
1.1-yr	57,400	35,700	50	7,800	4,500	25	57,400	33,700	50	38,500	38,500	10	47,900	47,400	50
2-yr	73,600	56,500	50	28,600	26,300	25	73,600	55,000	50	57,500	57,400	10	48,000	47,500	50
10-yr	111,800	105,600	110	77,700	77,600	70	111,800	105,200	180	102,200	102,000	40	48,200	47,700	50
25-yr	168,000	156,600	700	115,200	115,100	105	168,000	121,400	1,260	126,400	126,100	80	49,900	49,300	90
50-yr	170,400	156,700	800	141,300	140,800	130	170,400	133,700	1,300	155,300	154,900	90	52,700	51,900	100
100-yr	178,000	162,700	880	153,500	152,500	290	178,000	141,200	1,500	184,500	184,000	1,180	55,500	54,700	330
200-yr	188,000	162,800	990	205,800	185,100	6,150	188,000	171,200	3,920	228,600	216,200	1,200	60,500	57,500	640
500-yr	327,900	285,600	9,900	281,000	228,500	7,740	395,000	256,400	16,100	327,400	319,200	6,950	70,000	67,700	3,590
1000-yr	433,700	378,500	9,900	337,900	261,300	7,740	551,600	320,900	16,100	402,100	397,100	6,950	78,200	75,300	3,590
Max	888,400	778,000	9,900	573,400	396,300	7,740	888,400	416,300	16,100	588,500	588,500	6,950	83,800	80,500	3,590

	RA06			RA07			RA08			RA09			RA10		
Event	Inflow	Outflow	SD	Inflow	Outflow	SD	Inflow	Outflow	SD	Inflow	Outflow	SD	Inflow	Outflow	SD
1.1-yr	26,200	26,100	310	70,900	69,400	60	41,900	30,300	100	41,900	26,400	100	141,500	64,900	1,090
2-yr	26,200	26,200	310	112,000	103,500	60	43,800	30,400	100	43,800	27,500	100	197,300	71,500	1,090
10-yr	26,300	26,300	370	208,800	183,800	1,570	48,200	30,500	880	48,200	30,200	820	328,800	87,000	9,310
25-yr	35,800	33,800	670	309,600	257,300	4,440	49,900	32,800	950	49,900	32,500	890	448,700	99,600	12,800
50-yr	43,000	39,600	780	322,600	291,900	4,500	52,700	35,700	1,320	52,700	34,600	1,610	475,700	103,900	13,200
100-yr	49,200	44,100	2,190	342,400	322,900	5,500	55,500	38,500	2,910	55,500	37,900	3,250	545,800	105,000	14,200
200-yr	54,700	44,200	3,110	419,000	374,200	6,720	60,500	38,600	6,600	60,500	38,000	4,790	635,700	110,800	14,300
500-yr	62,000	44,300	4,300	657,500	474,700	31,900	70,000	38,700	7,240	70,000	38,100	4,850	911,400	115,200	16,300
1000-yr	67,500	44,400	4,300	837,900	550,700	31,900	77,200	38,800	7,240	77,200	38,200	4,850	1,120,000	118,500	16,300
Max	142,000	45,900	4,300	1,527,000	741,000	31,900	82,400	38,900	7,240	82,400	38,300	4,850	1,952,700	126,600	16,300

	RA11			RA12			RA13			RA14			RA15		
Event	Inflow	Outflow	SD	Inflow	Outflow	SD	Inflow	Outflow	SD	Inflow	Outflow	SD	Inflow	Outflow	SD
1.1-yr	141,500	71,300	1,070	139,200	80,200	1,370	141,500	62,900	1,050	21,100	19,700	20	21,100	20,300	20
2-yr	197,300	71,300	1,070	200,100	126,900	1,370	197,300	64,300	1,050	23,100	23,000	20	23,100	22,500	20
10-yr	328,800	85,400	9,310	343,600	237,000	7,510	328,800	67,700	9,310	27,900	30,700	30	27,900	27,700	130
25-yr	448,700	99,600	12,800	458,700	339,800	8,600	448,700	69,700	12,800	72,200	72,100	70	72,200	71,600	320
50-yr	475,700	103,900	13,200	492,200	384,900	8,900	475,700	103,500	13,100	72,300	72,200	70	72,300	71,700	350
100-yr	545,800	104,900	14,200	552,000	442,300	21,700	545,800	104,800	14,100	117,900	117,800	120	117,900	115,000	550
200-yr	635,700	110,600	14,300	646,600	450,100	36,100	635,700	104,900	14,200	422,700	290,000	18,900	422,700	209,400	20,000
500-yr	911,400	115,200	16,300	928,700	497,600	59,000	911,400	105,000	16,200	643,900	300,200	20,600	643,900	209,500	23,700
1000-yr	1,120,000	118,700	16,300	1,142,100	533,500	59,000	1,120,000	105,100	16,200	811,200	307,900	20,600	811,200	209,600	23,700
Max	1,952,700	127,000	16,300	1,907,200	654,300	59,000	1,952,700	105,500	16,200	1,333,900	333,000	20,600	1,333,900	209,900	23,700

Table C-14. HEC-FDA Input – Inflow vs. Outflow Relationships with Standard Deviations (SD) - Bear-Feather No. 1 EIP (continued)

	RA16			RA17			RA18			RA19			RA20		
Event	Inflow	Outflow	SD	Inflow	Outflow	SD	Inflow	Outflow	SD	Inflow	Outflow	SD	Inflow	Outflow	SD
1.1-yr	166,900	85,200	500	166,900	84,900	500	166,900	84,700	500	166,900	25,000	140	166,900	14,500	90
2-yr	224,300	89,000	500	224,300	88,700	500	224,300	88,600	500	224,300	25,100	140	224,300	14,700	90
10-yr	359,600	97,900	7,890	359,600	97,700	7,845	359,600	97,700	7,990	359,600	25,200	2,800	359,600	16,100	1,000
25-yr	525,300	98,000	8,050	525,300	97,800	7,850	525,300	97,800	7,995	525,300	25,300	2,810	525,300	17,000	1,120
50-yr	551,700	101,300	8,145	551,700	99,900	8,000	551,700	99,800	8,150	551,700	25,400	2,880	551,700	17,900	1,200
100-yr	666,700	117,600	9,460	666,700	117,300	9,410	666,700	117,300	9,590	666,700	29,700	3,360	666,700	21,200	1,700
200-yr	939,900	130,400	12,200	939,900	127,800	12,600	939,900	124,400	12,700	939,900	33,700	3,700	939,900	22,200	2,130
500-yr	1,133,400	142,700	13,900	1,133,400	134,700	14,200	1,133,400	133,800	14,800	1,133,400	33,800	5,390	1,133,400	22,300	3,340
1000-yr	1,279,800	152,000	13,900	1,279,800	139,900	14,200	1,279,800	140,900	14,800	1,279,800	33,900	5,390	1,279,800	22,400	3,340
Max	2,447,700	221,100	13,900	2,447,700	178,400	14,200	2,447,700	194,600	14,800	2,447,700	34,700	5,390	2,447,700	23,000	3,340

	RA21			RA22		
Event	Inflow	Outflow	SD	Inflow	Outflow	SD
1.1-yr	166,900	2,600	600	166,900	17,500	190
2-yr	224,300	2,700	600	224,300	20,100	190
10-yr	359,600	2,800	625	359,600	26,200	2,350
25-yr	525,300	2,900	645	525,300	27,700	2,560
50-yr	551,700	3,600	755	551,700	27,800	2,960
100-yr	666,700	6,100	1,380	666,700	33,200	4,370
200-yr	939,900	6,200	1,930	939,900	33,300	5,950
500-yr	1,133,400	6,300	2,240	1,133,400	33,400	7,190
1000-yr	1,279,800	6,400	2,240	1,279,800	33,500	7,190
Max	2,447,700	7,300	2,240	2,447,700	34,400	7,190

Table C-15. HEC-FDA Input – Inflow vs. Outflow Relationships with Standard Deviations (SD) - Feather No. 2 (Star Bend) EIP

	RA01			RA02			RA03			RA04			RA05		
Event	Inflow	Outflow	SD	Inflow	Outflow	SD	Inflow	Outflow	SD	Inflow	Outflow	SD	Inflow	Outflow	SD
1.1-yr	57,400	35,700	50	7,800	4,200	25	57,400	33,700	50	38,500	38,500	10	47,900	47,400	50
2-yr	73,600	56,500	50	28,600	26,100	25	73,600	55,000	50	57,500	57,400	10	48,000	47,500	50
10-yr	111,800	105,600	110	77,700	77,600	70	111,800	105,100	180	102,200	102,000	40	48,200	47,700	50
25-yr	168,000	156,500	700	115,200	115,100	105	168,000	121,000	1,260	126,400	126,100	80	49,900	49,300	90
50-yr	170,400	156,600	800	141,300	140,800	130	170,400	133,100	1,300	155,300	154,900	90	52,700	51,900	100
100-yr	178,000	162,100	880	153,500	152,500	290	178,000	140,100	1,500	184,500	184,000	1,180	55,500	54,600	330
200-yr	188,000	162,200	990	205,800	185,100	6,150	188,000	169,900	3,920	228,600	216,400	1,200	60,500	57,600	640
500-yr	327,900	285,300	9,900	281,000	228,300	7,740	395,000	242,700	16,100	327,400	319,100	6,950	70,000	67,700	3,590
1000-yr	433,700	378,400	9,900	337,900	261,000	7,740	551,600	297,800	16,100	402,100	396,800	6,950	78,200	75,300	3,590
Max	888,400	778,000	9,900	573,400	396,300	7,740	888,400	416,300	16,100	588,500	588,500	6,950	83,800	80,500	3,590

	RA06			RA07			RA08			RA09			RA10		
Event	Inflow	Outflow	SD	Inflow	Outflow	SD	Inflow	Outflow	SD	Inflow	Outflow	SD	Inflow	Outflow	SD
1.1-yr	26,200	25,200	310	70,900	69,100	60	41,900	30,300	100	41,900	26,400	100	141,500	71,300	1,090
2-yr	26,200	25,300	310	112,000	103,100	60	43,800	30,400	100	43,800	27,500	100	197,300	71,300	1,090
10-yr	26,300	25,400	370	208,800	183,100	1,570	48,200	30,500	880	48,200	30,200	820	328,800	86,900	9,310
25-yr	35,800	32,500	670	309,600	255,400	4,440	49,900	32,800	950	49,900	32,500	890	448,700	99,600	12,800
50-yr	43,000	37,300	780	322,600	289,100	4,500	52,700	35,900	1,320	52,700	34,800	1,610	475,700	103,600	13,200
100-yr	49,200	40,700	2,190	342,400	318,500	5,500	55,500	38,700	2,910	55,500	38,200	3,250	545,800	104,500	14,200
200-yr	54,700	40,800	3,110	419,000	369,400	6,720	60,500	38,800	6,600	60,500	38,300	4,790	635,700	110,800	14,300
500-yr	62,000	40,900	4,300	657,500	449,300	31,900	70,000	38,900	7,240	70,000	38,400	4,850	911,400	114,100	16,300
1000-yr	67,500	41,000	4,300	837,900	509,700	31,900	77,200	39,000	7,240	77,200	38,500	4,850	1,120,000	116,600	16,300
Max	142,000	42,400	4,300	1,527,000	741,000	31,900	82,400	39,100	7,240	82,400	38,600	4,850	1,952,700	126,600	16,300

	RA11			RA12			RA13			RA14			RA15		
Event	Inflow	Outflow	SD	Inflow	Outflow	SD	Inflow	Outflow	SD	Inflow	Outflow	SD	Inflow	Outflow	SD
1.1-yr	141,500	71,000	1,070	139,200	78,800	1,370	141,500	62,800	1,050	21,100	19,700	20	21,100	20,300	20
2-yr	197,300	71,000	1,070	200,100	126,300	1,370	197,300	64,300	1,050	23,100	23,000	20	23,100	22,500	20
10-yr	328,800	85,400	9,310	343,600	238,300	7,510	328,800	67,900	9,310	27,900	30,700	30	27,900	27,700	130
25-yr	448,700	99,600	12,800	458,700	339,400	8,600	448,700	69,900	12,800	72,200	72,100	70	72,200	71,600	320
50-yr	475,700	103,600	13,200	492,200	382,400	8,900	475,700	103,500	13,100	72,200	72,300	70	72,300	71,700	350
100-yr	545,800	104,500	14,200	552,000	439,800	21,700	545,800	104,400	14,100	117,900	117,800	120	117,900	115,000	550
200-yr	635,700	110,600	14,300	646,600	448,700	36,100	635,700	104,500	14,200	422,700	290,000	18,900	422,700	209,400	20,000
500-yr	911,400	114,000	16,300	928,700	494,600	59,000	911,400	104,600	16,200	643,900	300,400	20,600	643,900	209,500	23,700
1000-yr	1,120,000	116,600	16,300	1,142,100	529,300	59,000	1,120,000	104,700	16,200	811,200	308,300	20,600	811,200	209,600	23,700
Max	1,952,700	127,000	16,300	1,907,200	654,300	59,000	1,952,700	105,100	16,200	1,333,900	333,000	20,600	1,333,900	209,900	23,700

Table C-15. HEC-FDA Input – Inflow vs. Outflow Relationships with Standard Deviations (SD) - Feather No. 2 (Star Bend) EIP (continued)

	RA16			RA17			RA18			RA19			RA20		
Event	Inflow	Outflow	SD	Inflow	Outflow	SD	Inflow	Outflow	SD	Inflow	Outflow	SD	Inflow	Outflow	SD
1.1-yr	166,900	85,400	500	166,900	85,000	500	166,900	84,900	500	166,900	25,000	140	166,900	14,700	90
2-yr	224,300	89,100	500	224,300	88,800	500	224,300	88,700	500	224,300	25,100	140	224,300	14,700	90
10-yr	359,600	97,900	7,890	359,600	97,700	7,845	359,600	97,600	7,990	359,600	25,200	2,800	359,600	16,100	1,000
25-yr	525,300	98,000	8,050	525,300	97,800	7,850	525,300	97,700	7,995	525,300	25,300	2,810	525,300	17,000	1,120
50-yr	551,700	101,100	8,145	551,700	99,700	8,000	551,700	99,600	8,150	551,700	25,400	2,880	551,700	17,900	1,200
100-yr	666,700	117,400	9,460	666,700	117,200	9,410	666,700	117,200	9,590	666,700	29,700	3,360	666,700	21,200	1,700
200-yr	939,900	130,500	12,200	939,900	127,900	12,600	939,900	124,500	12,700	939,900	33,700	3,700	939,900	22,000	2,130
500-yr	1,133,400	142,800	13,900	1,133,400	134,700	14,200	1,133,400	133,800	14,800	1,133,400	33,800	5,390	1,133,400	22,100	3,340
1000-yr	1,279,800	152,100	13,900	1,279,800	139,800	14,200	1,279,800	140,800	14,800	1,279,800	33,900	5,390	1,279,800	22,200	3,340
Max	2,447,700	221,100	13,900	2,447,700	178,400	14,200	2,447,700	194,600	14,800	2,447,700	34,700	5,390	2,447,700	23,000	3,340

	RA21			RA22		
Event	Inflow	Outflow	SD	Inflow	Outflow	SD
1.1-yr	166,900	2,600	600	166,900	20,000	190
2-yr	224,300	2,700	600	224,300	20,000	190
10-yr	359,600	2,800	625	359,600	26,200	2,350
25-yr	525,300	2,900	645	525,300	27,700	2,560
50-yr	551,700	3,400	755	551,700	27,800	2,960
100-yr	666,700	6,100	1,380	666,700	33,200	4,370
200-yr	939,900	6,200	1,930	939,900	33,300	5,950
500-yr	1,133,400	6,300	2,240	1,133,400	33,400	7,190
1000-yr	1,279,800	6,400	2,240	1,279,800	33,500	7,190
Max	2,447,700	7,300	2,240	2,447,700	34,400	7,190

Table C-16. HEC-FDA Input – Inflow vs. Outflow Relationships with Standard Deviations (SD) - Bear-Feather No. 1-Feather No. 2 (Star Bend) EIP

	RA01			RA02			RA03			RA04			RA05		
Event	Inflow	Outflow	SD	Inflow	Outflow	SD	Inflow	Outflow	SD	Inflow	Outflow	SD	Inflow	Outflow	SD
1.1-yr	57,400	35,700	50	7,800	4,500	25	57,400	33,700	50	38,500	38,500	10	47,900	47,400	50
2-yr	73,600	56,500	50	28,600	26,300	25	73,600	55,000	50	57,500	57,400	10	48,000	47,500	50
10-yr	111,800	105,600	110	77,700	77,600	70	111,800	105,200	180	102,200	102,000	40	48,200	47,700	50
25-yr	168,000	156,600	700	115,200	115,100	105	168,000	121,400	1,260	126,400	126,100	80	49,900	49,300	90
50-yr	170,400	156,700	800	141,300	140,800	130	170,400	133,700	1,300	155,300	154,900	90	52,700	51,900	100
100-yr	178,000	162,700	880	153,500	152,500	290	178,000	141,200	1,500	184,500	184,000	1,180	55,500	54,700	330
200-yr	188,000	162,800	990	205,800	185,100	6,150	188,000	171,200	3,920	228,600	216,200	1,200	60,500	57,500	640
500-yr	327,900	285,700	9,900	281,000	228,500	7,740	395,000	256,400	16,100	327,400	318,900	6,950	70,000	67,700	3,590
1000-yr	433,700	378,700	9,900	337,900	261,300	7,740	551,600	320,900	16,100	402,100	396,600	6,950	78,200	75,300	3,590
Max	888,400	778,000	9,900	573,400	396,300	7,740	888,400	416,300	16,100	588,500	588,500	6,950	83,800	80,500	3,590

	RA06			RA07			RA08			RA09			RA10		
Event	Inflow	Outflow	SD	Inflow	Outflow	SD	Inflow	Outflow	SD	Inflow	Outflow	SD	Inflow	Outflow	SD
1.1-yr	26,200	26,100	310	70,900	69,500	60	41,900	30,300	100	41,900	26,400	100	141,500	64,900	1,090
2-yr	26,200	26,200	310	112,000	103,500	60	43,800	30,400	100	43,800	27,500	100	197,300	71,500	1,090
10-yr	26,300	26,300	370	208,800	183,700	1,570	48,200	30,500	880	48,200	30,200	820	328,800	87,000	9,310
25-yr	35,800	33,800	670	309,600	257,200	4,440	49,900	32,800	950	49,900	32,500	890	448,700	99,600	12,800
50-yr	43,000	39,600	780	322,600	291,900	4,500	52,700	35,700	1,320	52,700	34,600	1,610	475,700	103,900	13,200
100-yr	49,200	44,100	2,190	342,400	322,900	5,500	55,500	38,500	2,910	55,500	37,900	3,250	545,800	105,000	14,200
200-yr	54,700	44,200	3,110	419,000	374,200	6,720	60,500	38,600	6,600	60,500	38,000	4,790	635,700	110,800	14,300
500-yr	62,000	44,300	4,300	657,500	474,600	31,900	70,000	38,700	7,240	70,000	38,100	4,850	911,400	115,200	16,300
1000-yr	67,500	44,400	4,300	837,900	550,500	31,900	77,200	38,800	7,240	77,200	38,200	4,850	1,120,000	118,500	16,300
Max	142,000	45,900	4,300	1,527,000	741,000	31,900	82,400	38,900	7,240	82,400	38,300	4,850	1,952,700	126,600	16,300

	RA11			RA12			RA13			RA14			RA15		
Event	Inflow	Outflow	SD	Inflow	Outflow	SD	Inflow	Outflow	SD	Inflow	Outflow	SD	Inflow	Outflow	SD
1.1-yr	141,500	71,300	1,070	139,200	80,100	1,370	141,500	62,900	1,050	21,100	19,700	20	21,100	20,300	20
2-yr	197,300	71,300	1,070	200,100	126,900	1,370	197,300	64,300	1,050	23,100	23,000	20	23,100	22,500	20
10-yr	328,800	85,400	9,310	343,600	237,200	7,510	328,800	67,700	9,310	27,900	30,700	30	27,900	27,700	130
25-yr	448,700	99,600	12,800	458,700	339,800	8,600	448,700	69,700	12,800	72,200	72,100	70	72,200	71,600	320
50-yr	475,700	103,900	13,200	492,200	384,900	8,900	475,700	103,500	13,100	72,300	72,200	70	72,300	71,700	350
100-yr	545,800	104,900	14,200	552,000	442,400	21,700	545,800	104,800	14,100	117,900	117,800	120	117,900	115,000	550
200-yr	635,700	110,600	14,300	646,600	450,200	36,100	635,700	104,900	14,200	422,700	290,000	18,900	422,700	209,400	20,000
500-yr	911,400	115,200	16,300	928,700	497,600	59,000	911,400	105,000	16,200	643,900	300,000	20,600	643,900	209,500	23,700
1000-yr	1,120,000	118,700	16,300	1,142,100	533,500	59,000	1,120,000	105,100	16,200	811,200	307,600	20,600	811,200	209,600	23,700
Max	1,952,700	127,000	16,300	1,907,200	654,300	59,000	1,952,700	105,500	16,200	1,333,900	333,000	20,600	1,333,900	209,900	23,700

Table C-16. HEC-FDA Input – Inflow vs. Outflow Relationships with Standard Deviations (SD) - Bear-Feather No. 1-Feather No. 2 (Star Bend) EIP (continued)

	RA16			RA17			RA18			RA19			RA20		
Event	Inflow	Outflow	SD	Inflow	Outflow	SD	Inflow	Outflow	SD	Inflow	Outflow	SD	Inflow	Outflow	SD
1.1-yr	166,900	85,200	500	166,900	84,900	500	166,900	84,700	500	166,900	25,000	140	166,900	14,500	90
2-yr	224,300	89,000	500	224,300	88,700	500	224,300	88,600	500	224,300	25,100	140	224,300	14,700	90
10-yr	359,600	97,900	7,890	359,600	97,700	7,845	359,600	97,700	7,990	359,600	25,200	2,800	359,600	16,100	1,000
25-yr	525,300	98,000	8,050	525,300	97,800	7,850	525,300	97,800	7,995	525,300	25,300	2,810	525,300	17,000	1,120
50-yr	551,700	101,300	8,145	551,700	99,900	8,000	551,700	99,800	8,150	551,700	25,400	2,880	551,700	17,900	1,200
100-yr	666,700	117,600	9,460	666,700	117,300	9,410	666,700	117,300	9,590	666,700	29,700	3,360	666,700	21,200	1,700
200-yr	939,900	130,400	12,200	939,900	127,800	12,600	939,900	124,400	12,700	939,900	33,700	3,700	939,900	22,200	2,130
500-yr	1,133,400	142,700	13,900	1,133,400	134,700	14,200	1,133,400	133,800	14,800	1,133,400	33,800	5,390	1,133,400	22,300	3,340
1000-yr	1,279,800	152,000	13,900	1,279,800	139,900	14,200	1,279,800	140,900	14,800	1,279,800	33,900	5,390	1,279,800	22,400	3,340
Max	2,447,700	221,100	13,900	2,447,700	178,400	14,200	2,447,700	194,600	14,800	2,447,700	34,700	5,390	2,447,700	23,000	3,340

	RA21			RA22		
Event	Inflow	Outflow	SD	Inflow	Outflow	SD
1.1-yr	166,900	2,600	600	166,900	17,500	190
2-yr	224,300	2,700	600	224,300	20,100	190
10-yr	359,600	2,800	625	359,600	26,200	2,350
25-yr	525,300	2,900	645	525,300	27,800	2,560
50-yr	551,700	3,600	755	551,700	27,900	2,960
100-yr	666,700	6,200	1,380	666,700	33,200	4,370
200-yr	939,900	6,300	1,930	939,900	33,300	5,950
500-yr	1,133,400	6,400	2,240	1,133,400	33,400	7,190
1000-yr	1,279,800	6,500	2,240	1,279,800	33,500	7,190
Max	2,447,700	7,300	2,240	2,447,700	34,400	7,190

Table C-17. HEC-FDA Input – Inflow vs. Outflow Relationships with Standard Deviations (SD) - Natomas EIP

	RA01			RA02			RA03			RA04			RA05		
Event	Inflow	Outflow	SD	Inflow	Outflow	SD	Inflow	Outflow	SD	Inflow	Outflow	SD	Inflow	Outflow	SD
1.1-yr	57,400	35,700	50	7,800	4,200	25	57,400	33,700	50	38,500	38,500	10	47,900	47,400	50
2-yr	73,600	56,500	50	28,600	26,100	25	73,600	55,000	50	57,500	57,400	10	48,000	47,500	50
10-yr	111,800	105,600	110	77,700	77,600	70	111,800	105,200	180	102,200	102,000	40	48,200	47,700	50
25-yr	168,000	156,500	700	115,200	115,100	105	168,000	121,000	1,260	126,400	126,100	80	49,900	49,300	90
50-yr	170,400	156,600	800	141,300	140,800	130	170,400	133,000	1,300	155,300	154,900	90	52,700	51,900	100
100-yr	178,000	162,100	880	153,500	152,500	290	178,000	140,100	1,500	184,500	184,000	1,180	55,500	54,600	330
200-yr	188,000	162,200	990	205,800	185,100	6,150	188,000	169,900	3,920	228,600	216,300	1,200	60,500	57,500	640
500-yr	327,900	285,300	9,900	281,000	228,400	7,740	395,000	242,700	16,100	327,400	319,100	6,950	70,000	67,700	3,590
1000-yr	433,700	378,400	9,900	337,900	261,200	7,740	551,600	297,800	16,100	402,100	396,900	6,950	78,200	75,400	3,590
Max	888,400	778,000	9,900	573,400	396,300	7,740	888,400	416,300	16,100	588,500	588,500	6,950	83,800	80,500	3,590

	RA06			RA07			RA08			RA09			RA10		
Event	Inflow	Outflow	SD	Inflow	Outflow	SD	Inflow	Outflow	SD	Inflow	Outflow	SD	Inflow	Outflow	SD
1.1-yr	26,200	25,200	310	70,900	69,100	60	41,900	30,300	100	41,900	26,400	100	141,500	64,700	1,090
2-yr	26,200	25,300	310	112,000	103,100	60	43,800	30,400	100	43,800	27,500	100	197,300	71,300	1,090
10-yr	26,300	25,400	370	208,800	183,200	1,570	48,200	30,500	880	48,200	30,200	820	328,800	86,900	9,310
25-yr	35,800	32,500	670	309,600	255,400	4,440	49,900	32,800	950	49,900	32,500	890	448,700	99,600	12,800
50-yr	43,000	37,300	780	322,600	289,200	4,500	52,700	35,900	1,320	52,700	34,800	1,610	475,700	103,700	13,200
100-yr	49,200	40,700	2,190	342,400	318,500	5,500	55,500	38,600	2,910	55,500	38,100	3,250	545,800	105,100	14,200
200-yr	54,700	40,800	3,110	419,000	368,700	6,720	60,500	38,700	6,600	60,500	38,200	4,790	635,700	113,400	14,300
500-yr	62,000	40,900	4,300	657,500	448,800	31,900	70,000	38,800	7,240	70,000	38,300	4,850	911,400	119,800	16,300
1000-yr	67,500	41,000	4,300	837,900	509,400	31,900	77,200	38,900	7,240	77,200	38,400	4,850	1,120,000	124,600	16,300
Max	142,000	42,400	4,300	1,527,000	741,000	31,900	82,400	39,000	7,240	82,400	38,500	4,850	1,952,700	143,800	16,300

	RA11			RA12			RA13			RA14			RA15		
Event	Inflow	Outflow	SD	Inflow	Outflow	SD	Inflow	Outflow	SD	Inflow	Outflow	SD	Inflow	Outflow	SD
1.1-yr	141,500	71,000	1,070	139,200	79,300	1,370	141,500	62,800	1,050	21,100	19,700	20	21,100	20,400	20
2-yr	197,300	71,000	1,070	200,100	126,300	1,370	197,300	64,300	1,050	23,100	23,000	20	23,100	22,600	20
10-yr	328,800	85,400	9,310	343,600	237,000	7,510	328,800	67,900	9,310	27,900	30,700	30	27,900	27,700	130
25-yr	448,700	99,600	12,800	458,700	339,300	8,600	448,700	69,900	12,800	72,200	72,100	70	72,200	71,600	320
50-yr	475,700	103,700	13,200	492,200	382,200	8,900	475,700	103,500	13,100	72,300	72,200	70	72,300	71,700	350
100-yr	545,800	105,100	14,200	552,000	441,600	21,700	545,800	105,000	14,100	117,900	117,800	120	117,900	115,000	550
200-yr	635,700	113,400	14,300	646,600	450,600	36,100	635,700	105,100	14,200	422,700	290,000	18,900	422,700	209,400	20,000
500-yr	911,400	119,200	16,300	928,700	485,900	59,000	911,400	105,200	16,200	643,900	300,400	20,600	643,900	209,500	23,700
1000-yr	1,120,000	123,600	16,300	1,142,100	512,600	59,000	1,120,000	105,300	16,200	811,200	308,300	20,600	811,200	209,600	23,700
Max	1,952,700	141,200	16,300	1,907,200	654,300	59,000	1,952,700	105,700	16,200	1,333,900	333,000	20,600	1,333,900	209,900	23,700

Table C-17. HEC-FDA Input – Inflow vs. Outflow Relationships with Standard Deviations (SD) - Natomas EIP (continued)

	RA16			RA17			RA18			RA19			RA20		
Event	**Inflow**	**Outflow**	**SD**	**Inflow**	**Outflow**	**SD**	**Inflow**	**Outflow**	**SD**	**Inflow**	**Outflow**	**SD**	**Inflow**	**Outflow**	**SD**
1.1-yr	166,900	85,400	500	166,900	85,000	500	166,900	84,900	500	166,900	25,000	140	166,900	14,100	90
2-yr	224,300	89,100	500	224,300	88,800	500	224,300	88,700	500	224,300	25,100	140	224,300	14,700	90
10-yr	359,600	97,900	7,890	359,600	97,700	7,845	359,600	97,600	7,990	359,600	25,200	2,800	359,600	16,100	1,000
25-yr	525,300	98,000	8,050	525,300	97,800	7,850	525,300	97,700	7,995	525,300	25,300	2,810	525,300	17,000	1,120
50-yr	551,700	100,600	8,145	551,700	99,300	8,000	551,700	99,200	8,150	551,700	25,400	2,880	551,700	17,800	1,200
100-yr	666,700	117,200	9,460	666,700	117,000	9,410	666,700	117,000	9,590	666,700	29,600	3,360	666,700	21,200	1,700
200-yr	939,900	130,500	12,200	939,900	127,900	12,600	939,900	124,600	12,700	939,900	33,700	3,700	939,900	22,000	2,130
500-yr	1,133,400	144,600	13,900	1,133,400	135,400	14,200	1,133,400	134,700	14,800	1,133,400	33,800	5,390	1,133,400	22,100	3,340
1000-yr	1,279,800	155,300	13,900	1,279,800	141,100	14,200	1,279,800	142,300	14,800	1,279,800	33,900	5,390	1,279,800	22,200	3,340
Max	2,447,700	221,100	13,900	2,447,700	178,400	14,200	2,447,700	194,600	14,800	2,447,700	34,700	5,390	2,447,700	23,000	3,340

	RA21			RA22		
Event	**Inflow**	**Outflow**	**SD**	**Inflow**	**Outflow**	**SD**
1.1-yr	166,900	2,600	600	166,900	17,400	190
2-yr	224,300	2,700	600	224,300	20,000	190
10-yr	359,600	2,800	625	359,600	26,200	2,350
25-yr	525,300	2,900	645	525,300	27,700	2,560
50-yr	551,700	3,500	755	551,700	27,900	2,960
100-yr	666,700	6,100	1,380	666,700	33,200	4,370
200-yr	939,900	6,200	1,930	939,900	33,300	5,950
500-yr	1,133,400	6,300	2,240	1,133,400	33,400	7,190
1000-yr	1,279,800	6,400	2,240	1,279,800	33,500	7,190
Max	2,447,700	7,300	2,240	2,447,700	34,400	7,190

Table C-18. HEC-FDA Input – Inflow vs. Outflow Relationships with Standard Deviations (SD) - Bear-Feather No. 1-Feather No. 2 (Star Bend) Natomas EIP

	RA01			RA02			RA03			RA04			RA05		
Event	Inflow	Outflow	SD	Inflow	Outflow	SD	Inflow	Outflow	SD	Inflow	Outflow	SD	Inflow	Outflow	SD
1.1-yr	57,400	35,700	50	7,800	4,200	25	57,400	33,800	50	38,500	38,500	10	47,900	47,400	50
2-yr	73,600	56,500	50	28,600	26,100	25	73,600	55,100	50	57,500	57,400	10	48,000	47,500	50
10-yr	111,800	105,600	110	77,700	77,600	70	111,800	105,200	180	102,200	102,000	40	48,200	47,700	50
25-yr	168,000	156,600	700	115,200	115,100	105	168,000	121,400	1,260	126,400	126,100	80	49,900	49,300	90
50-yr	170,400	156,700	800	141,300	140,800	130	170,400	133,700	1,300	155,300	154,900	90	52,700	51,900	100
100-yr	178,000	162,800	880	153,500	152,500	290	178,000	141,200	1,500	184,500	184,000	1,180	55,500	54,700	330
200-yr	188,000	162,900	990	205,800	185,100	6,150	188,000	171,200	3,920	228,600	216,000	1,200	60,500	57,400	640
500-yr	327,900	285,700	9,900	281,000	228,500	7,740	395,000	256,400	16,100	327,400	318,900	6,950	70,000	67,700	3,590
1000-yr	433,700	378,600	9,900	337,900	261,300	7,740	551,600	320,900	16,100	402,100	396,700	6,950	78,200	75,300	3,590
Max	888,400	778,000	9,900	573,400	396,300	7,740	888,400	416,300	16,100	588,500	588,500	6,950	83,800	80,500	3,590

	RA06			RA07			RA08			RA09			RA10		
Event	Inflow	Outflow	SD	Inflow	Outflow	SD	Inflow	Outflow	SD	Inflow	Outflow	SD	Inflow	Outflow	SD
1.1-yr	26,200	26,100	310	70,900	69,600	60	41,900	30,300	100	41,900	26,400	100	141,500	71,500	1,090
2-yr	26,200	26,200	310	112,000	103,600	60	43,800	30,400	100	43,800	27,500	100	197,300	71,500	1,090
10-yr	26,300	26,300	370	208,800	183,700	1,570	48,200	30,500	880	48,200	30,200	820	328,800	86,900	9,310
25-yr	35,800	33,800	670	309,600	257,200	4,440	49,900	32,800	950	49,900	32,500	890	448,700	99,600	12,800
50-yr	43,000	39,600	780	322,600	291,900	4,500	52,700	35,700	1,320	52,700	34,600	1,610	475,700	103,900	13,200
100-yr	49,200	44,100	2,190	342,400	322,800	5,500	55,500	38,400	2,910	55,500	37,800	3,250	545,800	105,500	14,200
200-yr	54,700	44,200	3,110	419,000	373,500	6,720	60,500	38,500	6,600	60,500	37,900	4,790	635,700	113,700	14,300
500-yr	62,000	44,300	4,300	657,500	473,900	31,900	70,000	38,600	7,240	70,000	38,000	4,850	911,400	125,500	16,300
1000-yr	67,500	44,400	4,300	837,900	549,800	31,900	77,200	38,700	7,240	77,200	38,100	4,850	1,120,000	134,400	16,300
Max	142,000	45,900	4,300	1,527,000	741,000	31,900	82,400	38,800	7,240	82,400	38,200	4,850	1,952,700	143,800	16,300

	RA11			RA12			RA13			RA14			RA15		
Event	Inflow	Outflow	SD	Inflow	Outflow	SD	Inflow	Outflow	SD	Inflow	Outflow	SD	Inflow	Outflow	SD
1.1-yr	141,500	65,300	1,070	139,200	79,600	1,370	141,500	62,900	1,050	21,100	19,700	20	21,100	20,300	20
2-yr	197,300	71,300	1,070	200,100	127,000	1,370	197,300	64,300	1,050	23,100	23,000	20	23,100	22,500	20
10-yr	328,800	85,400	9,310	343,600	238,700	7,510	328,800	67,700	9,310	27,900	30,700	30	27,900	27,700	130
25-yr	448,700	99,600	12,800	458,700	339,800	8,600	448,700	69,700	12,800	72,200	72,100	70	72,200	71,600	320
50-yr	475,700	103,900	13,200	492,200	384,900	8,900	475,700	103,500	13,100	72,300	72,200	70	72,300	71,700	350
100-yr	545,800	105,400	14,200	552,000	444,200	21,700	545,800	105,400	14,100	117,900	117,800	120	117,900	115,000	550
200-yr	635,700	113,700	14,300	646,600	452,200	36,100	635,700	105,500	14,200	422,700	290,000	18,900	422,700	209,400	20,000
500-yr	911,400	124,400	16,300	928,700	501,000	59,000	911,400	105,600	16,200	643,900	300,200	20,600	643,900	209,500	23,700
1000-yr	1,120,000	132,500	16,300	1,142,100	537,900	59,000	1,120,000	105,700	16,200	811,200	307,900	20,600	811,200	209,600	23,700
Max	1,952,700	141,200	16,300	1,907,200	654,300	59,000	1,952,700	106,100	16,200	1,333,900	333,000	20,600	1,333,900	209,900	23,700

Table C-18. HEC-FDA Input – Inflow vs. Outflow Relationships with Standard Deviations (SD) - Bear-Feather No. 1-Feather No. 2 (Star Bend) Natomas EIP (continued)

	RA16			RA17			RA18			RA19			RA20		
Event	Inflow	Outflow	SD	Inflow	Outflow	SD	Inflow	Outflow	SD	Inflow	Outflow	SD	Inflow	Outflow	SD
1.1-yr	166,900	85,200	500	166,900	84,900	500	166,900	84,800	500	166,900	25,000	140	166,900	14,700	90
2-yr	224,300	89,000	500	224,300	88,700	500	224,300	88,600	500	224,300	25,100	140	224,300	14,700	90
10-yr	359,600	97,900	7,890	359,600	97,700	7,845	359,600	97,600	7,990	359,600	25,200	2,800	359,600	16,100	1,000
25-yr	525,300	98,000	8,050	525,300	97,800	7,850	525,300	97,700	7,995	525,300	25,300	2,810	525,300	17,000	1,120
50-yr	551,700	101,300	8,145	551,700	99,900	8,000	551,700	99,800	8,150	551,700	25,400	2,880	551,700	17,900	1,200
100-yr	666,700	117,800	9,460	666,700	117,500	9,410	666,700	117,400	9,590	666,700	29,700	3,360	666,700	21,300	1,700
200-yr	939,900	130,300	12,200	939,900	127,800	12,600	939,900	124,400	12,700	939,900	33,700	3,700	939,900	22,200	2,130
500-yr	1,133,400	144,500	13,900	1,133,400	135,400	14,200	1,133,400	134,600	14,800	1,133,400	33,800	5,390	1,133,400	22,300	3,340
1000-yr	1,279,800	155,200	13,900	1,279,800	141,100	14,200	1,279,800	142,300	14,800	1,279,800	33,900	5,390	1,279,800	22,400	3,340
Max	2,447,700	221,100	13,900	2,447,700	178,400	14,200	2,447,700	194,600	14,800	2,447,700	34,700	5,390	2,447,700	23,000	3,340

	RA21			RA22		
Event	Inflow	Outflow	SD	Inflow	Outflow	SD
1.1-yr	166,900	2,600	600	166,900	20,000	190
2-yr	224,300	2,700	600	224,300	20,000	190
10-yr	359,600	2,800	625	359,600	26,200	2,350
25-yr	525,300	2,900	645	525,300	27,800	2,560
50-yr	551,700	3,600	755	551,700	27,900	2,960
100-yr	666,700	6,200	1,380	666,700	33,300	4,370
200-yr	939,900	6,300	1,930	939,900	33,400	5,950
500-yr	1,133,400	6,400	2,240	1,133,400	33,500	7,190
1000-yr	1,279,800	6,500	2,240	1,279,800	33,600	7,190
Max	2,447,700	7,300	2,240	2,447,700	34,400	7,190

Table C-19. HEC-FDA Input - Stage vs. Discharge Relationships - Index Location RA01, Feather River

Index Location: RA01, Feather River
River Stationing: 42.24
Top of Levee: 89.39 feet

Event	Baseline Outflow	Baseline Stage	Bear Outflow	Bear Stage	Feather Outflow	Feather Stage	Bear-Feather Outflow	Bear-Feather Stage	SB Outflow	SB Stage	B-F-SB Outflow	B-F-SB Stage	Natomas Outflow	Natomas Stage	B-F-SB-N Outflow	B-F-SB-N Stage
1.01-yr	35,700		35,700		35,700		35,700		35,700		35,700		35,700		35,700	
2-yr	56,500	73.51	56,500	73.51	56,500	73.51	56,500	73.51	56,500	73.51	56,500	73.51	56,500	73.51	56,500	73.51
10-yr	105,600	77.57	105,600	77.57	105,600	77.56	105,600	77.56	105,600	77.57	105,600	77.56	105,600	77.57	105,600	77.56
25-yr	156,500	81.27	156,500	81.27	156,600	81.19	156,600	81.19	156,500	81.27	156,600	81.19	156,500	81.27	156,600	81.19
50-yr	156,600	81.48	156,600	81.48	156,700	81.41	156,700	81.41	156,600	81.35	156,700	81.41	156,600	81.48	156,700	81.41
100-yr	162,200	81.69	162,100	81.69	162,700	81.62	162,700	81.62	162,100	81.69	162,700	81.62	162,100	81.69	162,800	81.62
200-yr	162,300	83.36	162,200	83.36	162,800	82.99	162,800	82.99	162,200	83.36	162,800	82.99	162,200	83.36	162,900	82.99
500-yr	285,300	89.50	285,200	89.50	285,700	89.54	285,600	89.53	285,300	89.50	285,700	89.53	285,300	89.50	285,700	89.53
1000-yr	378,300	90.00	378,200	90.00	378,700	90.00	378,500	90.00	378,400	90.00	378,700	90.00	378,400	90.00	378,600	90.00
Max	778,000	91.00	778,000	91.00	778,000	91.00	778,000	91.00	778,000	91.00	778,000	91.00	778,000	91.00	778,000	91.00

Table C-20. HEC-FDA Input - Stage vs. Discharge Relationships - Index Location RA02, Yuba River

Index Location: RA02, Yuba River
River Stationing: 7
Top of Levee: 90.58 feet

Event	Baseline Outflow	Baseline Stage	Bear Outflow	Bear Stage	Feather Outflow	Feather Stage	Bear-Feather Outflow	Bear-Feather Stage	SB Outflow	SB Stage	B-F-SB Outflow	B-F-SB Stage	Natomas Outflow	Natomas Stage	B-F-SB-N Outflow	B-F-SB-N Stage
1.01-yr	4,200		4,200		4,200		4,500		4,200		4,500		4,200		4,200	
2-yr	26,100	79.12	26,100	79.12	26,100	79.12	26,300	79.12	26,100	79.12	26,300	79.12	26,100	79.12	26,100	79.12
10-yr	77,600	81.77	77,600	81.77	77,600	81.77	77,600	81.77	77,600	81.77	77,600	81.77	77,600	81.77	77,600	81.77
25-yr	115,100	85.82	115,100	85.82	115,100	85.82	115,100	85.82	115,100	85.82	115,100	85.82	115,100	85.82	115,100	85.82
50-yr	140,800	89.15	140,800	89.15	140,800	89.15	140,800	89.15	140,800	89.15	140,800	89.15	140,800	89.15	140,800	89.15
100-yr	152,500	90.34	152,500	90.34	152,500	90.33	152,500	90.33	152,500	90.34	152,500	90.33	152,500	90.34	152,500	90.33
200-yr	185,100	92.41	185,100	92.41	185,100	92.41	185,100	92.41	185,100	92.41	185,100	92.41	185,100	92.41	185,100	92.41
500-yr	228,300	93.25	228,400	93.25	228,500	93.24	228,500	93.24	228,300	93.25	228,500	93.24	228,400	93.25	228,500	93.24
Max	396,300	93.26	396,300	93.26	396,300	93.25	396,300	93.25	396,300	93.26	396,300	93.25	396,300	93.26	396,300	93.25

Table C-21. HEC-FDA Input - Stage vs. Discharge Relationships - Index Location RA03, Feather River

Index Location: RA03, Feather River
River Stationing: 29
Top of Levee: 83.23 feet

Event	Baseline Outflow	Baseline Stage	Bear Outflow	Bear Stage	Feather Outflow	Feather Stage	Bear-Feather Outflow	Bear-Feather Stage	SB Outflow	SB Stage	B-F-SB Outflow	B-F-SB Stage	Natomas Outflow	Natomas Stage	B-F-SB-N Outflow	B-F-SB-N Stage
1.01-yr	33,700		33,700		33,900		33,700		33,700		33,700		33,700		33,800	
2-yr	55,000	57.78	55,000	57.78	55,100	57.85	55,000	57.85	55,000	57.79	55,000	57.85	55,000	57.78	55,100	57.85
10-yr	105,200	65.80	105,200	65.80	105,100	65.64	105,200	65.65	105,100	65.80	105,200	65.64	105,200	65.80	105,200	65.64
25-yr	121,100	73.44	121,100	73.44	121,400	73.05	121,400	73.05	121,000	73.44	121,400	73.05	121,000	73.44	121,400	73.05
50-yr	133,100	74.20	133,100	74.20	133,800	73.67	133,700	73.67	133,100	74.20	133,700	73.67	133,000	74.20	133,700	73.67
100-yr	140,100	76.12	140,100	76.12	141,200	75.50	141,200	75.50	140,100	76.12	141,200	75.50	140,100	76.12	141,200	75.50
200-yr	169,900	78.99	169,800	78.99	171,300	78.20	171,200	78.20	169,900	78.99	171,200	78.19	169,900	78.99	171,200	78.19
500-yr	242,700	83.39	242,700	83.39	256,400	83.28	256,400	83.28	242,700	83.39	256,400	83.28	242,700	83.39	256,400	83.28
1000-yr	297,800	86.72	297,800	86.72	314,000	86.72	314,100	86.72	297,800	86.72	314,000	86.72	297,800	86.72	314,000	86.72
Max	416,300	86.80	416,300	86.80	416,300	86.80	416,300	86.80	416,300	86.80	416,300	86.80	416,300	86.80	416,300	86.80

Table C-22. HEC-FDA Input - Stage vs. Discharge Relationships - Index Location RA04, Sutter Bypass

Index Location: RA04, Sutter Bypass
River Stationing: 88.6
Top of Levee: 59.15 feet

Event	Baseline Outflow	Baseline Stage	Bear Outflow	Bear Stage	Feather Outflow	Feather Stage	Bear-Feather Outflow	Bear-Feather Stage	SB Outflow	SB Stage	B-F-SB Outflow	B-F-SB Stage	Natomas Outflow	Natomas Stage	B-F-SB-N Outflow	B-F-SB-N Stage
1.01-yr	38,500		38,500		38,500		38,500		38,500		38,500		38,500		38,500	
2-yr	57,400	48.59	57,400	48.59	57,400	48.59	57,400	48.59	57,400	48.59	57,400	48.59	57,400	48.59	57,400	48.59
10-yr	102,000	52.55	102,000	52.55	102,000	52.55	102,000	52.55	102,000	52.55	102,000	52.55	102,000	52.55	102,000	52.55
25-yr	126,100	54.48	126,100	54.48	126,100	54.49	126,100	54.48	126,100	54.48	126,100	54.48	126,100	54.48	126,100	54.48
50-yr	154,900	56.45	154,900	56.45	154,900	56.45	154,900	56.45	154,900	56.45	154,900	56.45	154,900	56.45	154,900	56.45
100-yr	184,000	58.33	184,000	58.33	184,000	58.33	184,000	58.33	184,000	58.33	184,000	58.33	184,000	58.33	184,000	58.33
200-yr	216,400	60.00	216,400	60.00	216,300	60.00	216,400	59.99	216,400	60.00	216,400	59.99	216,300	59.99	216,400	59.99
500-yr	319,100	60.49	316,000	60.56	319,700	60.54	319,200	60.56	319,100	60.49	318,900	60.56	319,100	60.49	318,900	60.56
Max	588,500	61.15	588,500	61.15	588,500	61.15	588,500	61.15	588,500	61.15	588,500	61.15	588,500	61.15	588,500	61.15

Table C-23. HEC-FDA Input - Stage vs. Discharge Relationships - Index Location RA05, Sacramento River

Index Location: RA05, Sacramento River
River Stationing: 119.75
Top of Levee: 54.50 feet

Event	Baseline Outflow	Baseline Stage	Bear Outflow	Bear Stage	Feather Outflow	Feather Stage	Bear-Feather Outflow	Bear-Feather Stage	SB Outflow	SB Stage	B-F-SB Outflow	B-F-SB Stage	Natomas Outflow	Natomas Stage	B-F-SB-N Outflow	B-F-SB-N Stage
1.01-yr	47,400		47,400		47,400		47,400		47,400		47,400		47,400		47,400	
2-yr	47,500	47.91	47,500	47.91	47,500	47.91	47,500	47.91	47,500	47.91	47,500	47.91	47,500	47.91	47,500	47.91
10-yr	47,700	48.29	47,700	48.29	47,700	48.30	47,700	48.30	47,700	48.29	47,700	48.30	47,700	48.29	47,700	48.30
25-yr	49,300	49.49	49,300	49.48	49,300	49.49	49,300	49.49	49,300	49.49	49,300	49.49	49,300	49.49	49,300	49.49
50-yr	51,900	50.73	51,900	50.73	51,900	50.74	51,900	50.74	51,900	50.73	51,900	50.74	51,900	50.73	51,900	50.74
100-yr	54,600	52.01	54,600	52.01	54,600	52.01	54,700	52.02	54,600	52.01	54,700	52.02	54,600	52.01	54,700	52.03
200-yr	57,600	52.58	57,600	52.57	57,600	52.57	57,500	52.57	57,600	52.58	57,500	52.57	57,500	52.56	57,400	52.55
500-yr	67,700	53.28	67,700	53.27	67,700	53.26	67,700	53.27	67,700	53.28	67,700	53.27	67,700	53.28	67,700	53.28
1000-yr	75,300	53.80	75,300	53.80	75,300	53.78	75,300	53.89	75,300	53.81	75,300	53.80	75,400	53.82	75,300	53.83
Max	80,500	56.50	80,500	56.50	80,500	56.50	80,500	56.50	80,500	56.50	80,500	56.50	80,500	56.50	80,500	56.50

Table C-24. HEC-FDA Input - Stage vs. Discharge Relationships - Index Location RA06, Bear River

Index Location: RA06, Bear River
River Stationing: 1.75
Top of Levee: 56.33 feet

Event	Baseline Outflow	Baseline Stage	Bear Outflow	Bear Stage	Feather Outflow	Feather Stage	Bear-Feather Outflow	Bear-Feather Stage	SB Outflow	SB Stage	B-F-SB Outflow	B-F-SB Stage	Natomas Outflow	Natomas Stage	B-F-SB-N Outflow	B-F-SB-N Stage
1.01-yr	25,200		26,100		25,200		26,100		25,200		26,100		25,200		26,100	
2-yr	25,300	47.84	26,200	45.49	25,300	47.84	26,200	45.49	25,300	47.84	26,200	45.49	25,300	47.84	26,200	45.49
10-yr	25,400	49.16	26,300	48.18	25,400	49.15	26,300	48.16	25,400	49.16	26,300	48.16	25,400	49.16	26,300	48.16
25-yr	32,500	51.89	33,900	51.23	32,400	51.90	33,800	51.25	32,500	51.88	33,800	51.24	32,500	51.88	33,800	51.24
50-yr	37,300	53.16	39,500	52.58	37,300	53.20	39,600	52.63	37,300	53.16	39,600	52.63	37,300	53.16	39,600	52.63
100-yr	40,700	54.33	44,200	53.88	40,600	54.37	44,100	53.93	40,700	54.33	44,100	53.93	40,700	54.33	44,100	53.93
200-yr	40,800	55.57	44,300	55.42	40,700	55.61	44,200	55.48	40,800	55.56	44,200	55.48	40,800	55.57	44,200	55.49
500-yr	40,900	57.17	44,400	57.58	40,800	57.43	44,300	58.09	40,900	57.17	44,300	58.09	40,900	57.18	44,300	58.11
1000-yr	41,000	58.37	44,500	59.21	40,900	58.37	44,400	60.06	41,000	58.39	44,400	60.06	41,000	58.40	44,400	60.09
Max	42,400	58.50	45,900	60.50	42,400	58.50	45,900	60.50	42,400	58.50	45,900	60.50	42,400	58.50	45,900	60.50

Table C-25. HEC-FDA Input - Stage vs. Discharge Relationships - Index Location RA07, Feather River

Index Location: RA07, Feather River
River Stationing: 9
Top of Levee: 56.55 feet

Event	Baseline Outflow	Baseline Stage	Bear Outflow	Bear Stage	Feather Outflow	Feather Stage	Bear-Feather Outflow	Bear-Feather Stage	SB Outflow	SB Stage	B-F-SB Outflow	B-F-SB Stage	Natomas Outflow	Natomas Stage	B-F-SB-N Outflow	B-F-SB-N Stage
1.01-yr	69,100		69,700		68,300		69,400		69,100		69,500		69,100		69,600	
2-yr	103,100	40.63	103,800	40.67	102,800	40.62	103,500	40.65	103,100	40.63	103,500	40.65	103,100	40.63	103,600	40.66
10-yr	183,200	44.19	184,100	44.22	184,100	44.19	183,800	44.21	183,100	44.19	183,700	44.21	183,200	44.19	183,700	44.21
25-yr	255,400	46.97	256,800	46.99	256,000	46.99	257,300	47.01	255,400	46.97	257,200	47.01	255,400	46.97	257,200	47.01
50-yr	289,200	48.03	290,000	48.10	290,700	48.08	291,900	48.14	289,100	48.03	291,900	48.14	289,200	48.03	291,900	48.14
100-yr	318,500	49.24	321,100	49.34	320,400	49.29	322,900	49.39	318,500	49.24	322,900	49.39	318,500	49.25	322,800	49.39
200-yr	369,400	50.83	372,200	50.89	371,500	50.88	374,200	50.94	369,400	50.83	374,200	50.94	368,700	50.86	373,500	50.98
500-yr	449,400	52.34	456,000	52.49	462,900	52.72	474,700	52.96	449,300	52.34	474,600	52.96	448,800	52.38	473,900	53.01
1000-yr	509,900	53.48	519,400	53.70	532,000	54.11	550,700	54.59	509,700	53.48	550,500	54.49	509,400	53.53	549,800	54.55
Max	741,000	58.55	741,000	58.55	741,000	58.55	741,000	58.55	741,000	58.55	741,000	58.55	741,000	58.55	741,000	58.55

Table C-26. HEC-FDA Input - Stage vs. Discharge Relationships - Index Location RA08, Sacramento River

Index Location: RA08, Sacramento River
River Stationing: 90
Top of Levee: 40.65 feet

Event	Baseline Outflow	Baseline Stage	Bear Outflow	Bear Stage	Feather Outflow	Feather Stage	Bear-Feather Outflow	Bear-Feather Stage	SB Outflow	SB Stage	B-F-SB Outflow	B-F-SB Stage	Natomas Outflow	Natomas Stage	B-F-SB-N Outflow	B-F-SB-N Stage
1.01-yr	30,300		30,300		30,300		30,300		30,300		30,300		30,300		30,300	
2-yr	30,400	36.73	30,400	36.73	30,400	36.73	30,400	36.73	30,400	36.73	30,400	36.73	30,400	36.73	30,400	36.73
10-yr	30,500	37.68	30,500	37.68	30,500	37.71	30,500	37.69	30,500	37.68	30,500	37.69	30,500	37.68	30,500	37.71
25-yr	32,800	39.39	32,800	39.38	32,800	39.40	32,800	39.39	32,800	39.39	32,800	39.39	32,800	39.38	32,800	39.39
50-yr	35,900	40.22	35,700	40.23	35,800	40.24	35,700	40.25	35,900	40.23	35,700	40.26	35,900	40.22	35,700	40.26
100-yr	38,700	41.32	38,600	41.34	38,600	41.34	38,500	41.36	38,700	41.32	38,500	41.36	38,600	41.35	38,400	41.40
200-yr	38,800	41.84	38,700	41.85	38,700	41.85	38,600	41.85	38,800	41.84	38,600	41.85	38,700	41.90	38,500	41.92
500-yr	38,900	42.03	38,800	42.05	38,800	42.07	38,700	42.10	38,900	42.03	38,700	42.10	38,800	42.16	38,600	42.22
Max	39,100	42.04	39,000	42.06	39,000	42.08	38,900	42.11	39,100	42.04	38,900	42.11	39,000	42.17	38,800	42.23

Table C-27. HEC-FDA Input - Stage vs. Discharge Relationships - Index Location RA09, Sacramento River

Index Location: RA09, Sacramento River
River Stationing: 86.5
Top of Levee: 41.13 feet

Event	Baseline Outflow	Baseline Stage	Bear Outflow	Bear Stage	Feather Outflow	Feather Stage	Bear-Feather Outflow	Bear-Feather Stage	SB Outflow	SB Stage	B-F-SB Outflow	B-F-SB Stage	Natomas Outflow	Natomas Stage	B-F-SB-N Outflow	B-F-SB-N Stage
1.01-yr	26,400		26,400		26,500		26,400		26,400		26,400		26,400		26,400	
2-yr	27,500	34.62	27,500	34.63	27,600	34.62	27,500	34.63	27,500	34.62	27,500	34.63	27,500	34.61	27,500	34.63
10-yr	30,200	36.77	30,200	36.77	30,200	36.80	30,200	36.78	30,200	36.77	30,200	36.78	30,200	36.77	30,200	36.81
25-yr	32,500	38.54	32,500	38.53	32,500	38.55	32,500	38.55	32,500	38.54	32,500	38.55	32,500	38.54	32,500	38.55
50-yr	34,800	39.32	34,600	39.34	34,800	39.34	34,600	39.36	34,800	39.32	34,600	39.36	34,800	39.32	34,600	39.36
100-yr	38,200	40.38	38,000	40.41	38,100	40.40	37,900	40.43	38,200	40.38	37,900	40.43	38,100	40.42	37,800	40.48
200-yr	38,300	41.05	38,100	41.06	38,200	41.06	38,000	41.07	38,300	41.05	38,000	41.07	38,200	41.18	37,900	41.21
500-yr	38,400	41.38	38,200	41.41	38,300	41.46	38,100	41.51	38,400	41.38	38,100	41.51	38,300	41.66	38,000	41.81
Max	38,600	41.39	38,400	41.42	38,500	41.47	38,300	41.52	38,600	41.39	38,300	41.52	38,500	41.67	38,200	41.82

Table C-28. HEC-FDA Input - Stage vs. Discharge Relationships - Index Location RA10, Sacramento River

Index Location: RA10, Sacramento River
River Stationing: 79.21
Top of Levee: 41.79 feet

Event	Baseline Outflow	Baseline Stage	Bear Outflow	Bear Stage	Feather Outflow	Feather Stage	Bear-Feather Outflow	Bear-Feather Stage	SB Outflow	SB Stage	B-F-SB Outflow	B-F-SB Stage	Natomas Outflow	Natomas Stage	B-F-SB-N Outflow	B-F-SB-N Stage
1.01-yr	64,700		64,800		65,000		64,900		64,700		64,900		64,700		65,000	
2-yr	71,300	33.91	71,400	33.92	71,500	33.91	71,500	33.92	71,300	33.91	71,500	33.92	71,300	33.91	71,500	33.92
10-yr	86,900	36.17	87,000	36.18	86,900	36.23	87,000	36.18	86,900	36.17	87,000	36.18	86,900	36.17	86,900	36.23
25-yr	99,500	38.05	99,500	38.05	99,600	38.06	99,600	38.06	99,600	38.05	99,600	38.06	99,600	38.05	99,600	38.06
50-yr	103,600	38.86	103,700	38.89	103,700	38.88	103,900	38.91	103,600	38.86	103,900	38.92	103,700	38.86	103,900	38.92
100-yr	104,500	39.94	104,800	39.97	104,700	39.96	105,000	40.00	104,500	39.94	105,000	40.00	105,100	40.00	105,500	40.07
200-yr	110,800	40.63	110,800	40.64	110,800	40.64	110,800	40.65	110,800	40.63	110,800	40.65	113,400	40.96	113,700	41.01
500-yr	114,100	40.88	114,200	40.90	114,900	40.95	115,200	40.99	114,100	40.88	115,200	40.99	119,800	41.64	125,500	41.91
1000-yr	116,600	41.07	116,600	41.10	118,000	41.18	118,500	41.24	116,600	41.07	118,500	41.25	124,600	42.15	134,400	42.59
Max	126,600	43.79	126,600	43.79	126,600	43.79	126,600	43.79	126,600	43.79	126,600	43.79	143,800	47.90	143,800	47.90

Table C-29. HEC-FDA Input - Stage vs. Discharge Relationships - Index Location RA11, Sacramento River

Index Location: RA11, Sacramento River
River Stationing: 76.25
Top of Levee: 40.91 feet

Event	Baseline Outflow	Baseline Stage	Bear Outflow	Bear Stage	Feather Outflow	Feather Stage	Bear-Feather Outflow	Bear-Feather Stage	SB Outflow	SB Stage	B-F-SB Outflow	B-F-SB Stage	Natomas Outflow	Natomas Stage	B-F-SB-N Outflow	B-F-SB-N Stage
1.01-yr	64,900		65,000		65,200		65,300		64,900		65,300		64,900		65,300	
2-yr	71,000	32.75	71,100	32.77	71,200	32.74	71,300	32.76	71,000	32.75	71,300	32.76	71,000	32.75	71,300	32.76
10-yr	85,400	34.80	85,400	34.80	85,400	34.90	85,400	34.81	85,400	34.80	85,400	34.81	85,400	34.80	85,400	34.91
25-yr	99,500	36.52	99,500	36.52	99,600	36.54	99,600	36.53	99,600	36.52	99,600	36.53	99,600	36.52	99,600	36.53
50-yr	103,600	37.33	103,700	37.36	103,700	37.35	103,900	37.38	103,600	37.33	103,900	37.38	103,700	37.32	103,900	37.38
100-yr	104,400	38.54	104,700	38.58	104,600	38.56	104,900	38.60	104,500	38.54	104,900	38.60	105,100	38.60	105,400	38.67
200-yr	110,600	39.15	110,600	39.17	110,600	39.16	110,600	39.18	110,600	39.15	110,600	39.18	113,400	39.46	113,700	39.50
500-yr	114,000	39.34	114,200	39.36	114,800	39.40	115,200	39.43	114,000	39.34	115,200	39.43	119,200	40.12	124,400	40.36
1000-yr	116,600	39.48	116,600	39.50	118,000	39.58	118,700	39.62	116,600	39.48	118,700	39.62	123,600	40.62	132,500	41.01
Max	127,000	42.91	127,000	42.91	127,000	42.91	127,000	42.91	127,000	42.91	127,000	42.91	141,200	46.12	141,200	46.12

Table C-30. HEC-FDA Input - Stage vs. Discharge Relationships - Index Location RA12, Yolo Bypass

Index Location: RA12, Yolo Bypass
River Stationing: 48.84
Top of Levee: 34.45 feet

Event	Baseline Outflow	Baseline Stage	Bear Outflow	Bear Stage	Feather Outflow	Feather Stage	Bear-Feather Outflow	Bear-Feather Stage	SB Outflow	SB Stage	B-F-SB Outflow	B-F-SB Stage	Natomas Outflow	Natomas Stage	B-F-SB-N Outflow	B-F-SB-N Stage
1.01-yr	79,400		80,200		78,800		80,200		78,800		80,100		79,300		79,600	
2-yr	126,300	22.57	126,900	22.59	126,400	22.58	126,900	22.59	126,300	22.58	126,900	22.59	126,300	22.57	127,000	22.59
10-yr	237,000	25.98	237,000	25.99	238,600	25.97	237,000	25.99	237,000	25.98	237,200	25.99	237,000	25.98	238,700	25.97
25-yr	339,400	28.64	339,200	28.64	340,000	28.65	339,800	28.65	339,400	28.64	339,800	28.65	339,300	28.63	339,800	28.65
50-yr	382,300	29.56	383,600	29.59	383,600	29.59	384,900	29.61	382,400	29.57	384,900	29.62	382,200	29.55	384,900	29.62
100-yr	439,700	31.07	441,400	31.09	440,600	31.08	442,300	31.11	439,800	31.07	442,400	31.11	441,600	31.09	444,200	31.13
200-yr	448,700	31.35	449,500	31.36	449,400	31.35	450,100	31.36	448,700	31.35	450,200	31.37	450,600	31.37	452,200	31.39
500-yr	494,700	31.65	495,700	31.67	496,100	31.68	497,600	31.69	494,600	31.65	497,600	31.69	485,900	32.01	501,000	32.20
1000-yr	529,500	31.87	530,600	31.90	531,400	31.93	533,500	31.94	529,300	31.87	533,500	31.93	512,600	32.49	537,900	32.80
Max	654,300	36.45	654,300	36.45	654,300	36.45	654,300	36.45	654,300	36.45	654,300	36.45	654,300	36.45	654,300	36.45

Table C-31. HEC-FDA Input - Stage vs. Discharge Relationships - Index Location RA13, Sacramento River

Index Location: RA13, Sacramento River
River Stationing: 63.82
Top of Levee: 35.66 feet

Event	Baseline Outflow	Baseline Stage	Bear Outflow	Bear Stage	Feather Outflow	Feather Stage	Bear-Feather Outflow	Bear-Feather Stage	SB Outflow	SB Stage	B-F-SB Outflow	B-F-SB Stage	Natomas Outflow	Natomas Stage	B-F-SB-N Outflow	B-F-SB-N Stage
1.01-yr	62,800		62,800		62,900		62,900		62,800		62,900		62,800		62,900	
2-yr	64,300	27.55	64,300	27.55	64,300	27.53	64,300	27.53	64,300	27.55	64,300	27.53	64,300	27.55	64,300	27.53
10-yr	67,900	28.94	67,900	28.94	67,700	28.94	67,700	28.94	67,900	28.94	67,700	28.94	67,900	28.94	67,700	28.94
25-yr	69,900	28.95	69,900	28.95	69,700	28.95	69,700	28.95	69,900	28.95	69,700	28.95	69,900	28.95	69,700	28.95
50-yr	103,500	29.09	103,500	29.09	103,500	29.08	103,500	29.08	103,500	29.09	103,500	29.08	103,500	29.09	103,500	29.08
100-yr	104,400	31.38	104,700	31.40	104,600	31.39	104,800	31.41	104,400	31.38	104,800	31.41	105,000	31.40	105,400	31.43
200-yr	104,500	32.59	104,800	32.58	104,700	32.57	104,900	32.56	104,500	32.59	104,900	32.56	105,100	32.59	105,500	32.56
500-yr	104,600	33.39	104,900	33.42	104,800	33.41	105,000	33.41	104,600	33.42	105,000	33.41	105,200	33.56	105,600	33.55
1000-yr	104,700	34.00	105,000	34.06	104,900	34.05	105,100	34.04	104,700	34.05	105,100	34.04	105,300	34.28	105,700	34.29
Max	105,100	37.66	105,400	37.66	105,300	37.66	105,500	37.66	105,100	37.66	105,500	37.66	105,700	37.66	106,100	37.66

Table C-32. HEC-FDA Input - Stage vs. Discharge Relationships - Index Location RA14, American River

Index Location: RA14, American River
River Stationing: 11
Top of Levee: 58.38 feet

Event	Baseline Outflow	Baseline Stage	Bear Outflow	Bear Stage	Feather Outflow	Feather Stage	Bear-Feather Outflow	Bear-Feather Stage	SB Outflow	SB Stage	B-F-SB Outflow	B-F-SB Stage	Natomas Outflow	Natomas Stage	B-F-SB-N Outflow	B-F-SB-N Stage
1.01-yr	19,700		19,700		19,700		19,700		19,700		19,700		19,700		19,700	
2-yr	23,000	32.30	23,000	32.30	23,000	32.29	23,000	32.29	23,000	32.30	23,000	32.29	23,000	32.30	23,000	32.29
10-yr	30,700	34.10	30,700	34.10	30,700	34.10	30,700	34.10	30,700	34.10	30,700	34.10	30,700	34.10	30,700	34.10
25-yr	72,100	43.06	72,100	43.07	72,100	43.06	72,100	43.07	72,100	43.07	72,100	43.07	72,100	43.07	72,100	43.07
50-yr	72,200	43.10	72,200	43.10	72,200	43.10	72,200	43.10	72,300	43.10	72,200	43.10	72,200	43.10	72,200	43.10
100-yr	117,800	49.78	117,800	49.78	117,800	49.78	117,800	49.78	117,800	49.78	117,800	49.78	117,800	49.78	117,800	49.78
200-yr	290,000	61.51	290,000	61.51	290,000	61.51	290,000	61.51	290,000	61.51	290,000	61.51	290,000	61.51	290,000	61.51
500-yr	300,400	62.07	300,000	62.07	300,200	62.07	300,200	62.07	300,400	62.07	300,000	62.07	300,400	62.07	300,200	62.07
1000-yr	308,300	62.49	307,600	62.49	307,900	62.49	307,900	62.49	308,300	62.49	307,600	62.49	308,300	62.49	307,900	62.49
Max	333,000	62.50	333,000	62.50	333,000	62.50	333,000	62.50	333,000	62.50	333,000	62.50	333,000	62.50	333,000	62.50

Table C-33. HEC-FDA Input - Stage vs. Discharge Relationships - Index Location RA15, American River

Index Location: RA15, American River
River Stationing: 3.75
Top of Levee: 44.49 feet

Event	Baseline Outflow	Baseline Stage	Bear Outflow	Bear Stage	Feather Outflow	Feather Stage	Bear-Feather Outflow	Bear-Feather Stage	SB Outflow	SB Stage	B-F-SB Outflow	B-F-SB Stage	Natomas Outflow	Natomas Stage	B-F-SB-N Outflow	B-F-SB-N Stage
1.01-yr	20,400		20,300		20,300		20,300		20,300		20,300		20,400		20,300	
2-yr	22,600	26.71	22,500	26.71	22,500	26.69	22,500	26.69	22,500	26.71	22,500	26.69	22,600	26.71	22,500	26.69
10-yr	27,700	28.50	27,700	28.50	27,700	28.49	27,700	28.50	27,700	28.50	27,700	28.50	27,700	28.50	27,700	28.49
25-yr	71,100	30.43	71,600	30.53	71,100	30.42	71,600	30.52	71,600	30.53	71,600	30.52	71,600	30.47	71,600	30.52
50-yr	71,200	30.92	71,700	30.92	71,200	30.90	71,700	30.90	71,700	30.92	71,700	30.90	71,700	30.83	71,700	30.90
100-yr	115,000	35.03	115,000	35.04	115,000	35.04	115,000	35.05	115,000	35.03	115,000	35.05	115,000	35.05	115,000	35.07
200-yr	209,400	40.12	209,300	40.12	209,400	40.11	209,400	40.11	209,400	40.12	209,400	40.11	209,400	40.12	209,400	40.11
500-yr	209,500	40.28	209,400	40.34	209,500	40.34	209,500	40.34	209,500	40.34	209,500	40.34	209,500	40.40	209,500	40.39
1000-yr	209,600	40.40	209,500	40.50	209,600	40.51	209,600	40.52	209,600	40.51	209,600	40.51	209,600	40.61	209,600	40.60
Max	209,900	46.49	209,900	46.49	209,900	46.49	209,900	46.49	209,900	46.49	209,900	46.49	209,900	46.49	209,900	46.49

Table C-34. HEC-FDA Input - Stage vs. Discharge Relationships - Index Location RA16, Sacramento River

Index Location: RA16, Sacramento River
River Stationing: 59.75
Top of Levee: 36.25 feet

Event	Baseline Outflow	Baseline Stage	Bear Outflow	Bear Stage	Feather Outflow	Feather Stage	Bear-Feather Outflow	Bear-Feather Stage	SB Outflow	SB Stage	B-F-SB Outflow	B-F-SB Stage	Natomas Outflow	Natomas Stage	B-F-SB-N Outflow	B-F-SB-N Stage
1.01-yr	85,400		85,400		85,200		85,200		85,400		85,200		85,400		85,200	
2-yr	89,100	25.76	89,100	25.76	89,000	25.75	89,000	25.74	89,100	25.76	89,000	25.74	89,100	25.76	89,000	25.74
10-yr	97,900	27.48	97,900	27.48	97,900	27.48	97,900	27.48	97,900	27.48	97,900	27.48	97,900	27.48	97,900	27.48
25-yr	98,000	27.50	98,000	27.50	98,000	27.50	98,000	27.50	98,000	27.50	98,000	27.50	98,000	27.50	98,000	27.50
50-yr	101,100	28.33	101,200	28.35	101,200	28.34	101,300	28.36	101,100	28.33	101,300	28.36	100,600	28.24	101,300	28.36
100-yr	117,400	31.25	117,500	31.27	117,400	31.26	117,600	31.28	117,400	31.25	117,600	31.28	117,200	31.28	117,800	31.30
200-yr	130,500	32.77	130,500	32.77	130,400	32.76	130,400	32.75	130,500	32.77	130,400	32.75	130,500	32.77	130,300	32.75
500-yr	142,100	33.72	142,800	33.75	142,700	33.75	142,700	33.74	142,800	33.76	142,700	33.74	144,600	33.88	144,500	33.87
1000-yr	150,900	34.43	152,100	34.49	152,000	34.50	152,000	34.49	152,100	34.51	152,000	34.49	155,300	34.72	155,200	34.72
Max	221,100	38.25	221,100	38.25	221,100	38.25	221,100	38.25	221,100	38.25	221,100	38.25	221,100	38.25	221,100	38.25

Table C-35. HEC-FDA Input - Stage vs. Discharge Relationships - Index Location RA17, Sacramento River

Index Location: RA17, Sacramento River
River Stationing: 46.5
Top of Levee: 29.64 feet

Event	Baseline Outflow	Baseline Stage	Bear Outflow	Bear Stage	Feather Outflow	Feather Stage	Bear-Feather Outflow	Bear-Feather Stage	SB Outflow	SB Stage	B-F-SB Outflow	B-F-SB Stage	Natomas Outflow	Natomas Stage	B-F-SB-N Outflow	B-F-SB-N Stage
1.01-yr	85,000		85,000		84,900		84,900		85,000		84,900		85,000		84,900	
2-yr	88,800	19.67	88,800	19.67	88,700	19.66	88,700	19.65	88,800	19.67	88,700	19.65	88,800	19.67	88,700	19.65
10-yr	97,700	21.18	97,700	21.18	97,700	21.18	97,700	21.18	97,700	21.18	97,700	21.18	97,700	21.18	97,700	21.18
25-yr	97,800	21.36	97,800	21.35	97,800	21.36	97,800	21.34	97,800	21.34	97,800	21.34	97,800	21.30	97,800	21.34
50-yr	99,700	22.19	99,800	22.22	99,800	22.20	99,900	22.23	99,700	22.19	99,900	22.23	99,300	22.13	99,900	22.23
100-yr	117,200	24.83	117,300	24.84	117,300	24.84	117,300	24.85	117,200	24.83	117,300	24.85	117,000	24.85	117,500	24.88
200-yr	127,900	25.92	127,900	25.91	127,900	25.90	127,800	25.89	127,900	25.92	127,800	25.89	127,900	25.92	127,800	25.89
500-yr	134,400	26.76	134,700	26.80	134,700	26.78	134,700	26.78	134,700	26.80	134,700	26.78	135,400	26.95	135,400	26.93
1000-yr	139,300	27.39	139,800	27.47	139,800	27.45	139,900	27.46	139,800	27.45	139,900	27.44	141,100	27.72	141,100	27.71
Max	178,400	31.64	178,400	31.64	178,400	31.64	178,400	31.64	178,400	31.64	178,400	31.64	178,400	31.64	178,400	31.64

Table C-36. HEC-FDA Input - Stage vs. Discharge Relationships - Index Location RA18, Sacramento River

Index Location: RA18, Sacramento River
River Stationing: 36.5
Top of Levee: 23.09 feet

Event	Baseline Outflow	Baseline Stage	Bear Outflow	Bear Stage	Feather Outflow	Feather Stage	Bear-Feather Outflow	Bear-Feather Stage	SB Outflow	SB Stage	B-F-SB Outflow	B-F-SB Stage	Natomas Outflow	Natomas Stage	B-F-SB-N Outflow	B-F-SB-N Stage
1.01-yr	84,900		84,900		84,800		84,700		84,900		84,700		84,900		84,800	
2-yr	88,700	14.27	88,700	14.26	88,600	14.25	88,600	14.25	88,700	14.26	88,600	14.25	88,700	14.27	88,600	14.25
10-yr	97,600	15.46	97,600	15.46	97,600	15.45	97,700	15.45	97,600	15.46	97,700	15.45	97,600	15.46	97,600	15.45
25-yr	97,700	16.06	97,700	16.05	97,700	16.05	97,800	16.04	97,700	16.04	97,800	16.04	97,700	16.01	97,700	16.04
50-yr	99,600	16.89	99,800	16.91	99,700	16.90	99,800	16.92	99,600	16.89	99,800	16.91	99,200	16.84	99,800	16.91
100-yr	117,200	18.89	117,300	18.89	117,200	18.89	117,300	18.91	117,200	18.88	117,300	18.91	117,000	18.91	117,400	18.93
200-yr	124,600	19.54	124,600	19.53	124,400	19.53	124,400	19.52	124,500	19.53	124,400	19.52	124,600	19.54	124,400	19.52
500-yr	133,600	19.94	133,800	19.96	133,900	19.94	133,800	19.94	133,800	19.96	133,800	19.93	134,700	20.12	134,600	20.10
1000-yr	140,400	20.24	140,800	20.29	141,100	20.25	140,900	20.36	140,800	20.25	140,900	20.24	142,300	20.55	142,300	20.53
Max	194,600	25.09	194,600	25.09	194,600	25.09	194,600	25.09	194,600	25.09	194,600	25.09	194,600	25.09	194,600	25.09

Table C-37. HEC-FDA Input - Stage vs. Discharge Relationships - Index Location RA19, Sutter Slough

Index Location: RA19, Sutter Slough
River Stationing: 25.23
Top of Levee: 21.45 feet

Event	Baseline Outflow	Baseline Stage	Bear Outflow	Bear Stage	Feather Outflow	Feather Stage	Bear-Feather Outflow	Bear-Feather Stage	SB Outflow	SB Stage	B-F-SB Outflow	B-F-SB Stage	Natomas Outflow	Natomas Stage	B-F-SB-N Outflow	B-F-SB-N Stage
1.01-yr	25,000		25,000		25,000		25,000		25,000		25,000		25,000		25,000	
2-yr	25,100	9.59	25,100	9.59	25,100	9.59	25,100	9.59	25,100	9.59	25,100	9.59	25,100	9.59	25,100	9.59
10-yr	25,200	10.79	25,200	10.78	25,200	10.87	25,200	10.79	25,200	10.79	25,200	10.79	25,200	10.79	25,200	10.87
25-yr	25,300	12.99	25,300	12.98	25,300	13.00	25,300	12.99	25,300	12.99	25,300	12.99	25,300	12.98	25,300	12.99
50-yr	25,400	13.74	25,400	13.77	25,400	13.76	25,400	13.79	25,400	13.74	25,400	13.79	25,400	13.72	25,400	13.79
100-yr	29,700	14.64	29,700	14.63	29,700	14.66	29,700	14.65	29,700	14.64	29,700	14.65	29,600	14.65	29,700	14.66
200-yr	33,700	14.98	33,700	14.97	33,700	14.98	33,700	14.98	33,700	14.98	33,700	14.98	33,700	14.98	33,700	14.98
500-yr	33,800	14.99	33,800	14.98	33,800	14.99	33,800	14.99	33,800	14.99	33,800	14.99	33,800	14.99	33,800	14.99
1000-yr	33,900	15.00	33,900	14.99	33,900	15.00	33,900	15.00	33,900	15.00	33,900	15.00	33,900	15.00	33,900	15.00
Max	34,700	23.45	34,700	23.45	34,700	23.45	34,700	23.45	34,700	23.45	34,700	23.45	34,700	23.45	34,700	23.45

Table C-38. HEC-FDA Input - Stage vs. Discharge Relationships - Index Location RA20, Georgiana Slough

Index Location: RA20, Georgiana Slough
River Stationing: 12.36
Top of Levee: 19.31 feet

Event	Baseline Outflow	Baseline Stage	Bear Outflow	Bear Stage	Feather Outflow	Feather Stage	Bear-Feather Outflow	Bear-Feather Stage	SB Outflow	SB Stage	B-F-SB Outflow	B-F-SB Stage	Natomas Outflow	Natomas Stage	B-F-SB-N Outflow	B-F-SB-N Stage
1.01-yr	14,100		14,100		14,400		14,500		14,100		14,500		14,100		14,100	
2-yr	14,700	9.92	14,700	9.92	14,700	9.91	14,700	9.91	14,700	9.92	14,700	9.91	14,700	9.92	14,700	9.91
10-yr	16,100	10.89	16,100	10.89	16,100	10.89	16,100	10.89	16,100	10.89	16,100	10.88	16,100	10.89	16,100	10.89
25-yr	17,000	12.04	17,000	12.03	17,000	12.04	17,000	12.03	17,000	12.03	17,000	12.03	17,000	12.02	17,000	12.03
50-yr	17,900	12.64	17,900	12.64	17,900	12.65	17,900	12.64	17,900	12.64	17,900	12.65	17,800	12.62	17,900	12.65
100-yr	21,200	14.09	21,200	14.09	21,200	14.09	21,200	14.10	21,200	14.07	21,200	14.10	21,200	14.10	21,300	14.12
200-yr	22,000	14.15	22,100	14.16	22,200	14.15	22,200	14.16	22,000	14.15	22,200	14.16	22,000	14.44	22,200	14.42
500-yr	22,100	14.23	22,200	14.25	22,300	14.23	22,300	14.23	22,100	14.25	22,300	14.23	22,100	14.88	22,300	14.91
1000-yr	22,200	14.29	22,300	14.32	22,400	14.29	22,400	14.29	22,200	14.33	22,400	14.29	22,200	15.22	22,400	15.28
Max	23,000	21.31	23,000	21.31	23,000	21.31	23,000	21.31	23,000	21.31	23,000	21.31	23,000	21.31	23,000	21.31

Table C-39. HEC-FDA Input - Stage vs. Discharge Relationships - Index Location RA21, Miner Slough

Index Location: RA21, Miner Slough
River Stationing: 19.11
Top of Levee: 18.20 feet

Event	Baseline Outflow	Baseline Stage	Bear Outflow	Bear Stage	Feather Outflow	Feather Stage	Bear-Feather Outflow	Bear-Feather Stage	SB Outflow	SB Stage	B-F-SB Outflow	B-F-SB Stage	Natomas Outflow	Natomas Stage	B-F-SB-N Outflow	B-F-SB-N Stage
1.01-yr	2,600		2,600		2,600		2,600		2,600		2,600		2,600		2,600	
2-yr	2,700	5.48	2,700	5.48	2,700	5.49	2,700	5.49	2,700	5.48	2,700	5.50	2,700	5.48	2,700	5.50
10-yr	2,800	9.62	2,800	9.61	2,800	9.59	2,800	9.62	2,800	9.62	2,800	9.63	2,800	9.62	2,800	9.59
25-yr	2,900	12.39	2,900	12.39	2,900	12.39	2,900	12.39	2,900	12.39	2,900	12.39	2,900	12.39	2,900	12.39
50-yr	3,400	13.23	3,300	13.23	3,400	13.24	3,600	13.25	3,400	13.23	3,600	13.25	3,500	13.21	3,600	13.25
100-yr	6,200	13.70	6,200	13.68	6,200	13.72	6,100	13.71	6,100	13.70	6,200	13.71	6,100	13.70	6,200	13.71
200-yr	6,300	13.72	6,300	13.71	6,300	14.17	6,200	13.75	6,200	13.72	6,300	13.75	6,200	14.02	6,300	14.05
500-yr	6,400	13.75	6,400	13.75	6,400	14.76	6,300	13.80	6,300	13.75	6,400	13.81	6,300	14.44	6,400	14.50
1000-yr	6,500	13.89	6,500	13.89	6,500	15.65	6,400	13.84	6,400	13.89	6,500	13.98	6,400	15.10	6,500	15.20
Max	7,300	20.20	7,300	20.20	7,300	20.20	7,300	20.20	7,300	20.20	7,300	20.20	7,300	20.20	7,300	20.20

Table C-40. HEC-FDA Input - Stage vs. Discharge Relationships - Index Location RA22, Sacramento River

Index Location: RA22, Sacramento River
River Stationing: 14.75
Top of Levee: 22.04 feet

Event	Baseline Outflow	Baseline Stage	Bear Outflow	Bear Stage	Feather Outflow	Feather Stage	Bear-Feather Outflow	Bear-Feather Stage	SB Outflow	SB Stage	B-F-SB Outflow	B-F-SB Stage	Natomas Outflow	Natomas Stage	B-F-SB-N Outflow	B-F-SB-N Stage
1.01-yr	17,400		17,500		17,100		17,500		17,400		17,500		17,400		17,400	
2-yr	20,000	4.80	20,100	4.80	20,000	4.80	20,100	4.80	20,000	4.80	20,100	4.80	20,000	4.80	20,000	4.80
10-yr	26,200	6.32	26,200	6.32	26,200	6.32	26,200	6.32	26,200	6.32	26,200	6.32	26,200	6.32	26,200	6.32
25-yr	27,800	7.99	27,700	7.98	27,800	7.99	27,700	7.99	27,700	7.99	27,800	7.99	27,700	7.98	27,800	7.99
50-yr	27,900	8.77	27,800	8.77	27,900	8.78	27,800	8.78	27,800	8.77	27,900	8.78	27,900	8.73	27,900	8.78
100-yr	33,300	9.53	33,300	9.51	33,300	9.53	33,200	9.53	33,200	9.50	33,200	9.53	33,200	9.53	33,300	9.54
200-yr	33,400	9.75	33,400	9.75	33,400	9.75	33,300	9.76	33,300	9.75	33,300	9.76	33,300	9.82	33,400	9.84
500-yr	33,500	10.25	33,500	10.00	33,500	9.95	33,400	9.95	33,400	10.25	33,400	9.95	33,400	10.78	33,500	10.73
1000-yr	33,600	10.62	33,600	10.19	33,600	10.10	33,500	10.11	33,500	10.62	33,500	10.09	33,500	11.50	33,600	11.39
Max	34,400	24.04	34,400	24.04	34,400	24.04	34,400	24.04	34,400	24.04	34,400	24.04	34,400	24.04	34,400	24.04

Table C-41. HEC-FDA Input – Stage Uncertainty

Index Location	2-yr (0.5)	10-yr (0.1)	25-yr (0.04)	50-yr (0.02_	100-yr (0.01)	200-yr (0.005)	500-yr (0.002)
RA01	0.7	0.7	0.7	0.7	0.8	0.8	0.8
RA02	0.7	0.7	0.7	0.7	0.8	0.8	0.8
RA03	0.8	0.8	0.8	0.8	0.8	1.0	1.0
RA04	0.7	0.8	0.9	1.1	1.1	1.1	1.1
RA05	0.9	0.9	1.0	1.1	1.1	1.2	1.2
RA06	0.7	0.7	0.7	0.7	0.8	0.8	0.8
RA07	0.7	0.7	0.7	0.8	0.9	0.9	0.9
RA08	0.7	0.7	0.7	0.7	0.8	0.8	0.8
RA09	0.7	0.7	0.7	0.7	0.8	0.8	0.8
RA10	0.7	0.7	0.7	0.7	0.8	0.8	0.8
RA11	0.7	0.7	0.7	0.7	0.8	0.8	0.8
RA12	0.7	0.8	0.9	0.9	0.9	0.9	0.9
RA13	0.7	0.7	0.7	0.7	0.8	0.8	0.8
RA14	0.8	0.8	1.1	1.1	1.2	1.2	1.2
RA15	0.7	0.7	0.7	0.7	0.8	0.8	0.8
RA16	0.7	0.7	0.7	0.7	0.8	0.8	0.8
RA17	0.7	0.7	0.7	0.7	0.8	0.8	0.8
RA18	0.7	0.7	0.7	0.7	0.8	0.8	0.8
RA19	0.7	0.7	0.7	0.7	0.8	0.8	0.8
RA20	0.7	0.7	0.7	0.7	0.8	0.8	0.8
RA21	0.7	0.7	0.7	0.7	0.8	0.8	0.8
RA22	0.7	0.7	0.7	0.7	0.8	1.1	1.1

Table C-42. HEC-FDA Input – Stage versus Damage Relationships - Index Location RA01

Stage (feet)	Discharge (CFS)	Sensitivity Damage (dollars)
70.0	0	0
72.0	100,000	1,000
74.0	200,000	2,000
76.0	300,000	3,000
78.0	400,000	4,000
80.0	500,000	5,000
82.0	600,000	6,000
84.0	700,000	7,000
86.0	800,000	8,000
88.0	900,000	9,000
90.0	1,000,000	10,000
92.0	1,100,000	11,000
94.0	1,200,000	12,000
96.0	1,300,000	13,000
98.0	1,400,000	14,000
100.0	1,500,000	15,000
102.0	1,600,000	16,000
104.0	1,700,000	17,000
106.0	1,800,000	18,000
108.0	1,900,000	19,000
110.0	2,000,000	20,000
112.0	2,100,000	21,000
114.0	2,200,000	22,000
116.0	2,300,000	23,000

Table C-43. HEC-FDA Input – Stage versus Damage Relationships - Index Location RA02

Stage (feet)	Discharge (CFS)	Sensitivity Damage (dollars)
78.0	0	0
79.0	100,000	1,000
80.0	200,000	2,000
81.0	300,000	3,000
82.0	400,000	4,000
83.0	500,000	5,000
84.0	600,000	6,000
85.0	700,000	7,000
86.0	800,000	8,000
87.0	900,000	9,000
88.0	1,000,000	10,000
89.0	1,100,000	11,000
90.0	1,200,000	12,000
91.0	1,300,000	13,000
92.0	1,400,000	14,000
93.0	1,500,000	15,000
94.0	1,600,000	16,000
95.0	1,700,000	17,000
96.0	1,800,000	18,000
97.0	1,900,000	19,000

Table C-44. HEC-FDA Input – Stage versus Damage Relationships - Index Location RA03

Stage (feet)	Discharge (CFS)	Sensitivity Damage (dollars)
54.0	0	0
56.0	100,000	1,000
58.0	200,000	2,000
60.0	300,000	3,000
62.0	400,000	4,000
64.0	500,000	5,000
66.0	600,000	6,000
68.0	700,000	7,000
70.0	800,000	8,000
72.0	900,000	9,000
74.0	1,000,000	10,000
76.0	1,100,000	11,000
78.0	1,200,000	12,000
80.0	1,300,000	13,000
82.0	1,400,000	14,000
84.0	1,500,000	15,000
86.0	1,600,000	16,000
88.0	1,700,000	17,000
90.0	1,800,000	18,000
92.0	1,900,000	19,000
94.0	2,000,000	20,000
96.0	2,100,000	21,000
98.0	2,200,000	22,000
100.0	2,300,000	23,000
102.0	2,400,000	24,000
104.0	2,500,000	25,000

Table C-45. HEC-FDA Input – Stage versus Damage Relationships - Index Location RA04

Stage (feet)	Discharge (CFS)	Sensitivity Damage (dollars)
42.0	0	0
43.0	100,000	1,000
44.0	200,000	2,000
45.0	300,000	3,000
46.0	400,000	4,000
47.0	500,000	5,000
48.0	600,000	6,000
49.0	700,000	7,000
50.0	800,000	8,000
51.0	900,000	9,000
52.0	1,000,000	10,000
53.0	1,100,000	11,000
54.0	1,200,000	12,000
55.0	1,300,000	13,000
56.0	1,400,000	14,000
57.0	1,500,000	15,000
58.0	1,600,000	16,000
59.0	1,700,000	17,000
60.0	1,800,000	18,000
61.0	1,900,000	19,000
62.0	2,000,000	20,000
63.0	2,100,000	21,000
64.0	2,200,000	22,000
65.0	2,300,000	23,000

Table C-46. HEC-FDA Input – Stage versus Damage Relationships - Index Location RA05

Stage (feet)	Discharge (CFS)	Sensitivity Damage (dollars)
40.0	0	0
42.0	100,000	1,000
44.0	200,000	2,000
46.0	300,000	3,000
48.0	400,000	4,000
50.0	500,000	5,000
52.0	600,000	6,000
54.0	700,000	7,000
56.0	800,000	8,000
58.0	900,000	9,000
60.0	1,000,000	10,000
62.0	1,100,000	11,000
64.0	1,200,000	12,000
66.0	1,300,000	13,000
68.0	1,400,000	14,000
70.0	1,500,000	15,000
72.0	1,600,000	16,000
74.0	1,700,000	17,000
76.0	1,800,000	18,000
78.0	1,900,000	19,000

Table C-47. HEC-FDA Input – Stage versus Damage Relationships - Index Location RA06

Stage (feet)	Discharge (CFS)	Sensitivity Damage (dollars)
46.0	0	0
48.0	100,000	1,000
50.0	200,000	2,000
52.0	300,000	3,000
54.0	400,000	4,000
56.0	500,000	5,000
58.0	600,000	6,000
60.0	700,000	7,000
62.0	800,000	8,000
64.0	900,000	9,000
66.0	1,000,000	10,000
68.0	1,100,000	11,000
70.0	1,200,000	12,000
72.0	1,300,000	13,000
74.0	1,400,000	14,000
76.0	1,500,000	15,000
78.0	1,600,000	16,000
80.0	1,700,000	17,000
82.0	1,800,000	18,000
84.0	1,900,000	19,000

Table C-48. HEC-FDA Input – Stage versus Damage Relationships - Index Location RA07

Stage (feet)	Discharge (CFS)	Sensitivity Damage (dollars)
26.0	0	0
28.0	100,000	1,000
30.0	200,000	2,000
32.0	300,000	3,000
34.0	400,000	4,000
36.0	500,000	5,000
38.0	600,000	6,000
40.0	700,000	7,000
42.0	800,000	8,000
44.0	900,000	9,000
46.0	1,000,000	10,000
48.0	1,100,000	11,000
50.0	1,200,000	12,000
52.0	1,300,000	13,000
54.0	1,400,000	14,000
56.0	1,500,000	15,000
58.0	1,600,000	16,000
60.0	1,700,000	17,000
62.0	1,800,000	18,000
64.0	1,900,000	19,000

Table C-49. HEC-FDA Input – Stage versus Damage Relationships - Index Location RA08

Stage (feet)	Discharge (CFS)	Sensitivity Damage (dollars)
30.0	0	0
31.0	100,000	1,000
32.0	200,000	2,000
33.0	300,000	3,000
34.0	400,000	4,000
35.0	500,000	5,000
36.0	600,000	6,000
37.0	700,000	7,000
38.0	800,000	8,000
39.0	900,000	9,000
40.0	1,000,000	10,000
41.0	1,100,000	11,000
42.0	1,200,000	12,000
43.0	1,300,000	13,000
44.0	1,400,000	14,000
45.0	1,500,000	15,000
46.0	1,600,000	16,000
47.0	1,700,000	17,000
48.0	1,800,000	18,000
49.0	1,900,000	19,000
50.0	2,000,000	20,000

Table C-50. HEC-FDA Input – Stage versus Damage Relationships - Index Location RA09

Stage (feet)	Discharge (CFS)	Sensitivity Damage (dollars)
30.0	0	0
31.0	100,000	1,000
32.0	200,000	2,000
33.0	300,000	3,000
34.0	400,000	4,000
35.0	500,000	5,000
36.0	600,000	6,000
37.0	700,000	7,000
38.0	800,000	8,000
39.0	900,000	9,000
40.0	1,000,000	10,000
41.0	1,100,000	11,000
42.0	1,200,000	12,000
43.0	1,300,000	13,000
44.0	1,400,000	14,000
45.0	1,500,000	15,000
46.0	1,600,000	16,000
47.0	1,700,000	17,000
48.0	1,800,000	18,000
49.0	1,900,000	19,000
50.0	2,000,000	20,000

Table C-51. HEC-FDA Input – Stage versus Damage Relationships - Index Location RA10

Stage (feet)	Discharge (CFS)	Sensitivity Damage (dollars)
30.0	0	0
31.0	100,000	1,000
32.0	200,000	2,000
33.0	300,000	3,000
34.0	400,000	4,000
35.0	500,000	5,000
36.0	600,000	6,000
37.0	700,000	7,000
38.0	800,000	8,000
39.0	900,000	9,000
40.0	1,000,000	10,000
41.0	1,100,000	11,000
42.0	1,200,000	12,000
43.0	1,300,000	13,000
44.0	1,400,000	14,000
45.0	1,500,000	15,000
46.0	1,600,000	16,000
47.0	1,700,000	17,000
48.0	1,800,000	18,000
49.0	1,900,000	19,000
50.0	2,000,000	20,000

Table C-52. HEC-FDA Input – Stage versus Damage Relationships - Index Location RA11

Stage (feet)	Discharge (CFS)	Sensitivity Damage (dollars)
30.0	0	0
31.0	100,000	1,000
32.0	200,000	2,000
33.0	300,000	3,000
34.0	400,000	4,000
35.0	500,000	5,000
36.0	600,000	6,000
37.0	700,000	7,000
38.0	800,000	8,000
39.0	900,000	9,000
40.0	1,000,000	10,000
41.0	1,100,000	11,000
42.0	1,200,000	12,000
43.0	1,300,000	13,000
44.0	1,400,000	14,000
45.0	1,500,000	15,000
46.0	1,600,000	16,000
47.0	1,700,000	17,000
48.0	1,800,000	18,000
49.0	1,900,000	19,000
50.0	2,000,000	20,000

Table C-53. HEC-FDA Input – Stage versus Damage Relationships - Index Location RA12

Stage (feet)	Discharge (CFS)	Sensitivity Damage (dollars)
20.0	0	0
21.0	100,000	1,000
22.0	200,000	2,000
23.0	300,000	3,000
24.0	400,000	4,000
25.0	500,000	5,000
26.0	600,000	6,000
27.0	700,000	7,000
28.0	800,000	8,000
29.0	900,000	9,000
30.0	1,000,000	10,000
31.0	1,100,000	11,000
32.0	1,200,000	12,000
33.0	1,300,000	13,000
34.0	1,400,000	14,000
35.0	1,500,000	15,000
36.0	1,600,000	16,000
37.0	1,700,000	17,000
38.0	1,800,000	18,000
39.0	1,900,000	19,000

Table C-54. HEC-FDA Input – Stage versus Damage Relationships - Index Location RA13

Stage (feet)	Discharge (CFS)	Sensitivity Damage (dollars)
25.0	0	0
26.0	100,000	1,000
27.0	200,000	2,000
28.0	300,000	3,000
29.0	400,000	4,000
30.0	500,000	5,000
31.0	600,000	6,000
32.0	700,000	7,000
33.0	800,000	8,000
34.0	900,000	9,000
35.0	1,000,000	10,000
36.0	1,100,000	11,000
37.0	1,200,000	12,000
38.0	1,300,000	13,000
39.0	1,400,000	14,000
40.0	1,500,000	15,000
41.0	1,600,000	16,000
42.0	1,700,000	17,000
43.0	1,800,000	18,000
44.0	1,900,000	19,000
45.0	2,000,000	20,000

Table C-55. HEC-FDA Input – Stage versus Damage Relationships - Index Location RA14

Stage (feet)	**Discharge (CFS)**	**Sensitivity Damage (dollars)**
26.0	0	0
28.0	100,000	1,000
30.0	200,000	2,000
32.0	300,000	3,000
34.0	400,000	4,000
36.0	500,000	5,000
38.0	600,000	6,000
40.0	700,000	7,000
42.0	800,000	8,000
44.0	900,000	9,000
46.0	1,000,000	10,000
48.0	1,100,000	11,000
50.0	1,200,000	12,000
52.0	1,300,000	13,000
54.0	1,400,000	14,000
56.0	1,500,000	15,000
58.0	1,600,000	16,000
60.0	1,700,000	17,000
62.0	1,800,000	18,000
64.0	1,900,000	19,000
66.0	2,000,000	20,000
68.0	2,100,000	21,000

Table C-56. HEC-FDA Input – Stage versus Damage Relationships - Index Location RA15

Stage (feet)	Discharge (CFS)	Sensitivity Damage (dollars)
22.0	0	0
23.0	100,000	1,000
24.0	200,000	2,000
25.0	300,000	3,000
26.0	400,000	4,000
27.0	500,000	5,000
28.0	600,000	6,000
29.0	700,000	7,000
30.0	800,000	8,000
31.0	900,000	9,000
32.0	1,000,000	10,000
33.0	1,100,000	11,000
34.0	1,200,000	12,000
35.0	1,300,000	13,000
36.0	1,400,000	14,000
37.0	1,500,000	15,000
38.0	1,600,000	16,000
39.0	1,700,000	17,000
40.0	1,800,000	18,000
41.0	1,900,000	19,000
42.0	2,000,000	20,000
43.0	2,100,000	21,000
44.0	2,200,000	22,000
45.0	2,300,000	23,000
46.0	2,400,000	24,000
47.0	2,500,000	25,000
48.0	2,600,000	26,000
49.0	2,700,000	27,000
50.0	2,800,000	28,000
51.0	2,900,000	29,000

Table C-57. HEC-FDA Input – Stage versus Damage Relationships - Index Location RA16

Stage (feet)	Discharge (CFS)	Sensitivity Damage (dollars)
25.0	0	0
26.0	100,000	1,000
27.0	200,000	2,000
28.0	300,000	3,000
29.0	400,000	4,000
30.0	500,000	5,000
31.0	600,000	6,000
32.0	700,000	7,000
33.0	800,000	8,000
34.0	900,000	9,000
35.0	1,000,000	10,000
36.0	1,100,000	11,000
37.0	1,200,000	12,000
38.0	1,300,000	13,000
39.0	1,400,000	14,000
40.0	1,500,000	15,000
41.0	1,600,000	16,000
42.0	1,700,000	17,000
43.0	1,800,000	18,000
44.0	1,900,000	19,000
45.0	2,000,000	20,000

Table C-58. HEC-FDA Input – Stage versus Damage Relationships - Index Location RA17

Stage (feet)	Discharge (CFS)	Sensitivity Damage (dollars)
20.0	0	0
21.0	100,000	1,000
22.0	200,000	2,000
23.0	300,000	3,000
24.0	400,000	4,000
25.0	500,000	5,000
26.0	600,000	6,000
27.0	700,000	7,000
28.0	800,000	8,000
29.0	900,000	9,000
30.0	1,000,000	10,000
31.0	1,100,000	11,000
32.0	1,200,000	12,000
33.0	1,300,000	13,000
34.0	1,400,000	14,000
35.0	1,500,000	15,000
36.0	1,600,000	16,000
37.0	1,700,000	17,000
38.0	1,800,000	18,000
39.0	1,900,000	19,000

Table C-59. HEC-FDA Input – Stage versus Damage Relationships - Index Location RA18

Stage (feet)	Discharge (CFS)	Sensitivity Damage (dollars)
15.0	0	0
16.0	100,000	1,000
17.0	200,000	2,000
18.0	300,000	3,000
19.0	400,000	4,000
20.0	500,000	5,000
21.0	600,000	6,000
22.0	700,000	7,000
23.0	800,000	8,000
24.0	900,000	9,000
25.0	1,000,000	10,000
26.0	1,100,000	11,000
27.0	1,200,000	12,000
28.0	1,300,000	13,000
29.0	1,400,000	14,000
30.0	1,500,000	15,000
31.0	1,600,000	16,000
32.0	1,700,000	17,000
33.0	1,800,000	18,000
34.0	1,900,000	19,000

Table C-60. HEC-FDA Input – Stage versus Damage Relationships - Index Location RA19

Stage (feet)	Discharge (CFS)	Sensitivity Damage (dollars)
10.0	0	0
11.0	100,000	1,000
12.0	200,000	2,000
13.0	300,000	3,000
14.0	400,000	4,000
15.0	500,000	5,000
16.0	600,000	6,000
17.0	700,000	7,000
18.0	800,000	8,000
19.0	900,000	9,000
20.0	1,000,000	10,000
21.0	1,100,000	11,000
22.0	1,200,000	12,000
23.0	1,300,000	13,000
24.0	1,400,000	14,000
25.0	1,500,000	15,000
26.0	1,600,000	16,000
27.0	1,700,000	17,000
28.0	1,800,000	18,000
29.0	1,900,000	19,000
30.0	2,000,000	20,000

Table C-61. HEC-FDA Input – Stage versus Damage Relationships - Index Location RA20

Stage (feet)	Discharge (CFS)	Sensitivity Damage (dollars)
10.0	0	0
10.5	100,000	1,000
11.0	200,000	2,000
11.5	300,000	3,000
12.0	400,000	4,000
12.5	500,000	5,000
13.0	600,000	6,000
13.5	700,000	7,000
14.0	800,000	8,000
14.5	900,000	9,000
15.0	1,000,000	10,000
15.5	1,100,000	11,000
16.0	1,200,000	12,000
16.5	1,300,000	13,000
17.0	1,400,000	14,000
17.5	1,500,000	15,000
18.0	1,600,000	16,000
18.5	1,700,000	17,000
19.0	1,800,000	18,000
19.5	1,900,000	19,000
20.0	2,000,000	20,000
20.5	2,100,000	21,000
21.0	2,200,000	22,000
21.5	2,300,000	23,000
22.0	2,400,000	24,000

Table C-62. HEC-FDA Input – Stage versus Damage Relationships - Index Location RA21

Stage (feet)	Discharge (CFS)	Sensitivity Damage (dollars)
10.0	0	0
10.5	100,000	1,000
11.0	200,000	2,000
11.5	300,000	3,000
12.0	400,000	4,000
12.5	500,000	5,000
13.0	600,000	6,000
13.5	700,000	7,000
14.0	800,000	8,000
14.5	900,000	9,000
15.0	1,000,000	10,000
15.5	1,100,000	11,000
16.0	1,200,000	12,000
16.5	1,300,000	13,000
17.0	1,400,000	14,000
17.5	1,500,000	15,000
18.0	1,600,000	16,000
18.5	1,700,000	17,000
19.0	1,800,000	18,000
19.5	1,900,000	19,000
20.0	2,000,000	20,000
20.5	2,100,000	21,000
21.0	2,200,000	22,000
21.5	2,300,000	23,000

Table C-63. HEC-FDA Input – Stage versus Damage Relationships - Index Location RA22

Stage (feet)	Discharge (CFS)	Sensitivity Damage (dollars)
5.0	0	0
6.0	100,000	1,000
7.0	200,000	2,000
8.0	300,000	3,000
9.0	400,000	4,000
10.0	500,000	5,000
11.0	600,000	6,000
12.0	700,000	7,000
13.0	800,000	8,000
14.0	900,000	9,000
15.0	1,000,000	10,000
16.0	1,100,000	11,000
17.0	1,200,000	12,000
18.0	1,300,000	13,000
19.0	1,400,000	14,000
20.0	1,500,000	15,000
21.0	1,600,000	16,000
22.0	1,700,000	17,000
23.0	1,800,000	18,000
24.0	1,900,000	19,000
25.0	2,000,000	20,000
26.0	2,100,000	21,000

Appendix D

Sensitivity Analysis of HEC-FDA Input Data

Appendix D

Sensitivity Analysis of HEC-FDA Input Data

A sensitivity analysis of some of the HEC-FDA input relationships was completed to obtain a better understanding of how the relationships and associated assumptions considered in developing each relationship influence the risk analysis results. The analysis was completed by iteratively revising the relationships in the HEC-FDA model. The HEC-FDA results for select index locations were then compared with the HEC-FDA results for the adopted relationship and conclusions from the comparison were noted. It is recognized that some of the relationship revisions were applicable only to some of the index locations. Information related to this analysis is documented in the remainder of this Appendix.

D.1 Stage versus Damage Relationship

Utilization of HEC-FDA requires that economic data be defined in terms of a stage-damage relationship, even if the user is only interested in evaluating the project performance. To accommodate this input requirement, an artificial set of data was defined and utilized for this study. The stage-damage relationship was developed at each index location by assuming the relationship increases linearly at a slope of $100,000 of damage for a stage increase of either one or two feet over the entire range of the levee structure. This relationship was adjusted to increase linearly at a slope of $1,000 of damage for a stage increase of either one or two feet. Both relationships developed for Index Location RA02 are shown in Figure D-1.

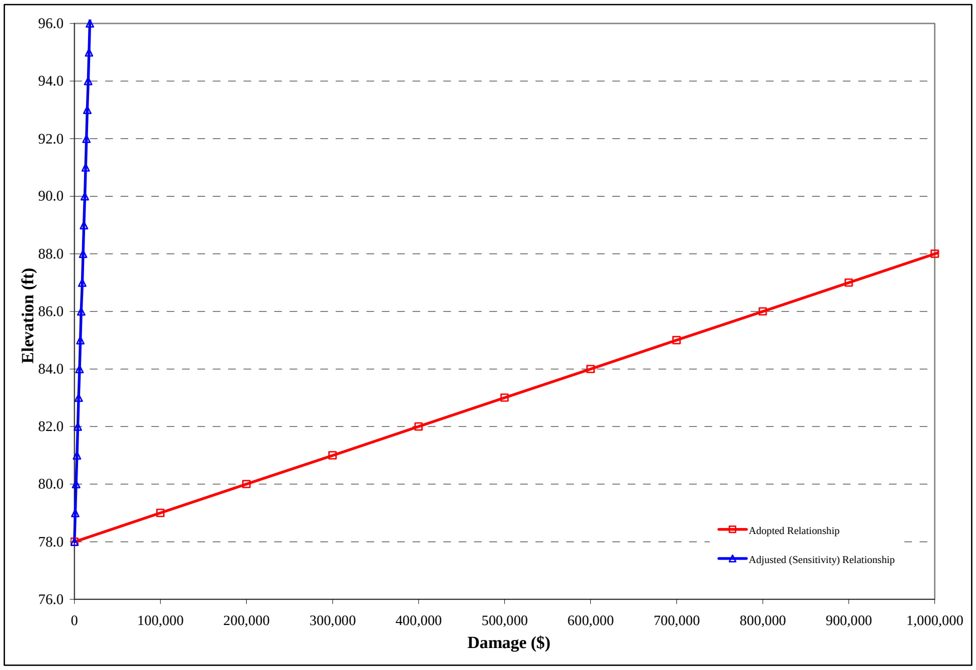


Figure D-1. Adopted and Adjusted Stage versus Damage Relationships for Index Location RA02

A copy of the HEC-FDA results for the adopted stage-damage relationship is provided in Figure D-2, and a copy of the HEC-FDA (HEC, 2008) results for the adjusted stage-damage relationship is provided in Figure D-3. As shown in the figures, the results for the adjusted stage-damage relationship are the same as those for the adopted stage-damage relationship.

					Target Stage Annual Exceedance Probability		Long-Term Risk (years)			Conditional Non-Exceedance Probability by Events					
Stream Name	Stream Description	Damage Reach Name	Damage Reach Description	Target Stage	Median	Expected	10	30	50	10%	4%	2%	1%	.4%	.2%
American River	ONE Reach - T	RA15	Index RA15	levee	0.0003	0.0021	0.0204	0.0502	0.0980	1.0000	1.0000	1.0000	1.0000	0.5968	0.5172
		RA14	Index RA14	levee	0.0056	0.0054	0.0526	0.1263	0.2367	1.0000	1.0000	1.0000	1.0000	0.1154	0.0273
Bear River	ONE Reach - C	RA06	Index RA06	levee	0.0032	0.0076	0.0730	0.1726	0.3154	1.0000	0.9750	0.8255	0.7232	0.6494	0.6110
Feather River	THREE reache	RA07	Index RA07	levee	0.0003	0.0002	0.0017	0.0043	0.0086	1.0000	1.0000	1.0000	1.0000	0.9998	0.9811
		RA03	Index RA03	levee	0.0026	0.0027	0.0269	0.0658	0.1273	1.0000	0.9976	0.9968	0.9935	0.8931	0.2946
		RA01	Index RA01	levee	0.0020	0.0016	0.0163	0.0402	0.0787	1.0000	0.9996	0.9993	0.9981	0.9600	0.6098
Georgiana Slou	ONE Reach - C	RA20	Index RA20	levee	0.0001	0.0038	0.0374	0.0908	0.1734	1.0000	0.9703	0.9529	0.8562	0.6703	0.6281
Miner Slough	ONE Reach - C	RA21	Index RA21	levee	0.0001	0.0046	0.0453	0.1094	0.2069	1.0000	0.9589	0.9361	0.8272	0.6685	0.6334
Sacramento Ri	FOUR Reache	RA22	Index RA22	levee	0.0001	0.0080	0.0775	0.1826	0.3318	0.9997	0.9178	0.8834	0.7439	0.6003	0.5803
		RA18	Index RA18	levee	0.0001	0.0002	0.0023	0.0057	0.0114	1.0000	1.0000	1.0000	0.9995	0.9671	0.9175
		RA17	Index RA17	levee	0.0001	0.0004	0.0043	0.0108	0.0215	1.0000	0.9998	0.9998	0.9968	0.9373	0.8762
		RA16	Index RA16	levee	0.0001	0.0004	0.0037	0.0091	0.0182	1.0000	1.0000	0.9999	0.9991	0.9540	0.8898
		RA13	Index RA13	levee	0.0003	0.0141	0.1324	0.2989	0.5084	0.9995	0.8163	0.7451	0.6171	0.5320	0.5141
		RA11	Index RA11	levee	0.0004	0.0061	0.0591	0.1413	0.2626	0.9982	0.9345	0.9117	0.8524	0.7537	0.6632
		RA10	Index RA10	levee	0.0005	0.0083	0.0801	0.1885	0.3414	0.9955	0.9080	0.8802	0.8111	0.7022	0.6106
		RA09	Index RA09	levee	0.0040	0.0052	0.0503	0.1211	0.2276	0.9999	0.9992	0.9419	0.7229	0.6673	0.6647
		RA08	Index RA08	levee	0.0153	0.0153	0.1428	0.3196	0.5371	0.9948	0.9545	0.6669	0.3723	0.3749	0.3758
		RA05	Index RA05	levee	0.0009	0.0011	0.0109	0.0269	0.0531	1.0000	1.0000	0.9995	0.9891	0.9274	0.8290
Sutter Bypass	ONE Reach - C	RA04	Index RA04	levee	0.0070	0.0079	0.0761	0.1796	0.3270	1.0000	0.9996	0.9577	0.7344	0.2472	0.1180
Sutter Slough	ONE Reach - C	RA19	Index RA19	levee	0.0001	0.0040	0.0395	0.0959	0.1826	0.9998	0.9820	0.9706	0.8875	0.6711	0.6217
Yolo Bypass	ONE Reach - C	RA12	Index RA12	levee	0.0003	0.0003	0.0030	0.0074	0.0148	1.0000	0.9999	0.9998	0.9994	0.9872	0.9176
Yuba R	ONE Reach - C	RA02	Index RA02	levee	0.0092	0.0142	0.1333	0.3007	0.5110	1.0000	0.9487	0.7304	0.5912	0.1147	0.0267

Figure D-2. HEC-FDA Results for Adopted Stage-Damage Relationship

					Target Stage Annual Exceedance Probability		Long-Term Risk (years)			Conditional Non-Exceedance Probability by Events					
Stream Name	Stream Description	Damage Reach Name	Damage Reach Description	Target Stage	Median	Expected	10	30	50	10%	4%	2%	1%	.4%	.2%
American River	ONE Reach - T	RA15	Index RA15	levee	0.0003	0.0021	0.0204	0.0502	0.0980	1.0000	1.0000	1.0000	1.0000	0.5968	0.5172
		RA14	Index RA14	levee	0.0056	0.0054	0.0526	0.1263	0.2367	1.0000	1.0000	1.0000	1.0000	0.1154	0.0273
Bear River	ONE Reach - C	RA06	Index RA06	levee	0.0032	0.0076	0.0730	0.1726	0.3154	1.0000	0.9750	0.8255	0.7232	0.6494	0.6110
Feather River	THREE reache	RA07	Index RA07	levee	0.0003	0.0002	0.0017	0.0043	0.0086	1.0000	1.0000	1.0000	1.0000	0.9998	0.9811
		RA03	Index RA03	levee	0.0026	0.0027	0.0269	0.0658	0.1273	1.0000	0.9976	0.9968	0.9935	0.8931	0.2946
		RA01	Index RA01	levee	0.0020	0.0016	0.0163	0.0402	0.0787	1.0000	0.9996	0.9993	0.9981	0.9600	0.6098
Georgiana Slou	ONE Reach - C	RA20	Index RA20	levee	0.0001	0.0038	0.0374	0.0908	0.1734	1.0000	0.9703	0.9529	0.8562	0.6703	0.6281
Miner Slough	ONE Reach - C	RA21	Index RA21	levee	0.0001	0.0046	0.0453	0.1094	0.2069	1.0000	0.9589	0.9361	0.8272	0.6685	0.6334
Sacramento Ri	FOUR Reache	RA22	Index RA22	levee	0.0001	0.0080	0.0775	0.1826	0.3318	0.9997	0.9178	0.8834	0.7439	0.6003	0.5803
		RA18	Index RA18	levee	0.0001	0.0002	0.0023	0.0057	0.0114	1.0000	1.0000	1.0000	0.9995	0.9671	0.9175
		RA17	Index RA17	levee	0.0001	0.0004	0.0043	0.0108	0.0215	1.0000	0.9998	0.9998	0.9968	0.9373	0.8762
		RA16	Index RA16	levee	0.0001	0.0004	0.0037	0.0091	0.0182	1.0000	1.0000	0.9999	0.9991	0.9540	0.8898
		RA13	Index RA13	levee	0.0003	0.0141	0.1324	0.2989	0.5084	0.9995	0.8163	0.7451	0.6171	0.5320	0.5141
		RA11	Index RA11	levee	0.0004	0.0061	0.0591	0.1413	0.2626	0.9982	0.9345	0.9117	0.8524	0.7537	0.6632
		RA10	Index RA10	levee	0.0005	0.0083	0.0801	0.1885	0.3414	0.9955	0.9080	0.8802	0.8111	0.7022	0.6106
		RA09	Index RA09	levee	0.0040	0.0052	0.0503	0.1211	0.2276	0.9999	0.9992	0.9419	0.7229	0.6673	0.6647
		RA08	Index RA08	levee	0.0153	0.0153	0.1428	0.3196	0.5371	0.9948	0.9545	0.6669	0.3723	0.3749	0.3758
		RA05	Index RA05	levee	0.0009	0.0011	0.0109	0.0269	0.0531	1.0000	1.0000	0.9995	0.9891	0.9274	0.8290
Sutter Bypass	ONE Reach - C	RA04	Index RA04	levee	0.0070	0.0079	0.0761	0.1796	0.3270	1.0000	0.9996	0.9577	0.7344	0.2472	0.1180
Sutter Slough	ONE Reach - C	RA19	Index RA19	levee	0.0001	0.0040	0.0395	0.0959	0.1826	0.9998	0.9820	0.9706	0.8875	0.6711	0.6217
Yolo Bypass	ONE Reach - C	RA12	Index RA12	levee	0.0003	0.0003	0.0030	0.0074	0.0148	1.0000	0.9999	0.9998	0.9994	0.9872	0.9176
Yuba R	ONE Reach - C	RA02	Index RA02	levee	0.0092	0.0142	0.1333	0.3007	0.5110	1.0000	0.9487	0.7304	0.5912	0.1147	0.0267

Figure D-3. HEC-FDA Results for Adjusted Stage-Damage Relationship

D.2 Extension of Relationships for 0.999 and 0.001 Exceedance Probabilities

As discussed in the main report, the order statistics method was used to estimate the uncertainty in the inflow discharge versus exceedance probability relationship. The uncertainty defined using this approach is influenced by the sampling range. Therefore, it is recommended by the HEC-FDA User's Manual (HEC, 2008) that the range of the function include the 0.999 and 0.001 exceedance probabilities. As seen in Figure D-4, this recommendation was adhered to for this study. Values for both the 0.999 and 0.001 exceedance probabilities were linearly extrapolated for the inflow discharge versus exceedance probability relationship.

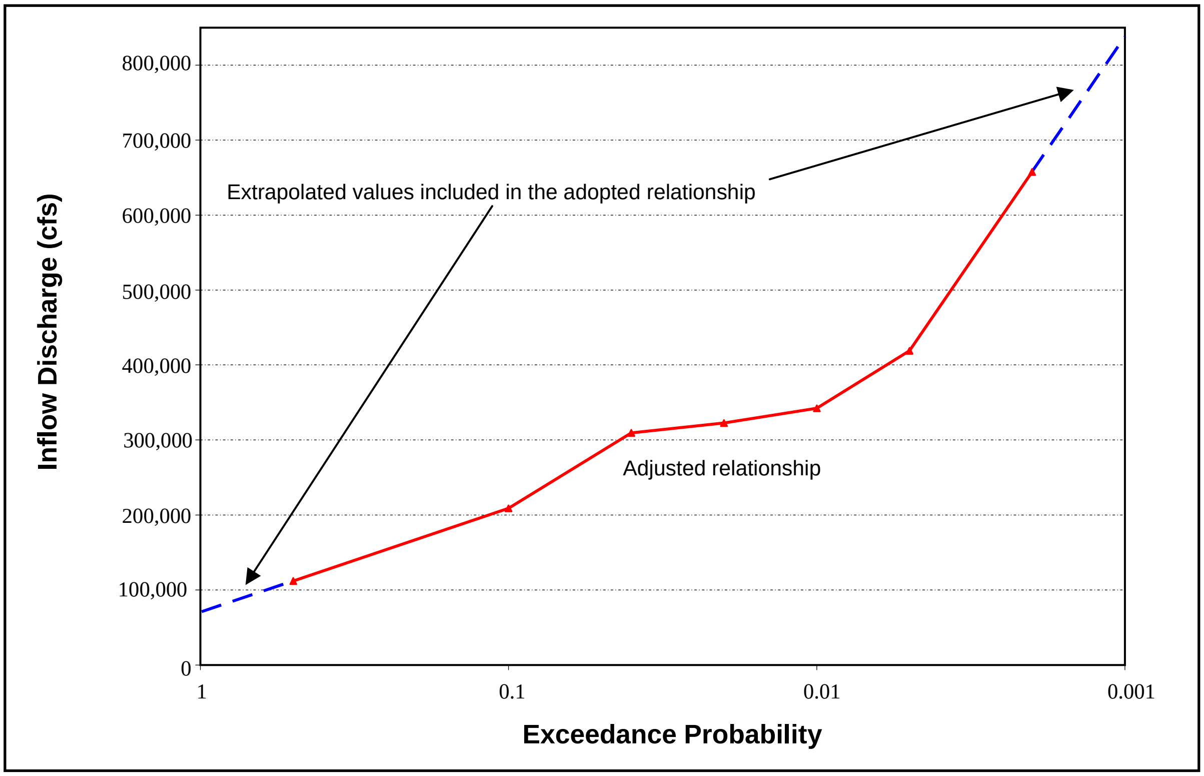


Figure D-4. Illustration of the Adjustments made to Inflow Discharge versus Exceedance Probability Relationship

To assess the affect of not extrapolating values for the 0.999 and 0.001 exceedance probabilities, the values for the 0.999 and 0.001 exceedance probabilities in the inflow discharge versus exceedance probability relationship were eliminated. The corresponding inflow discharge versus outflow relationship is shown in Figure D-5. As seen in Figure D-6, the HEC-FDA results show that eliminating the 0.999 and 0.001 exceedance probabilities in the inflow discharge versus exceedance probability relationship cause an increase in the uncertainty bounds for the inflow discharge versus exceedance probability relationship. Especially near the lower and upper end of the relationship. This difference is summarized in Table D-1.

The HEC-FDA results for the adjusted (elimination of 0.999 and 0.001 exceedance probabilities) inflow discharge versus exceedance probability and inflow discharge versus outflow discharge relationships were compared to the HEC-FDA results for the adopted relationships. Conclusions from this comparison are summarized in Table D-2. Based on the recommendations in HEC-FDA User's Manual (HEC, 2008), it is recommended for future risk analysis evaluations that the inflow discharge versus exceedance probability and inflow discharge versus outflow discharge relationships defined in HEC-FDA include the exceedance probabilities of 0.999 and 0.001.

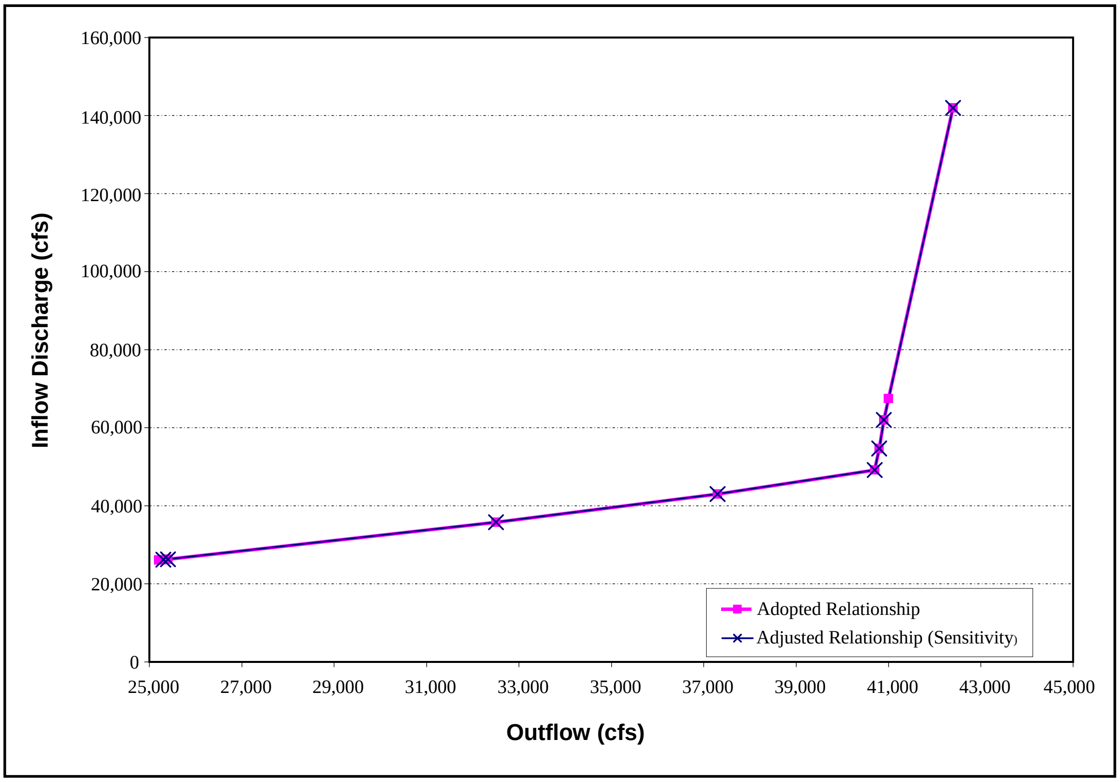


Figure D-5. Illustration of the Adjustments made to the Inflow Discharge versus Outflow Discharge Relationship

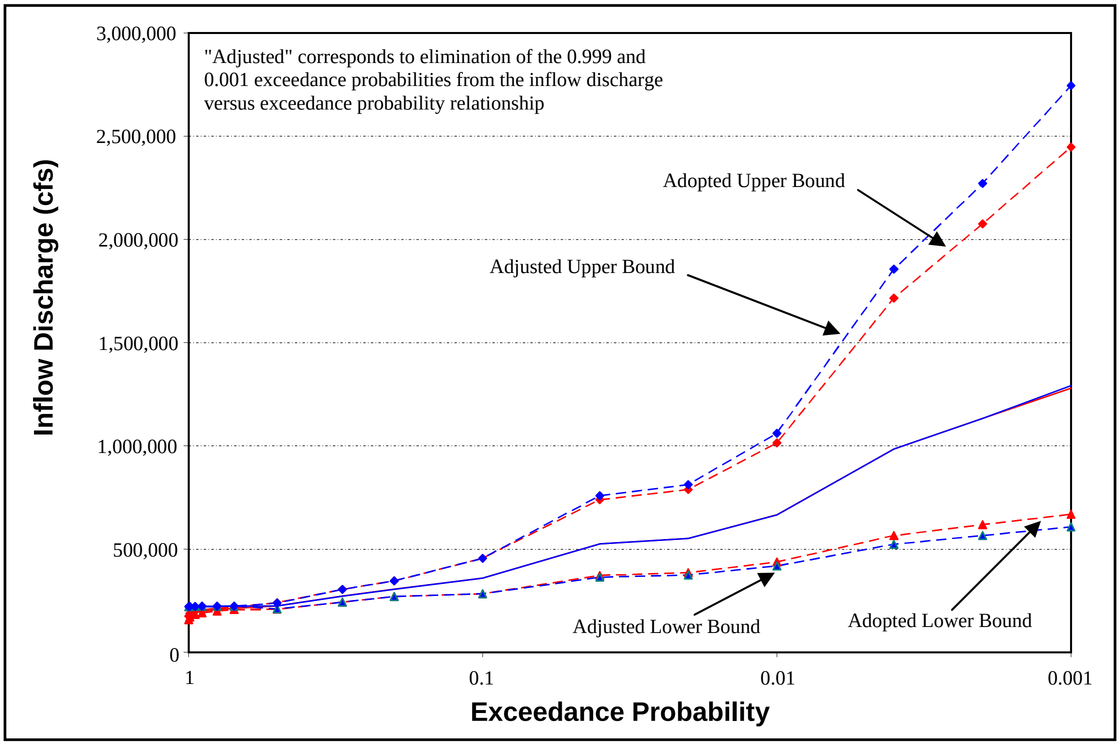


Figure D-6. Comparison of the Uncertainty Boundaries of the Adopted and Adjusted Inflow Discharge versus Exceedance Probability Relationship

Table D-1. Comparison of Adopted and Adjusted (Elimination of 0.999 and 0.001 Exceedance Probabilities) Inflow Discharge versus Exceedance Probability Relationships at Index Location RA06.

Exceedance Probability	Adopted Relationship			Adjusted Relationship			Percent Change		
	Lower Bound	Median	Upper Bound	Lower Bound	Median	Upper Bound	Lower Bound	Median	Upper Bound
0.999	158,600	166,900	175,600	221,100	211,600	222,000	39.4%	26.8%	26.4%
0.990	171,200	179,600	188,300	221,800	222,200	222,600	29.5%	23.8%	18.2%
0.950	183,200	191,600	200,500	222,400	222,800	223,300	21.4%	16.3%	11.4%
0.900	191,000	198,400	206,200	222,800	223,200	223,500	16.7%	12.5%	8.4%
0.800	200,500	207,000	213,600	223,300	223,500	223,800	11.4%	8.0%	4.8%
0.700	207,200	213,300	219,700	223,600	223,800	224,100	7.9%	4.9%	2.0%
0.500	208,800	224,300	241,000	210,600	224,300	238,900	0.9%	0.0%	-0.9%
0.300	243,100	272,100	304,500	243,100	272,100	304,500	0.0%	0.0%	0.0%
0.200	270,200	305,800	346,100	270,200	305,800	346,100	0.0%	0.0%	0.0%
0.100	283,700	359,600	455,800	283,700	359,600	455,800	0.0%	0.0%	0.0%
0.040	373,200	525,300	739,400	363,700	525,300	758,700	-2.5%	0.0%	2.6%
0.020	385,900	551,700	788,700	374,600	551,700	812,500	-2.9%	0.0%	3.0%
0.010	438,300	666,700	1,014,200	418,900	666,700	1,061,200	-4.4%	0.0%	4.6%
0.004	565,700	985,300	1,716,200	523,100	985,300	1,855,900	-7.5%	0.0%	8.1%
0.002	619,100	1,133,400	2,075,100	565,700	1,133,400	2,270,700	-8.6%	0.0%	9.4%
0.001	669,100	1,279,800	2,447,700	608,500	1,292,400	2,745,000	-9.1%	1.0%	12.1%

Table D-2. Changes in the HEC-FDA Results Identified from Eliminating the 0.999 and 0.001 Exceedance Probabilities from the Inflow Discharge-Exceedance Probability and Inflow-Outflow Relationships.

Number	Conclusion	Comment
1	Not considering 0.999 and 0.001 exceedance probabilities causes an increase in the median and expected AEP.	The average percent of change was about forty percent for the median AEP and about twenty-five percent for the expected AEP.
2	Not considering 0.999 and 0.001 exceedance probabilities causes a reduction in the assurance (CNP).	The average percent of change was about -0.7%, -0.9%, and -3.0% for the 0.01, 0.004, and 0.002 exceedance probability events, respectively.
3	Not considering 0.999 and 0.001 exceedance probabilities causes a reduction in the 90 percent assurance of containment.	The average percent of change was about -eighteen percent.
4	Not considering 0.999 and 0.001 exceedance probabilities causes a reduction in the number of potential impacts to the AEP.	There were a total of nineteen potential impacts to the AEP (median and expected) for the adopted relationship and only eleven for the adjusted relationship.
5	Not considering 0.999 and 0.001 exceedance probabilities causes an increase in the number of potential impacts to the Event Assurance (CNP).	There were a total of sixty-two potential impacts to the assurance (CNP for the 0.01, 0.004, and 0.002 exceedance probability events) for the adopted relationship and seventy-six for the adjusted relationship.
6	Not considering 0.999 and 0.001 exceedance probabilities causes an increase in the total number of potential impacts.	There were a total of 103 potential impacts for the adopted relationship and 109 for the adjusted relationship.

D.3 Extension of Stage versus Outflow Discharge Relationship to Top of Levee Elevations

HEC-FDA requires that stage versus outflow discharge relationship include the target stage, which was assumed to be the top of levee for this study. There were several index locations where the stage for the 0.002 exceedance probability flood was significantly below the top of levee elevation. At these locations, the stage-outflow discharge relationship was linearly extrapolated out to the 0.01 exceedance probability flood and then equal to a stage that is two feet above the top of levee. The influence of this assumption was evaluated by assuming that the maximum stage was 0.1 feet above the top of the levee elevation instead of two feet. An example of the adopted and adjusted stage-outflow discharge relationship is shown in Figure D-7.

The HEC-FDA results for the adjusted (maximum stage 0.1 feet above top of levee elevation) stage versus outflow discharge relationship were compared to the HEC-FDA results for the adopted relationship. Conclusions from this comparison are summarized in Table D-3. For future risk analysis evaluations where the stage-outflow discharge relationship has to be extended to be above the target stage, it is recommended that the maximum stage be defined as 0.1 feet above the target stage.

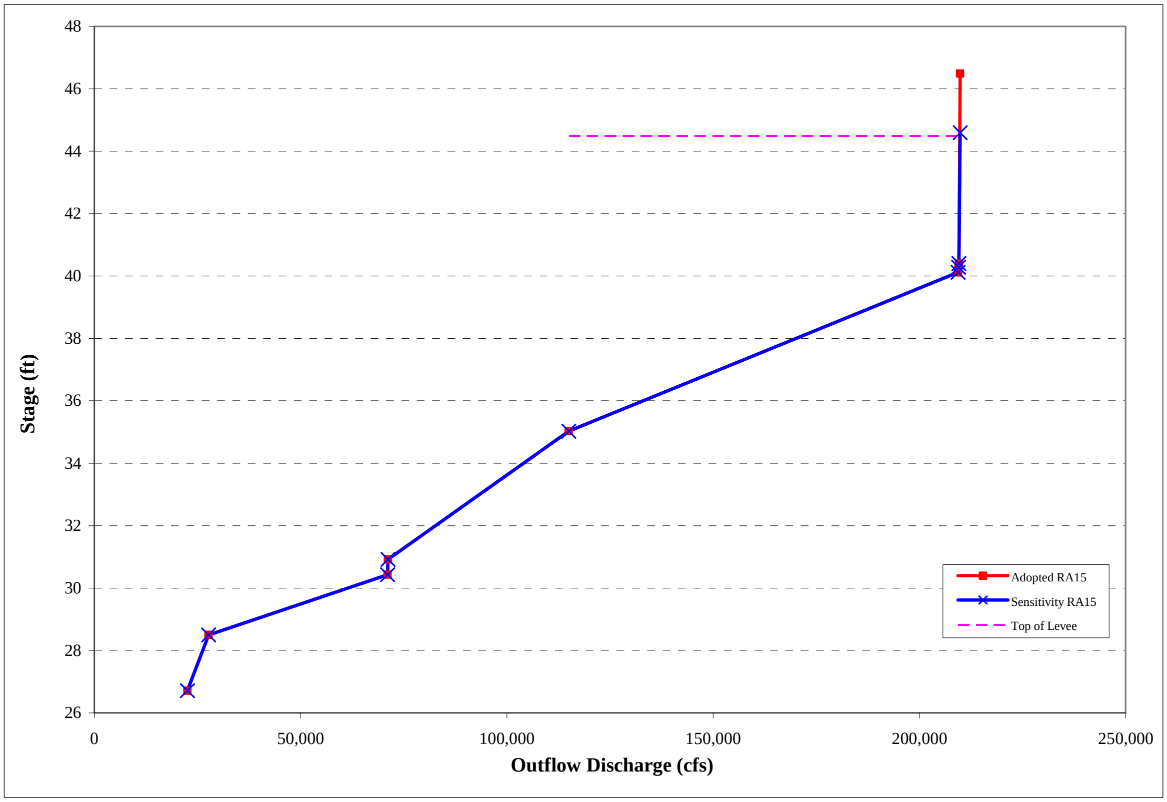


Figure D-7. Adopted and Adjusted Stage versus Discharge Relationship at Index Location RA15

Table D-3. Changes in the HEC-FDA Results Related to Lower the Maximum Stage in the Stage-Outflow Discharge Relationship.

Number	Conclusion	Comment
1	Lowering the maximum stage in the stage-outflow relationship causes a reduction in the median and expected AEP.	The average percent of change was about -45% for the median AEP and about -60% for the expected AEP.
2	Lowering the maximum stage in the stage-outflow relationship causes an increase in the assurance (CNP).	The average percent of change was about 8%, 15%, and 19% for the 0.01, 0.004, and 0.002 exceedance probability events, respectively.
3	Lowering the maximum stage in the stage-outflow relationship causes a reduction in the 90 percent assurance of containment.	The average percent of change was greater than 1000%.
4	Lowering the maximum stage in the stage-outflow relationship causes a reduction in the number of potential impacts to the AEP.	There were a total of eighteen potential impacts to the AEP (median and expected) for the adopted relationship and only five for the adjusted relationship.
5	Lowering the maximum stage in the stage-outflow relationship causes an increase in the number of potential impacts to the assurance (CNP).	There were a total of fifty-six potential impacts to the assurance (CNP for the 0.01, 0.004, and 0.002 exceedance probability events) for the adopted relationship and sixty-eight for the adjusted relationship.
6	Lowering the maximum stage in the stage-outflow relationship causes an increase in the total number of potential impacts.	There were a total of ninety-six potential impacts for the adopted relationship and ninety-seven for the adjusted relationship.

D.4 Uncertainty in the Regulated Flow versus Exceedance Probability Relationship

As presented in Section 3.1.10 of this report, the uncertainty in the inflow discharge versus exceedance probability was estimated using the Equivalent Years of Record (EYR) for combining the uncertainty of the unregulated and regulated flow conditions. The uncertainty for the unregulated flow was estimated using the direct analytical approach documented in Bulletin 17B (USGS, 1982) and information provided in the Comprehensive Study (USACE, 2002). The uncertainty for the regulated flow conditions was estimated assuming that the 95% confidence boundaries are defined as ±10% of the median value. The influence of this assumption was evaluated by assuming that the 95% confidence boundaries of the regulated flow conditions are defined as ±5% and ±15% of the median value. The estimated EYR at the handoff locations and index locations for the assumed percentage of the regulated flow conditions is provided in Tables D-4 and D-5, respectively. An example of the changes to the inflow versus exceedance probability uncertainty boundaries associated with the changes in EYR for the assumed regulated flow conditions is shown in Figure D-8, and the percent changes for these boundaries are summarized in Table D-6.

Table D-4. Equivalent Years of Record (EYR) at the Handoff Locations.

Location	Number of Years	Equivalent Years of Record		
		Regulated Uncertainty of ±5% Median	Regulated Uncertainty of ±10% Median	Regulated Uncertainty of ±15% Median
Upstream Sacramento	76	73	68	60
Upstream Feather River	96	95	89	81
Yuba River	94	92	88	80
Bear River	93	90	85	77
American River	93	92	87	80
Putah Creek	68	67	62	56
Cache Creek	73	71	66	61
Yuba River at RS 13.59 (Deer Creek)	62	60	56	51

The HEC-FDA results for the adjusted EYR (uncertainty bounds of the inflow versus discharge relationship) were compared to the HEC-FDA results for the adopted EYR. Conclusions from this comparison are summarized in Table D-7. As shown in the table, the adjustments to the EYR did not significantly influence the risk analysis results. It is recommended that future studies use the EYR associated with uncertainty for the regulated flows defined as ±10% of the median value, unless information about the regulated flow uncertainty is defined from a detailed sensitivity analysis of the various reservoirs.

D.5 Inflow Discharge versus Outflow Discharge Relationship

HEC-FDA requires that the inflow discharge versus outflow discharge relationship have an increasing slope. This relationship was developed by combining the inflow versus exceedance

Table D-5. Equivalent Years of Record (EYR) at the Index Locations.

Index Location	Regulated Uncertainty of ±5% Median	Regulated Uncertainty of ±10% Median	Regulated Uncertainty of ±15% Median
RA01	87	84	75
RA02	85	81	75
RA03	87	84	75
RA04	55	55	55
RA05	73	68	60
RA06	90	85	77
RA07	86	83	75
RA08	73	68	60
RA09	73	68	60
RA10	73	71	66
RA11	73	71	66
RA12	74	72	67
RA13	73	71	66
RA14	92	87	80
RA15	92	87	80
RA16	75	73	68
RA17	75	73	68
RA18	75	73	68
RA19	75	73	68
RA20	75	73	68
RA21	75	73	68
RA22	75	73	68

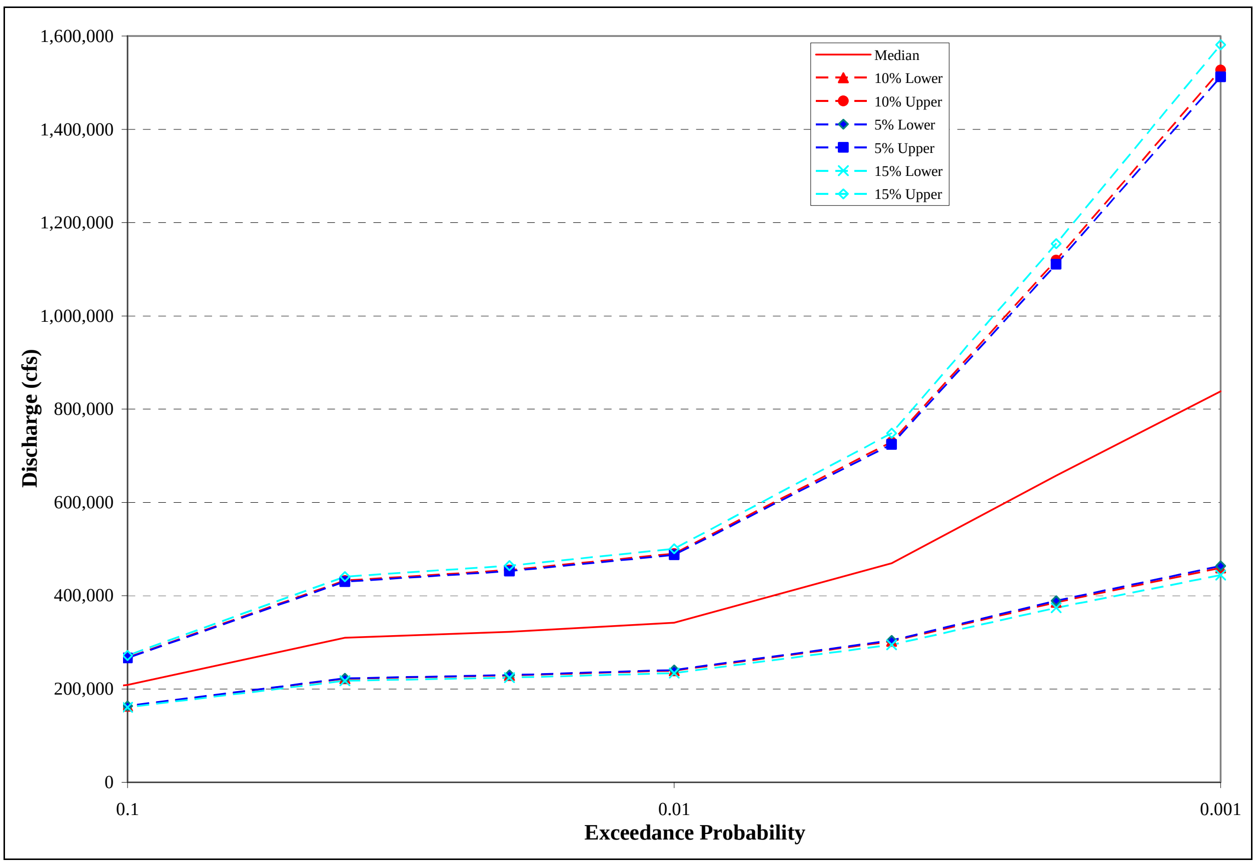


Figure D-8. Uncertainty Boundaries to the Inflow Discharge versus Exceedance Probability Relationship

Table D-6. Percent Change in the Uncertainty Boundaries of the Inflow Discharge versus Exceedance Probability Relationship Associated with the Assumed Regulated Flow Conditions.

Exceedance Probability	Regulated Uncertainty of ±5% Median		Regulated Uncertainty of ±15% Median	
	Lower Bound	Upper Bound	Lower Bound	Upper Bound
0.999	0.1%	-0.1%	-0.6%	0.2%
0.990	0.1%	-0.1%	-0.2%	0.2%
0.950	0.1%	-0.1%	-0.2%	0.2%
0.900	0.1%	-0.1%	-0.3%	0.3%
0.800	0.0%	0.0%	-0.3%	0.3%
0.700	0.1%	-0.1%	-0.2%	0.2%
0.500	0.3%	-0.3%	-0.5%	0.5%
0.300	0.2%	-0.2%	-0.7%	0.8%
0.200	0.1%	-0.1%	-0.9%	0.9%
0.100	0.4%	-0.4%	-1.4%	1.5%
0.040	0.5%	-0.5%	-1.9%	2.0%
0.020	0.5%	-0.5%	-2.0%	2.0%
0.010	0.6%	-0.6%	-2.1%	2.1%
0.004	0.7%	-0.7%	-2.5%	2.6%
0.002	0.8%	-0.8%	-3.1%	3.1%
0.001	0.9%	-0.9%	-3.4%	3.6%

Table D-7. Changes in the HEC-FDA Results Related to Assumed Regulated Flow Conditions.

Number	Conclusion	Comment
Related to Uncertainty in Regulated Flow Reduced to ±5% Median		
1	No changes occurred to the median and expected AEP.	
2	An increase in the assurance (CNP).	The average percent of change was 0%, 0.05%, and 0.1% for the 0.01, 0.004, and 0.002 exceedance probability events, respectively.
3	An increase in the 90 percent assurance of containment.	The average percent of change was about four percent.
4	No changes in the number of potential impacts to the AEP.	
5	Minor change in the potential impacts to the assurance (CNP).	The change in number of potential impacts was -3, 3, and 0 for the 0.01, 0.004, and 0.002 exceedance probability events, respectively.
Related to Uncertainty in Regulated Flow Increased to ±15% Median		
1	No changes occurred to the median AEP. There was an increase in the expected AEP for one of the index locations reviewed.	
2	A reduction in the assurance (CNP).	The average percent of change was 0%, -0.2%, and -0.3% for the 1%, 0.4%, and 0.2% chance exceedance flood events, respectively.
3	A reduction in the 90 percent assurance of containment.	The average percent of change was about negative eight percent.
4	No changes in the number of potential impacts to the AEP.	
5	Minor change in the number of potential impacts to the assurance (CNP).	The change in number of potential impacts was 0, -1, and 0 for the 0.01, 0.004, and 0.002 exceedance probability events, respectively.

probability relationship with the outflow discharge exceedance probability relationship. There were several incidents where the outflow discharge did not increase with decreasing exceedance probability, which would result in a negative slope in the inflow-outflow relationship. As a result, the outflow discharge versus exceedance probability relationship was adjusted. Two approaches for adjusting this relationship were utilized. The first and most common approach involved using a discharge slightly greater than the discharge for the next larger exceedance probability flood or on occasion a discharge slightly less than the discharge for the next smaller exceedance probability flood. The second approach involved interpolation using the bounding exceedance probability floods (for example, the discharge for the 0.005 exceedance probability was interpolated using the discharges for the 0.01 and 0.002 exceedance probabilities). It should be noted that any adjustments to the outflow discharge in the inflow-outflow relationship resulted in a change to the stage-outflow discharge relationship.

A sensitivity analysis of the inflow-outflow and stage-outflow discharge relationship was completed for seven index locations that required adjustment to these relationships. Information related to the adjustments made at each index location is summarized in Table D-8. As indicated in the table, there are four index locations where the adjustment to the inflow-outflow relationship was required for the exceedance probabilities between 0.10 and 0.01. An example of the adopted and adjusted (sensitivity) inflow discharge versus exceedance probability for one of the index locations is shown in Figure D-9, and the stage versus outflow discharge relationships at this location is shown in Figure D-10.

Table D-8. Information Related to Sensitivity Analysis of Adjustments to Outflow Discharge-Exceedance Probability and Stage-Outflow Discharge Relationships.

Index Location	Exceedance Probabilities Adjusted for Outflow Discharge versus Exceedance Probability Relationship	Changes to Outflow Discharge versus Exceedance Probability Relationship	Changes to Stage versus Outflow Discharge Relationship
RA01	0.02 and 0.01	Minor increase in the relationship between the exceedance probabilities of 0.04 and 0.02 and a reduction between exceedance probabilities of 0.02 and 0.004.	Reduction in discharge for stages between about 81 and 89 feet.
RA03	0.04	Increase in the relationship between the exceedance probabilities of 0.10 and 0.02.	Increase in discharge for stages between about 66 and 74 feet.
RA06	0.004 and 0.001	Reduction in the relationship between the exceedance probabilities of 0.02 and 0.002.	Reduction in discharge for stages above 53 feet.
RA09	0.004 and 0.001	Reduction in the relationship between the exceedance probabilities of 0.02 and 0.002.	Reduction in discharge for stages above 31 feet.
RA15	0.04, 0.004, and 0.001	Reduction in the relationship between the exceedance probabilities of 0.10 and 0.02, and 0.01 and 0.002.	Reduction in discharge for stages between about 28.5 and 31 feet and stages above 35 feet.
RA17	0.10	Reduction in the relationship between the exceedance probabilities of 0.50 and 0.02.	Reduction in discharge for stages between about 19 and 22 feet.
RA18	0.04	Minor increase in the relationship between the exceedance probabilities of 0.10 and 0.02.	Increase in discharge for stages between about 15 and 17 feet.

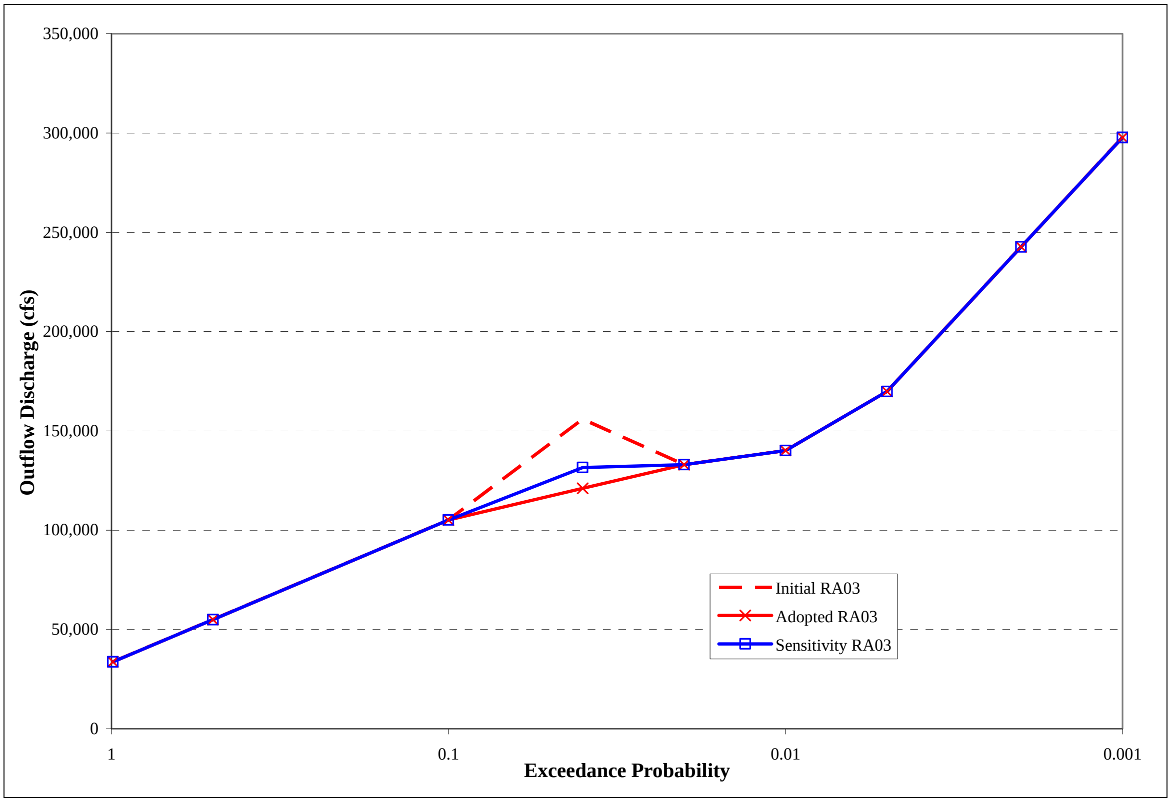


Figure D-9 Adopted and Adjusted Outflow Discharge versus Exceedance Probability Relationship at Index Location RA03

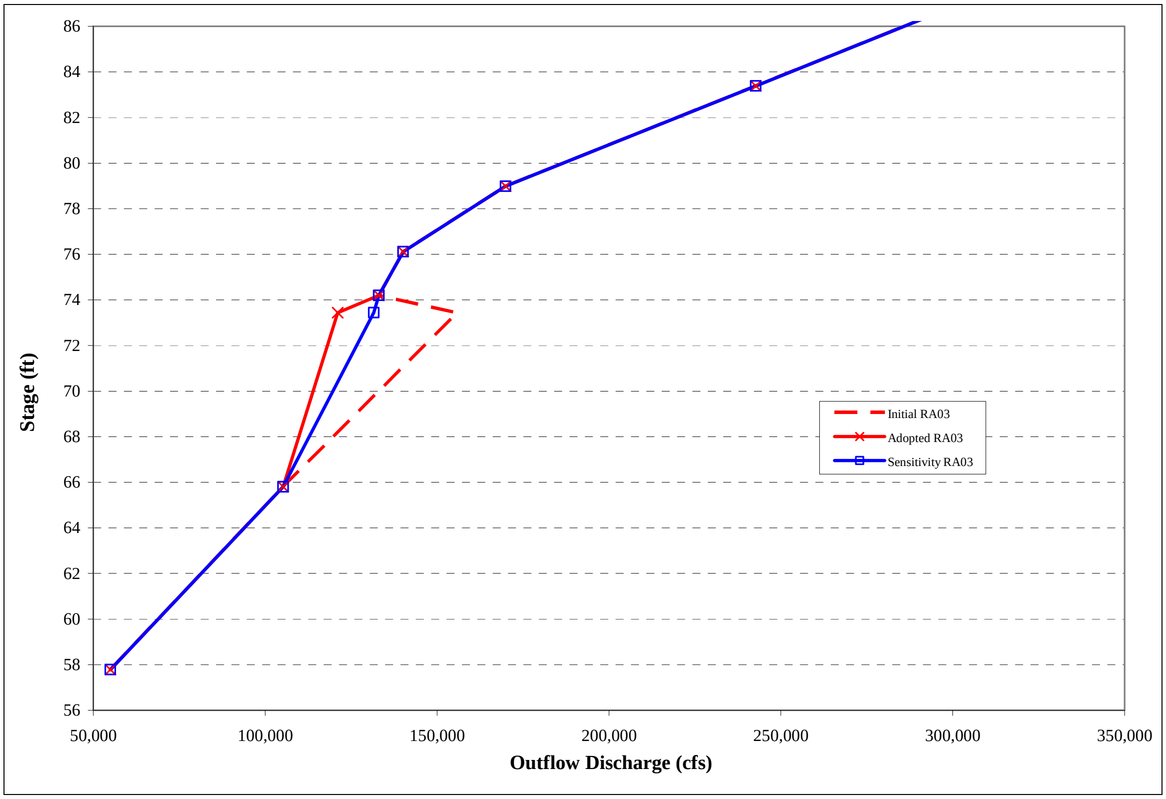


Figure D-10. Adopted and Adjusted Stage versus Outflow Discharge Relationship at Index Location RA03

Table D-8 also indicates that there are three Index Locations where the adjustment to the inflow-outflow relationship was required at lower exceedance probabilities of 0.004 and 0.002. An example of the adopted and adjusted (sensitivity) inflow discharge versus exceedance probability for one of the index locations is shown in Figure D-11, and the stage versus outflow relationships for the same index location is shown in Figure D-12.

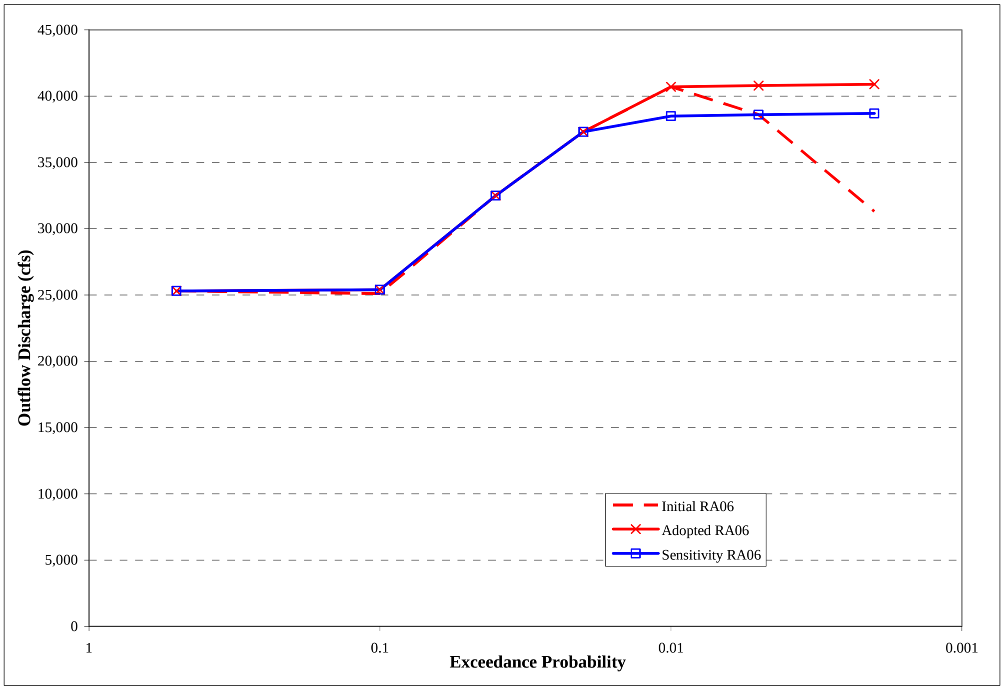


Figure D-11. Adopted and Adjusted Outflow Discharge versus Exceedance Probability Relationship at Index Location RA06

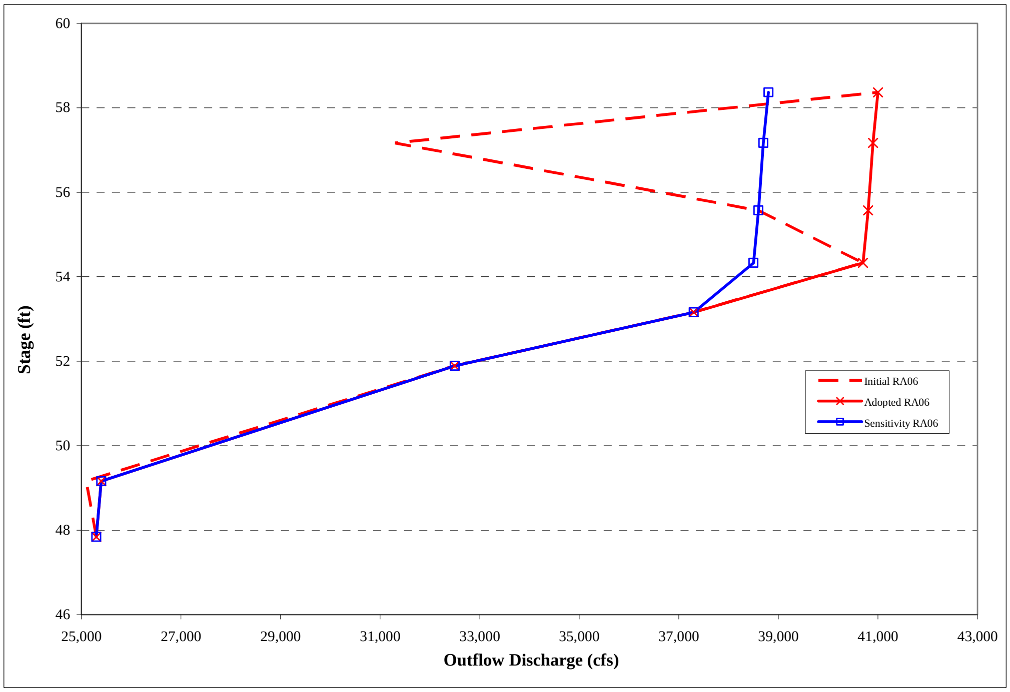


Figure D-12. Adopted and Adjusted Stage versus Outflow Discharge Relationship at Index Location RA06

The HEC-FDA results for the adjusted relationships (inflow-outflow and stage-outflow) were compared to the HEC-FDA results for the adopted relationships. Conclusions from this comparison are summarized in Table D-9. This comparison shows that the HEC-FDA results are only sensitivity to how the inflow-outflow relationship was adjusted for the case where the reduction in the outflow discharge-exceedance relationship occurred for the 0.004 and 0.001 exceedance probabilities. For this condition, the adopted relationship was defined by using a discharge slightly greater than the discharge before the decrease in the outflow discharge versus exceedance probability relationship, and the adjusted relationship was defined by using the outflow discharge for the 0.004 exceedance probability as the control point (outflow discharge for the 0.01 exceedance probability was defined to be slightly less than the outflow discharge for the 0.004 exceedance probability and the outflow discharge for the 0.001 was defined to be slightly greater than the outflow discharge for the 0.004 exceedance probability). It is recommend for future risk analysis studies that adjustments are made to the stage-outflow discharge relationship to account for the influences in the reduction of flow from upstream floodplain storage caused by levee overtopping or breaching during infrequent flood events.

Table D-9. Changes in the HEC-FDA Results Related to Adjustments to Inflow-Outflow and Stage-Outflow Discharge Relationships.

Type	Index Locations	Conclusion	Comment
Adjustments made to the middle portion of exceedance probabilities relationship (0.04 and 0.01)	RA01, RA03, RA17, and RA18	Adjustments to the relationships caused: ■ no changes to the median and expected AEP, assurance (CNP), number of potential impacts to the AEP, and number of potential impacts to the assurance (CNP) ■ minor increases to the 90 percent assurance of containment	
Adjustments made to the lower end of the exceedance probabilities relationship (0.004 and 0.001)	RA06, RA09, and RA15	Adjustments to the relationships caused: ■ a reduction in the median and expected AEP ■ an increase in the assurance (CNP) ■ a reduction in the 90 percent assurance of containment ■ a reduction in the number of potential impacts to the AEP ■ a slight reduction in the number of potential impacts to the assurance (CNP) ■ a reduction in the total number of potential impacts	■ The average percent of change was about -87% for the median AEP and about -68% for the expected AEP ■ The average percent of change in the assurance (CNP) was about 14%, 38%, and 46% for the 0.01, 0.004, and 0.002 exceedance probability events, respectively. ■ The average percent of change was greater than 1000%. ■ There were a total of 31 potential impacts to the AEP (median and expected) for the adopted relationship and only 10 for the adjusted relationship. ■ There were a total of 45 potential impacts to the assurance (CNP for the 0.01, 0.004, and 0.002 exceedance probability events) for the adopted relationship and only 33 for the adjusted relationship ■ There were a total of 97 potential impacts for the adopted relationship and 54 for the adjusted relationship.

Appendix E

Phase II Summary Comments

Number	Organization (Person)	Comment	Response
1	SPD (S.T. Su)	Executive Summary, Page iv - The statement:" Criteria for defining the significance of risk analysis results should be developed." Comment: Need to be more specific - is it referring to "significant hydraulic impact results?" or other results?	The comment was modified as follows: "Potential impacts are determined from comparison of analysis results for existing and proposed conditions. The potential impacts defined from deterministic analysis results are changes in water surface elevation and freeboard that are defined in units of length such as feet. Due to the common use of length units in everyday affairs, the significance of differences expressed in units of length are generally well understood. In contrast, the potential impacts defined from risk analysis results are changes in probabilities. In general, the significance of differences in probabilities, particularly small differences in probabilities, are generally difficult to conceptualize. Consequently, a need exists for development of guidance or criteria to define the significance of risk analysis results."
2	SPD (S.T. Su)	Comment: Need a Table of Contents, also, a list of tables and figures.	A table of contents, tables, and figures has been added to the report.
3	SPD (S.T. Su)	Page 5, Section 1.4 - Comment: Attachment A should be mentioned in Section 1.4.	Section 1.4 has been revised to mention Attachment A (all attachments are now referred to as appendices).
4	SPD (S.T. Su)	Page 68, Section 4.1.9 - Comment: The intent of this subsection should be "a measure of how much additional effort in conducting risk analysis than conducting the deterministic analysis." It is not clear what does the 30 percent mean in light of the above comparison. Need clarification.	Section 4.1.9 was retitled as: "Additional Work Effort Required to Conduct Risk Analysis" The text of the Section was rewritten as follows: "Based on an examination of the labor hours expended for this study, it was identified that approximately 38 percent of the work effort was attributed to conducting risk analysis. About 8 percent of the work effort was attributable solely to the deterministic analysis and 54 percent of the work effort was common to both the analysis approaches. Thus, the risk analysis required an increase of 48 percent in the level of work effort compared to the deterministic analysis. It is noted that the amount of work effort required is generally unique to every project and dependent on the objectives of the study, the size and complexity of the study area, and the availability of existing data and, information. It is recognized that for a large complex system such as the SRFCP, the development of hydrology and hydraulic models are very significant work efforts, but required for either risk analysis or deterministic analysis methods. For the current study, both hydrology and hydraulic models were available."
5	SPD (S.T. Su)	There are inconsistencies between paragraphs on Page 10 and Table 2.	Concur. The inconsistencies have been revised.
6	SPD (S.T. Su)	There are inconsistencies between Table 2 and Attachment A.	Concur. The inconsistencies have been revised.
7	SPD (Edwin Townsley)	Insert Section 2.4 Hydrology in text to correspond with Table 2. The Section should include a statement on storm centering, asserting that the user should define and justify the choice of a single centering that is representative of reasonable system loading.	Concur. Section 2.4 has been added to the report.
8	SPD (Edwin Townsley)	Expand on the 30% incremental effort statements on page ii. Suggest that the total incremental cost of explicitly capture more than just labor. Also suggest including a statement on project complexity, available data, etc may result in a different incremental cost.	See response to Comment No. 4
9	SPD (Edwin Townsley)	Section 2.11 (should be 2.12 based on first comment) and Table 2 should reflect that impact identification can have different criteria depending on task. For example, Corps guidance for FEMA certification, 408 permits, and planning all have different metrics and require capturing different uncertainties.	Concur. Section 2.12 (formerly Section 2.11) was rewritten as follows: Potential impacts are identified by comparing analysis results for baseline and alternative conditions. After potential impacts are defined, their significance must be assessed. The criteria used for assessing significance are specific to the objectives of the investigation (e.g., FEMA levee certification, Section 408 permits, and planning studies).
10	SPD (Edwin Townsley)	A statement defining risk analysis (RA) for this project should be included. In this context, RA only considers the probabilistic scenarios and does not include any consequences. The lack of consistent risk definitions in Corps documents, makes it imperative that each application explicitly define what is included and what is not included.	Concur. The following statement defining the risk analysis conducted for this project was included in the Executive Summary, Introduction, and Conclusions of the report: "Risk Analysis is defined as an analysis of flood hazard and consequence based on the uncertainty of contributing factors related to the hydrology, hydraulics, and levee performance. The Corps current guidance related to risk analysis is documented in EM 1110-2-1619, Risk-Based Analysis for Flood Damage Reduction Studies (Corps, 1996).

Number	Organization (Person)	Comment	Response
			The current study is limited to the evaluation of risk associated with levee performance associated with overtopping. It is not a comprehensive example of risk analysis for flood consequences such as flood damages."
11	SPD (Edwin Townsley)	Page 34, Section 3.1.12, 4th paragraph: Reason #3 states that the AEP is greater than the 1% exceedence event. If AEP is "the probability that flooding will occur in any given year considering the full range of possible annual floods." (FDA user manual), this statement is confusing. Is the AEP greater than the 1% flow event, or greater than the 1% stage event or what 1% event. Doesn't this compare a specific flow or stage to a probability?	Reason 3 has been changed to the following, "AEP is significantly smaller than the 0.01 probability considered in the CNP." The comment is based on the fact that minor changes in an extremely small AEP did not result in a change to the CNP for the 0.01 exceedance probability flood event.
12	SPD (Edwin Townsley)	Table 27: Water surface elevation increases for locations RA7-9 are not intuitively grasped as the Natomas EIP is some distance downstream.	There were no increases for RA7, and the increases at RA8-9 are related to the increase (backwater) in water surface elevations within the reach of the Natomas EIP. A brief discussion related to the results at RA09 has been added to the report. It is recognized that improvements to the existing HEC-RAS model could be made.
13	SPD (Edwin Townsley)	Page 69, Section 4.2.2, last sentence: "are strong affected by" could be changed to "have strong impacts from"	Concur. Revisions were made per comment.
14	SPD (Ed Sing)	Need a clear upfront statement of purpose of this project, to include documenting the RA methodology per Corps guidance as it will be used for determining system wide impacts of modifications to the SRFCP, and demonstration of that process.	Concur. The executive summary was revised as follows to clarify the purpose of the project: "A process was defined *per Corps guidance* to apply risk analysis methodologies to identify potential system-wide hydraulic impacts resulting from alterations and modifications to the Sacramento River Flood Control Project (SRFCP). The process was applied to illustrate the evaluation of potential system-wide impacts associated with several Early Implementation Projects (EIP) proposed for the SRFCP. Results from the risk analysis methods were also compared against results derived from deterministic analysis methods. The example application also illustrates the complexities and effort required in conducting a risk analysis."
15	SPD (Ed Sing)	Clarify that SPD had requested this project be coordinated (or other wording) by HEC.	The following was inserted into the Executive Summary and Introduction of the report: "The work effort for this study was coordinated by the Hydrologic Engineering Center (HEC) at the request of the South Pacific Division (SPD) of the U.S. Army Corps of Engineers."
16	SPD (Ed Sing)	Clarify that Corps guidance on the requirement on the use of RA is not new but that the process for using this methodology has until now not been entirely documented.	The following clarifications were added to the report: Executive Summary, in Paragraph 3. "It is noted that the Corps policy for use of risk analysis is not recent. It was first issued in March 1996 and more recently updated in January 2006. The current work is intended to provide additional detailed guidance for risk analysis efforts." Section 1.0 Introduction, after Paragraph 3. "It is Corps policy (ER 1105-2-101) to utilize risk analysis and its results in planning flood damage reduction studies. The goal of the policy is a comprehensive approach in which the key variables, parameters, and components of flood damage reduction studies are subject to probabilistic analysis. The benefit of the proposed process for the evaluation of proposed modifications to the SRFCP is an increased understanding of the risk inherent in proposed modification alternatives. Risk analysis will quantify assurance in the available flood protection and provide confidence that a proposed modification project is appropriate. It is noted that the Corps policy for use of risk analysis is not recent. It was first issued in March 1996 but recently updated in January 2006. The current work is intended to provide additional detailed guidance for Risk Analysis efforts."
17	SPD (Ed Sing)	Ensure that the report emphasizes that the 11 (or whatever it is) RA process steps includes 9 of the same steps needed for the DA method.	In Section 2.0 Analytical Methods, Paragraph 2, second sentence, it is noted that most of the steps of risk analysis and deterministic analysis approaches are the same.
18	SPD (Ed Sing)	Many of the assumptions made for the RA method are similar or the same as those for the DA method.	Concur. The same assumptions used in the risk and deterministic analyses were identified in Table 1 and noted in Section 1.5.

Number	Organization (Person)	Comment	Response
19	SPD (Ed Sing)	Ensure that the process step numbering in the process explanation in the body of the report, in Table 2 of the report and in Attachment A are the same and consistent.	Concur. The step numbering in Table 2 and Appendix A (formerly Attachment A) were revised to be consistent.
20	SPD (Ed Sing)	Provide a more detailed explanation of interpretation of RA results, cross referencing DA results. (A table only is referred to now.)	The discussion in Section 3.3 was expanded to provide further illustration and explanation of the similarities and differences between risk analysis and deterministic analysis results.
21	SPD (Ed Sing)	Provide a more detailed explanation of system-wide impacts for an example case – say one EIP scenario for a given return frequency flood. (A table only is referred to now.) Noting difference in DA results between baseline and project conditions, then adding in how RA results complement the DA results as well as provide critical decision making information not available in DA to the process.	A detailed comparison of results for one EIP was added to Section 3.3 to illustrate the similarities and differences between risk analysis and deterministic analysis results.
22	SPD (Ed Sing)	Wording was often used in the report to the effect "Efforts were made to compare……." Which makes the reader think that perhaps the effort was not successful? A better, more positive wording would be "A comparison was made……"	Concur. Text was revised per this comment.
23	SPD (Ed Sing)	Ensure that appropriate wording is included acknowledging that local flood control agencies and/or their representatives participated in IPRs and provided input to this project which was appreciated.	Concur. The following was added to the Executive Summary and Introduction: "State and local flood control agencies and their representatives were invited to participate in four Intermediate Progress Review (IPR) meetings (9/18/08, 9/30/08, 10/20/08, and 12/10/08) conducted for this study. Additionally, their review and comment was also solicited on the draft report for the project. Their input to the project is greatly appreciated."
24	SPD (Ed Sing)	Ensure that appropriate wording is included clearly stating that certain assumptions were made (and which) solely for the purposes of this demonstration project. It is expected that the applicants and/or their engineers would need to validate use of similar assumptions and adopt different ones (and document/substantiate such assumptions) in actual Sec 408 applications.	The following statement was added to the Executive Summary and Section 1.5 of the report: "It is expected that assumptions will be required by applicant for Section 408 permits. All employed assumptions would need to be documented and substantiated by permit applicants."
25	SPD (Ed Sing)	EXECUTIVE SUMMARY. Please add an acknowledgement within the Executive Summary and within the Introduction section of this report that this report was commissioned by South Pacific Division. Purpose of this project was to outline the process for utilizing Risk Analysis (probabilistic with uncertainty) methodology for assessing system wide hydraulic impacts of modifications to SFRCP levees and also to demonstrate this process on four EIPs. Computed results from the RA of this project are for illustrative purposes only and not for use in the actual evaluation of potential hydraulic impacts of the EIPs evaluated. The above should be the first paragraph.	See response to Comment No. 15. The following was inserted into the Executive Summary and Introduction of the report: "The work effort for this study was coordinated by the Hydrologic Engineering Center (HEC) at the request of the South Pacific Division (SPD) of the U.S. Army Corps of Engineers." The purpose of the study, as described in the Executive Summary, was modified as follows: "A process was defined to apply risk analysis methodologies to identify potential system-wide hydraulic impacts resulting from alterations and modifications to the *levees* of the Sacramento River Flood Control Project (SRFCP). The process was applied to illustrate the evaluation of potential system-wide impacts associated with *four* Early Implementation Projects (EIP) proposed for the SRFCP. Results from the risk analysis methods were also compared against results derived from deterministic analysis methods. The example application also illustrates the complexities and effort required in conducting a risk analysis. *The computed results of the Risk Analysis are for illustrative purposes only and not for use in the actual evaluation of potential hydraulic impacts of the EIPs evaluated.* The purpose of the project (Section 1.1) was modified as follows: The objective of this study is to define a process for evaluating system-wide hydraulic impacts of proposed modifications to *levees of* the SRFCP utilizing risk analysis methods. Because the study is being conducted to define a process, the results of the study do not provide a definitive assessment for any particular project or site. *Example* applications of the developed analysis process were made to *four EIPs* to illustrate and contrast the results of risk and deterministic analysis methods. The hydraulic information developed under this effort is not intended for use in any specific 408 permit request or for any other purpose but to demonstrate the two analytical methods. The examples also illustrate the complexities and effort required in conducting a risk analysis.

Number	Organization (Person)	Comment	Response
26	SPD (Ed Sing)	Executive Summary. Need to define "risk" as it is used by the Corps in these type analyses. Also, focus of these risk analyses are determination of hydraulic impacts, only.	See response to Comment No. 10.
27	SPD (Ed Sing)	Executive Summary. Need to state that the steps used in both type analyses are similar except for the how these two different methods treat uncertainty.	The following statement was added to Paragraph 5 of the Executive Summary: "The specific steps for conducted risk analysis are very similar to those for deterministic analysis."
28	SPD (Ed Sing)	Executive Summary. GRR of what? Please elaborate.	Concur. Text was revised to indicate that the GRR referenced in the report is American River Common Features GRR.
29	SPD (Ed Sing)	Executive Summary. Mixing terminologies – please correct.	Concur. The sentence referenced for this comment was revised to: "The model consists of plans for seven events ranging from the 0.50 to 0.002 exceedance probability floods."
30	SPD (Ed Sing)	Executive Summary. Clarify that this the additional time in excess of what's need for deterministic analyses (if this is the case).	Concur. The discussion related to the work efforts in the Executive Summary was revised per the response to Comment No. 4.
31	SPD (Ed Sing)	Executive Summary. It is suggested that index points also be include in the immediate vicinity of the EIP work so that proper performance of the risk models can be validated.	Concur. Information about Index Locations near the proposed modifications has been added to the discussion in the Executive Summary.
32	SPD (Ed Sing)	Add Median and Risk to glossary.	Concur. The definition for Median and Risk has been added to the report.
33	SPD (Ed Sing)	Add Table of Contents	A table of contents, tables, and figures has been added to the report.
34	SPD (Ed Sing)	Introduction. As noted in the Executive Summary, please add note that project was commissioned by SPD.	Concur. See response to Comment No. 15.
35	SPD (Ed Sing)	Purpose. Need to a text that the process follows Corps policy for use of RA as outlined in ER XXXX and EC XXXX.	Concur. A statement of policy has been added to Section 1.1 of the report.
36	SPD (Ed Sing)	Section 1.3.4. Somehow need to emphasize in this text that the same hydraulic model results from the deterministic methods is use for input to the RA. Same with flow frequency information.	The following has been added to the end of Section 1.3.4, "The data required to perform both approaches are obtained from the same hydraulic model developed for the site, and the same level of effort would be required in developing the model for either approach."
37	SPD (Ed Sing)	Section 1.3.5. Sorry – I have not yet read forward in the report. I assume that there is a brief description of what these project entail (levee raising, setback, etc.)	Yes, a brief description of the EIPs is provided in Section 3.1.1 of the report and the following sentence been added to Section 1.3.5. "Description of each EIP is provided in Section 3.1.1 of this report."
38	SPD (Ed Sing)	Section 1.3.6. See comment for para 1.3.4 above.	The following has been added to the end of 1st paragraph of Section 1.3.6, "It should be noted that the development of a hydraulic model necessary in completing either approach would require the same level of effort."
39	SPD (Ed Sing)	Section 1.5. Similarly, aren't there some assumptions that were made for the deterministic procedure? Please include as part of the same table. This will reinforce the similarity of the assumptions in the two methods.	Yes and no. The assumptions used in both the risk and deterministic analyses were identified in Table 1 and noted in Section 1.5.
40	SPD (Ed Sing)	Table 1. Please add that baseline top of levee was assumed to be the authorized levee profile.	The assumption related to the top of levee was incorporated into Table 1.
41	SPD (Ed Sing)	Table 1. Storm centering where????	Reference to the storm centering has been incorporated into Table 1.
42	SPD (Ed Sing)	Section 2. Please ensure that steps numbers and descriptions here, in Table 2 an Attachment A are consistent.	Concur. The step numbering in Table 2 and Appendix A (formerly Attachment A) were revised to be consistent
43	SPD (Ed Sing)	Section 2.2. Add in titles, hyperlinks	Concur. The titles and hyperlinks for the various codes referenced in Section 2.2 have been incorporated into the report.
44	SPD (Ed Sing)	Section 2.4. Develop for the Comp Study? State source.	Concur. Information related to the model is provided in Section 3.1.5, so the following sentence has been added to Section 2.5 (formerly Section 2.4): ""Additional information about this model is presented in Section 3.1.5 of this report."
45	SPD (Ed Sing)	Section 3. Report jumps right to RA. Again, somehow nee to emphasize in report that most the steps in the RA also must be accomplished for DA.	Concur. The title and introductory paragraph of Section 3 has been revised to indicate that the section will include a demonstration of the risk and deterministic analysis procedures.

Number	Organization (Person)	Comment	Response
46	SPD (Ed Sing)	Section 3. Actually, para 3 summarizes both risk and deterministic methods. Please clarify para title and state more clearly upfront in this intro para that both methods are given.	Concur. The title and introductory paragraph of Section 3 has been revised to indicate that the section will include a demonstration of the risk and deterministic analysis procedures.
47	SPD (Ed Sing)	Section 3.1.2. Need to repeat this info up in the Introduction section.	Concur. The 1st paragraph of Section 3.1.2 has been added to the Introduction Section.
48	SPD (Ed Sing)	Section 3.1.10. Include titles of documents referenced.	Concur. The titles of the document referenced have been incorporated into the report.
49	SPD (Ed Sing)	Section 3.3. Why is this the case?	The reasons include: (1) the risk analysis at some of the Index Locations was not sensitive to the minor changes in water surface elevations, and/or (2) the increase in water surface elevation was offset by an increase in discharge.
50	SPD (Ed Sing)	Section 3.3. Paragraph 3.3 needs to be expanded to focus on one index point and make a side by side comparison of the results RA vs DA methods. For example, in Figure 8 for Index Location RA09: Text needs to be added in this paragraph.	Paragraph 3.3 was revised to include a side by side comparison of the risk analysis and deterministic analysis approaches.
51	SPD (Ed Sing)	Section 3.3. This figure shows the median AEP under baseline conditions and with various EIPs in place computed using RA being the same as using the DA. This needs to be explained. Wouldn't it be different since RA is supposed to account for uncertainty in estimates of the input parameters? Text should be added to the effect that both methods shown an increase in AEP from 0.0040 (1/250 chance in any given year) under baseline conditions to 0.0054 (1/185 chance in any given year) under a condition with all four EIPs in place. This is one type of information that can be used by decision makers in whether this increase in risk is acceptable to the public.	The Figures in Section 3.3 were revised to include both the median and expected AEP. The text was also revised to state that the median AEP is computed directly from the discharge-exceedance probability and stage-discharge relationships defined at each of the Index Locations, whereas the expected AEP is obtained from annual exceedance probability curves with uncertainty included, which is calculated as part of the Monte Carlo simulation. The report also included several references related to the cumulative potential impacts of multiple EIPs.
52	SPD (Ed Sing)	Section 3.3. As the AEP seems to be available in both methodologies, other information is available from the risk analyses that can be used to define risks involved in implementing the proposed projects.	Concur. The risk analysis provides other information, such as assurance of containment for flood events.
53	SPD (Ed Sing)	Section 3.3. Under DA, the results show an increase in the water surface elevation for the 1% event between baseline and with four EIPs conditions of 0.10 feet. This change does not seem like a significant amount. Without some characterization of the risk associated with this change in water surface, a 0.10 foot increase in water surface might be deemed minor. However, the risk analyses shows that the CNP for the 1% event between the baseline and with four projects in place condition decreases from 71.9% to 63.6%, an approximate 11% decrease in the CNP for the 1% flood.	Paragraph 3.3 was revised to include several comparisons to the change in water surface elevations and Event Assurance. The comparison showed that there is no correlation between the magnitude of change in the water surface elevation and the Event Assurance. The fact that there was no correlation was anticipated since the deterministic approach is related to a specific flood event, while the risk analysis considers the full range of potential flooding probabilities.
54	SPD (Ed Sing)	Section 3.3. Similarly text could be added illustrating the effects on risk of adding incremental projects on the probabilities at this Index Location.	Section 3.3 was revised to illustrate the effects on risk of adding incremental projects on the probabilities at this Index Location.
55	SPD (Ed Sing)	Section 3.3. Similarly, since this is a system wide evaluation, focus in on a particular event (say 1%) and follow the impacts (in a text description) of a project or group of projects d/s to the lower end of the watershed.	Section 3.3 was revised to illustrate that a system-wide analysis needs to be completed for a complex system.
56	SPD (Ed Sing)	Table 33. Why wouldn't the number of the number of adverse changes for combined projects be equal to or greater than the number of adverse changes for individual projects?	The reason is that there are several occasions where the effects of one EIP counteract another EIP when they are combined. One incident is presented in Section 3.3.
57	SPD (Ed Sing)	Section 4.1.2. Should we state here that is also USACE policy to look at impacts from a watershed or system perspective?	The following was added to the end of the first sentence of the second paragraph of Section 4.1.2, ", which is consistent with Corps policy."
58	SPD (Ed Sing)	Section 4.1.2. As noted in a previous section, we need to add text description of an example tracing of the impacts of an EIP throughout the system to demonstrate the value to the system and RA approach.	Section 3.3 was revised to illustrate that a system-wide approach is necessary and the cumulative effects associated with a multiple EIPs.

Number	Organization (Person)	Comment	Response
59	SPD (Ed Sing)	Section 4.18. Do we need to reword or elaborate on this point? To ensure that we are consistent with USACE policy that any computed impact is an impact!	The subject sentence was revised as follows, "All noted changes are potential impacts. Potential impacts can be positive or negative and large or small, and must be assessed for significance."
60	SPD (Ed Sing)	Section 4.1.9. Reword to clarify what portion of the labor hours would have been spent on DA work that also must be performed for RA and what portion is purely in support of RA.	Concur. See response to Comment No. 4.
61	SPD (Ed Sing)	Section 4.2.3. What does this mean? Please clarify, or let's discuss.	This section indicates that levee fragility curves (defined as the probability of failure versus stage) was not considered for the present study, but could be included in future evaluations if the information is available.
62	SPD (Ed Sing)	Section 4.2.4. Please check to make sure that this is also mentioned in the section of this report on hydrology. I don't remember seeing it.	It is referenced in Sections 3.1.3 and 3.1.4 of the report.
63	SPD (Ed Sing)	Attachment A 2.c. I believe we should also include change in w.s. stemming from DA.	The change in w.s. from the deterministic analysis was not included include in the procedure presented in Appendix A (formerly Attachment A) since there is no correlation between this value and the risk analysis results.
64	SPD (Ed Sing)	Attachment A 6.b. Type II or Type III distribution?	Concur. Type II has been changed to Type III.
65	SPD (Ed Sing)	Attachment A 10.a. I believe we should include compute changes in w.s. in this evaluation. This type information is more reasily understood by the public. The RA information serves to complement the w.s. data and helps to provide light on the risks involved in the changes in w.s.	See response to Comment No. 63.
66	SPK (Ethan Thompson)	It was identified that 30% of the effort was needed to conduct risk analysis. There were several simplyfying assumptions made because this was a demonstration project and information was not available. If there was further investigation and consideration needed of the some of the simplifying assumptions would the time requirement hold true? Also, hydraulic impact assessments I have seen done in the past have simply compared with and without project conditions and held everything else constant without incorporating much as far as sensitivity analyses. This is different than what is being described here under the deterministic approach.	In terms of the work effort, the report was revised to include additional information related to the work effort. The discussion clearly states that further investigation and improvement of the process would change the level of work effort related to the process. The requirement of a sensitivity analysis is described in 3.2.10 of the report. It is noted that the affects of levee breaching on water surfaces in the system makes it necessary to evaluate sensitivity of selected breaching parameters.
67	SPK (Ethan Thompson)	Geotechnical fragility curves are not considered as part of the analysis; however, use of a fragility curve may be one advantage to using the Risk approach as opposed to determinstic approach. Fragility curves could be especially helpful at the index point locations by helping define significance of a stage increase. For example, perhaps you raise the water surface at a particular location, but in reality the chance of failure doesn't change because of geotechnical considerations. Perhaps this raise in water surface wouldn't be considered an impact or is determined to be insignificant in this case.	Concur. The addition of levee fragility curves is presented as a recommendation in Section 4.2.3 of the report.
68	SPK (Ethan Thompson)	Upper bound of breach widths was set at 500 feet. There have been examples of breach widths within the Sacramento Levee of much larger than 500 feet. This doesn't appear to capture the full range of possibilities.	Concur. Data related to actual breach width within the SRFCP was not provided for this study. So, the breach characteristics utilized for the study were somewhat randomly selected to demonstrate the use of levee breaches for the developed process. The median value of 300 feet was selected based on recommendations during one of the Intermediate Progress Review Meetings. The lower and upper boundaries were then selected to be 100 and 500 feet, respectively. Also, see response to Comment 66.
69	SPK (Ethan Thompson)	Pg. 67, it states, "based on current data and technology, the assumptions utilized are reasonable for the purpose of defining a general process for identifying hydraulic impacts". This seems to weaken the stance of the overall paper as I thought the purpose was to define the process for determining hydraulic impacts.	Unfortunately, assumptions are necessary for both the deterministic and risk analysis approaches.

Number	Organization (Person)	Comment	Response
70	SPK (Greg Kukas)	Terminology. The assessment demonstrated in the report is a system performance impact assessment, and not a hydraulic impact assessment. Actually, it is system 'containment' performance impact assessment, in that the AEP's and CNP's produced only relate to overtopping. I recommend: (1) adding an introductory paragraph clearly characterizing the type of RA conducted and why (i.e. establish the context for this application) and (2) replacing 'hydraulic impact' w/ 'system performance impact' everywhere in the document, unless hydraulic impact is being used to characterize a change in water surface elevation only. There are multiple other instances where relatively simple changes could provide more technically correct and specific language that would assist in the understanding of this particular RA application (e.g. substitute 'system performance results' for 'risk analysis results' on page ii, 2nd paragraph, last sentence). The fact is that there are already differing types of RA that may be applied to a given studies/project/system, each of them appropriate based on the specific purpose of the analysis. We need to find a way to describe the differences and not just describe everything as 'risk analysis.' Otherwise, it will be very confusing to many when 'risk analyses' of the same system yield significantly different results. Given that consequences of non-containment weren't captured in the analysis, this demonstration didn't really (technically) even address risk.	The report was revised to clearly state what type of risk analysis was completed for this study.
71	SPK (Greg Kukas)	Terminology. CNP, and especially "conditional non-exceedence probability" is unnecessarily wordy and a confusing term for popular use. "Assurance" is a much more immediately meaningful and readily understandable term. "Event assurance" also works in more generic, stand alone applications. Either could be defined as CNP in the glossary to aid in transition. I think its important to take opportunities like this to simplify the language if we want others to more readily understand RA.	Concur. All references to "CNP" have been changed to either "Assurance (CNP)" or "Event Assurance (CNP)".
72	SPK (Greg Kukas)	Terminology. Due to the simplifying methods and assumptions used, the assessment demonstrated is not pure RA (and that's OK). I think it is important to acknowledge and even actively communicate when simplifying assumptions (and perhaps methods) used in conducting the RA are significant enough to be 'conditions' of the outputs. For example, in this case it may be appropriate to add the qualifier 'assuming no system levee failure before overtopping' to the tables including the FDA outputs. Otherwise, I think the emphasis the report places on identifying the assumptions/simplifying methods used is a step in the right direction.	Concur, the developed process is not a pure risk analysis procedure. Additional notes have been added to the FDA output results to indicate that they are based on the top of levee elevation and the main mechanism for levee failure is from overtopping flow. It is agreed that the documenting involved assumptions for any analysis is a good policy.
73	SPK (Greg Kukas)	Policy/Procedures. Was the potential for overtopping induced levee failure considered under pre-project conditions at the locations of the proposed modifications? It seems inappropriate to consider the potential for overtopping induced failures in the system, but not in the locations of proposed modifications.	Yes. The potential for overtopping induced levee failure was considered throughout the entire system (even at the locations of the proposed modifications) for the pre-project conditions. However for the proposed conditions, the potential for levee failure from overtopping was not considered based on the fact that structure stability of the levee will be improved as part of the proposed modifications.
74	SPK (Greg Kukas)	Policy/Procedures. Index points should also be located at points of maximum water surface difference and somewhat concentrated around the proposed modifications.	Concur. The report was revised to state that the Index Locations should be near the proposed modifications and at maximum difference in the calculated water surface elevation.
75	SPK (Greg Kukas)	Reporting. Tables (perhaps in an Appendix) containing FDA input for each of the conditions assessed would be helpful in understanding and judging the appropriateness of the methods used.	Tables of the FDA input have been incorporated into the report as Appendix C.

Number	Organization (Person)	Comment	Response
76	SPK (Greg Kukas)	Reporting. Tabulated stage profiles, w/ the computed difference between the post-project - pre-project water surface elevations, are necessary to assure that the index points aren't in locations of minimal difference, i.e. aren't understating impacts.	The Index Locations were selected based on the information provided in the Comprehensive Study or in the Draft Interim Risk and Uncertainty Procedure prepared by the Department of Water Resources and The Central Valley Flood Protection Board (CVFCB). No consideration to maximum change in water surface elevations created by the EIP was considered in the selection of the Index Locations. The report was revised to state that Index Locations should be considered at maximum difference in the calculated water surface elevation.
77	MBK Engineers (Ric Reinhardt)	Specific Comments. Table 1, #9 – The stage discharge-exceedance probability relationship was revised extending it above the top of levee. The details of this should be explained.	As described in the report (Section 3.1.9) and illustrated in Figure 7, when the stage-discharge relationship leveled off and the water surface elevation for the 0.2% chance exceedance flood was below the top of levee, the stage-discharge was extrapolated out to the 0.1% chance exceedance flood and then increased to be two feet above the top of levee. Furthermore, in response to this and other similar comments, a sensitivity analysis of this assumption was conducted. The results of this analysis are presented in a new Appendix D.
78	MBK Engineers (Ric Reinhardt)	Specific Comments. Page 12 – Second and third bullets appear to be exactly the same.	Concur. Third bullet was removed.
79	MBK Engineers (Ric Reinhardt)	Specific Comments. Page 16, Hydrology – The JFP is an authorized project, as such it should be evaluated as a without project condition, consistent with the TRLIA Feather setback and Natomas Phase 2 EISs.	The work for this study was completed using the hydrology provided by the Corps, which did not include JFP. For future evaluations, we agree that the JFP should be incorporated into the baseline condition.
80	MBK Engineers (Ric Reinhardt)	Specific Comments. Page 33, last paragraph – It states HEC-FDA version 1.2.3b was used. Would it be more appropriate to use version 1.2.4 if it is the version being certified?	The latest version of HEC-FDA was used, and the report was revised to state that the current version of the software was used.
81	David Ford Consulting Engineers (Ford)	**Uses unregulated-to-regulated flow transforms in out-of-ordinary manner.** The demonstration report notes on pg. 10 that operational uncertainty should be considered in evaluating hydraulic impacts. It goes on to say that, *Operational uncertainty reflects levee system performance, flood fight activities, and reservoir operations.* The so-called regulated-unregulated flow transform was added to computer program HEC-FDA for analysis of uncertainty of reservoir operation. The demonstration analysis uses that transform to model uncertainty of levee performance, rather than modeling that as uncertainty about the flow frequency function. While this may, in fact, be an appropriate procedure for modeling this, it is out of the ordinary and, to the best of our knowledge, has not been tested for use in this manner outside this demonstration study. Thus, its applicability to other studies or under other circumstances is not clear. Further, to the best of our knowledge, this use has not been subjected to peer review outside the immediate, small group. As it will have broad impact, it should be subject to such review before it is presented as the required method. Finally, the method for deriving the functions is not clear. Steps 6.e. and 6.f. on pg. A-6 seem to be the only information in the report regarding derivation of the function in this study, and the functions themselves are not included in the documentation. Additional details should be presented.	The transform function was used to separate the uncertainty in the routing of the inflow hydrograph from the uncertainty of the probability function. It was not used to model the uncertainty of levee performance. The uncertainty in the routed flow at each Index Location included the uncertainty in the roughness coefficient, weir coefficients, levee performance, and levee breach characteristics. The use of the transform function is consistent with application of the function as described in the HEC-FDA function, "A flow transfer relationship may be used to define a relationship between unregulated and regulated flow, inflow and outflow, or another relationship to transfer the flow defined by the discharge-or stage-probability. This transform flow relationship could be the result of reservoir or channel routing, channel diversion, etc." The derived functions and an example of how the functions were determined have been incorporated into the report as a new Appendix B.

Number	Organization (Person)	Comment	Response
82	David Ford Consulting Engineers (Ford)	**Lacks information to permit reproduction of results.** If the demonstration is to be a template for other similar studies; the documentation must provide more information about the models, inputs, and assumptions. For example, as noted above, the flow frequency curves were extrapolated, but the manner in which this was done is not documented. Does the estimate of the p=0.001 flow have an impact on the AEP estimates? One presumes that they do so additional guidance about how best to extrapolate those would be helpful. Similarly, the stage-damage functions what were used in the demonstration are not presented for review, and decisions about this input to the HEC-FDA program are not described. Our experience with the HEC-FDA program is that the sample size selected by the program depends on convergence of the EAD values computed, subject to a maximum sample. Computed values of AEP, in turn, are sensitive to the sample size. Therefore, changes in the stage-damage functions used may yield changes in the AEP values. This is critical, so information on the stage-damage functions used should be reported, and sensitivity to this input should be assessed in the demonstration. Likewise, the manner in which the stage-flow transforms are developed is not clear. Does the function represent the concurrent-in-time stage for the peak flow of a routed hydrograph, the maximum stage for the peak flow regardless of timing, or what? Such information would help assess the applicability of the methods used, would help with future applications, and would confirm that the demonstration yields consistent results throughout as flow quantiles are transformed to stages.	The HEC-FDA input data has been included in the report as a new Appendix C. Also, an example of the calculations for the Baseline and one of the EIP was included in Appendix B of the report. The stage-damage function is one of the relationships included in Appendix C (HEC-FDA input data). The relationship was artificially developed. A sensitivity analysis of this relationship was considered. The relationship and sensitivity of the analysis have been incorporated into the report. As indicated in the 1st paragraph on page 27, the discharge for the stage-discharge relationship corresponds to the discharge associated with the maximum stage. An example of how the relationship was determined has been added to Appendix B.
83	David Ford Consulting Engineers (Ford)	**Doesn't permit assessment of level of effort required for other studies.** The report suggests that the risk with uncertainty analysis added only 30% effort to the study. We don't question the accuracy of this accounting, but we do question whether one could infer from this demonstration study that *any* system wide risk analysis would be completed for only 30% more effort than a deterministic analysis. We have completed a variety of risk analyses, using HEC-FDA and other applications identical or similar to those used in the demonstration study. Our experience is that the effort is significantly greater than an additional 30°/o. This difference may be, in part, because the analysts in this demonstration had available a body of knowledge gained at HEC and in the Sacramento District regarding appropriate choices for Index Locations, sensitivity of results to model parameter changes, reasonable choices for uncertainty model parameters, etc. Other analysts are forced to develop that knowledge, probably with repeated application of models for sensitivity analysis, and to complete sufficient analyses to support and justify, for example, assumptions about upstream levee failures or choices of uncertainty model parameters.	The discussion related to the work effort provided in the report has been revised to indicate that the risk analysis would require about 48% more work effort. This conclusion was related to the work completed for the development and demonstration of the process. We agree that it is only applicable for the current system and an indicator for any system wide risk analysis. There are many factors that will influence the level of effort, including, size and complexity of the system, availability of data and information, improvements to process and assumptions, and familiarity with process.
84	FloodSAFE California (Rod Mayer)	The demonstration uses the hydrology for one storm centering (at the latitude of Sacramento) to incorrectly assign probabilities to flows at other distant locations in the system. The proper approach involves significantly more work, using numerous storm centerings.	Concur. The report was revised to recommend that a minimum of two centerings should be considered with one at the downstream end of the watershed and the other near the proposed modifications.

Number	Organization (Person)	Comment	Response
85	FloodSAFE California (Rod Mayer)	Executive Summary. Insert a disclaimer here saying that the evaluations were done solely as a demonstration and did not include the rigor that would be expected for actual evaluations and therefore the results should not be considered indicative of actual impacts.	The Executive Summary has been revised to indicate that the evaluations were done solely as a demonstration of the process, and the results do not represent an actual evaluation of the various EIPs.
86	FloodSAFE California (Rod Mayer)	Executive Summary. Which GRR? Was it American River Common Features?	Text was revised to indicate that the GRR referenced in the report is American River Common Features GRR.
87	FloodSAFE California (Rod Mayer)	Section 2.12Here and throughout the report it is important to not refer to the changes in water surface, AEP, or CNP as impacts. Alternatives would be potential impacts, differences, or some similar term.	Concur. All references to "impact" in the report have been changed to "potential impact".
88	FloodSAFE California (Rod Mayer)	Section 2.12 The logic does not follow that lack of criteria means significance should be evaluated on a site specific basis. It means that criteria should be established, against which potential impacts should be evaluated for significance. It may be on a site specific basis and it may not.	Concur. Section 2.12 (formerly 2.11) was revised to indicate that the criteria used for assessing significance are specific to the objectives of the investigation (e.g., FEMA levee certification, Section 408 permits, and planning studies).
89	FloodSAFE California (Rod Mayer)	Section 3.1.4. This is important. EIPs are projects that precede the Central Valley Flood Protection Plan, and would include the JFP. Therefore, a cumulative analysis could exclude the JFP from the baseline condition as done here, but include it as another EIP.	Concur. The conditions described in this comment can be applied to actual future applications of the described process or similar process in evaluating potential impacts associated with proposed modifications.
90	FloodSAFE California (Rod Mayer)	Table 10 It would be helpful to place these numbers in context by showing a similar table using percentages of expected discharge.	The percentage of standard deviation to the median outflow discharge has been added to Table 10.
91	FloodSAFE California (Rod Mayer)	Section 3.1.12 Explain why that would be the case.	The reason that the expected AEP is more sensitive (more locations with an increase in the value) than the median AEP to the changes caused by an EIP has been added to the end of Section 3.1.12.
92	FloodSAFE California (Rod Mayer)	Section 3.2.11. I have not seen this traditionally, if ever. I usually see, if impacts appear to be significant, a takings analysis under the constitution. Although that may include an stage-damage function, it may be limited to an analysis of the impact on real estate market value and economic uses of the land.	Concur. Hydraulic analysis associated with a deterministic evaluation would be necessary to define stage-damage functions used in evaluation of economic impacts (consequences).
93	Kirby Consulting Group (Ken Kirby)	Executive Summary. How? Related to the 3rd sentence in 3rd Paragraph	Additional discussions related to the result have been added to Section 3.3 of the report to show the need for system-wide assessment of potential hydraulic impacts.
94	Kirby Consulting Group (Ken Kirby)	Analyst does not "define" uncertainty, but rather estimates or approximates it. Related to 3rd sentence in the last paragraph. on page i.	The reference to "define" in the 3rd sentence of the last paragraph on page i has been changed to "estimate".
95	Kirby Consulting Group (Ken Kirby)	Use "estimates" in lieu of "defines" in the 4th sentence in the last paragraph on page i.	The reference to "define" in the 3rd sentence of the last paragraph on page i has been changed to "estimate".
96	Kirby Consulting Group (Ken Kirby)	This study does not consider the "full range of probabilities" (nor does any other). This study considers the affects of estimated uncertainties for select parameters. Related to the statement, "the full range of probabilities" in the last sentence in the last paragraph on page i.	This statement was made to indicate that the risk analysis evaluation considers the entire range of probabilities of the stage-discharge relationship and not for a specific flood event. Therefore, the reference to "full range of probabilities" in the last sentence of the last paragraph on page i was changed to "full range of potential flooding probabilities."
97	Kirby Consulting Group (Ken Kirby)	Add "risk-based" in front of "fragility" in the last sentence in the second bullet on page iii.	The last sentence in the second bullet on page iii was revised per this comment.
98	Kirby Consulting Group (Ken Kirby)	Add "and more prone to data entry errors." to the end of the 3rd sentence for 5th bullet on page iii.	The end of the 3rd sentence for 5th bullet on page iii was revised per this comment.
99	Kirby Consulting Group	Include "Impacts" in the glossary section of the report.	"Impacts" was added to the glossary section of the report.

Number	Organization (Person)	Comment	Response
	(Ken Kirby)		
100	Kirby Consulting Group (Ken Kirby)	For "impacts" in the 2^{nd} sentence of Section 1.3.7 - In this context, it is more precise to say "computational differences". This process is an intermediate step in determining whether "impacts" would occur.	All references to "impacts" in the report have been changed to "potential impacts".
101	Kirby Consulting Group (Ken Kirby)	For "Impact Identification" in Table 2 - A numerical difference in computed water surface elevations should not be characterized as an "impact". Additional evaluation is required to determine whether an impact occurs.	The reference to ""Impact Identification" in Table 2 has been changed to "Identification of Potential Impacts".
102	Kirby Consulting Group (Ken Kirby)	Change "identified impacts" to "computed numerical differences" in the 3^{rd} sentence in Section 2.11.	Section 2.12 (formerly 2.11) was revised to include references to potential impacts.
103	Kirby Consulting Group (Ken Kirby)	Add "and determination of whether computed numerical differences represent a reasonable likelihood of impact" after "Significance" in the last sentence of Section 2.11.	The 2^{nd} sentence of Section 2.12 (formerly 2.11) was revised to include "and determination of whether computed numerical differences represent a reasonable likelihood of impact" in the discussion of significance.
104	Kirby Consulting Group (Ken Kirby)	Change "is not intended to provide a definitive hydraulic impact evaluation of the involved EIPs" to "cannot be used as credible information about potential impacts of the involved EIPs" in the 3^{rd} sentence of the 1^{st} paragraph for Section 3.	The reference to "is not intended to provide a definitive hydraulic impact evaluation of the involved EIPs" in Section 3 was changed to "cannot be used as credible information about potential impacts of the involved EIPs".
105	Kirby Consulting Group (Ken Kirby)	Change "any involved" to "key" in the 4^{th} sentence of the 1^{st} paragraph for Section 3	The reference to "any involved" in the 4^{th} sentence of the 1^{st} paragraph for Section 3 was changed to "key".
106	Kirby Consulting Group (Ken Kirby)	Change "impacts defined" to "numerical differences computed" in the 1^{st} sentence of the 3^{rd} paragraph for Section 3.1.2.	The reference to "impacts defined" in the 1^{st} sentence of the 3^{rd} paragraph for Section 3.1.2 was changed to "potential impacts defined".
107	Kirby Consulting Group (Ken Kirby)	Change "impacts" to "numerical differences" in the 2^{nd} sentence of the 3^{rd} paragraph for Section 3.1.2.	The reference to "impacts" in the 2^{nd} sentence of the 3^{rd} paragraph for Section 3.1.2 was changed to "potential impacts".
108	Kirby Consulting Group (Ken Kirby)	Change "of adverse changes" to "where the numerical difference of computed water surface elevations is higher with project" in the 2^{nd} paragraph of the 3^{rd} paragraph in Section 3.3.	All references to "adverse changes" in Section 3.3 have been changed to "potential impacts".
109	Kirby Consulting Group (Ken Kirby)	Change "adverse changes" to "numerical increases" in the 2^{nd} paragraph of the 3^{rd} paragraph in Section 3.3.	All references to "adverse changes" in Section 3.3 have been changed to "potential impacts".
110	Kirby Consulting Group (Ken Kirby)	Change "hydraulic impacts" to "potential changes in water surface elevations" in the 1^{st} sentence in the 1^{st} paragraph of Section 4.	The reference to "hydraulic impacts" in the 1^{st} sentence in the 1^{st} paragraph of Section 4 was changed to "potential hydraulic impacts".
111	Kirby Consulting Group (Ken Kirby)	For the sentence, "The hydraulic modeling results of this study clearly demonstrate the need for system-wide assessment of hydraulic impacts." In the 2^{nd} paragraph of Section 4.12. How? This study shows numerical differences between different approaches. There does not appear to have been sufficient follow up on notable numeric results to have confidence as to the origin of the numerical results.	Additional discussions related to the result have been added to Section 3.3 of the report to show the need for system-wide assessment of potential hydraulic impacts.
112	Kirby Consulting Group (Ken Kirby)	Change "to define cumulative hydraulic impact effects." to "result in numerical differences in the computational outputs when evaluating potential effects of multiple projects." in the 1^{st} sentence of Section 4.1.3.	The reference to "to define cumulative hydraulic impact effects." in the 1^{st} sentence of Section 4.1.3 was changed to "to evaluate the potential of cumulative impacts associated with multiple projects"
113	Kirby Consulting Group (Ken Kirby)	Change "defining" to "estimating potential changes in hydraulic conditions" in the 1^{st} sentence of Section 4.1.4.	The reference to "defining" in the 1^{st} sentence of Section 4.1.4 was changed to "estimating potential".

Number	Organization (Person)	Comment	Response
114	Kirby Consulting Group (Ken Kirby)	Change "hydraulic-impacts" to "potentially" in the 1st sentence of Section 4.1.4.	The 1st sentence of Section 4.1.4 was not revised per this comment since the reference to "potential" was incorporated in another section of the sentence.
115	Kirby Consulting Group (Ken Kirby)	In relation to the 2nd and 3rd paragraphs of section 4.1.4 - Please see comment for similar passage in introductory portion of document.	The 3rd paragraph of Section 4.1.4 was revised per response to Comment No. 96.
116	Kirby Consulting Group (Ken Kirby)	In relation to the "an increase understanding of the risk inherent" in the 1st sentence of Section 4.1.5 – "I am not clear how what is shown in this report contributes to "an increased understanding about the risk inherent in proposed modification alternatives". Clearly, the approach produces some additional information, but this report does little to describe how the different information can be interpreted in a meaningful way to further understanding."	The purpose of conducting a risk assessment is to define involved uncertainty and the effect on flood hazard risk. Risk analysis can define the probability of containment for a specific flood event while the deterministic approach does not.
117	Kirby Consulting Group (Ken Kirby)	In relation to the "considering the full range of potential floods, not just specific design floods" in the 2nd sentence of Section 4.1.5 – Please see comment in similar passage in introductory portion of the document.	This statement was made to indicate that the risk analysis evaluation considers the entire range of probabilities of the stage-discharge relationship and not for a specific flood event. Therefore, the reference to "full range of floods" was changed to "full range of potential flood probabilities."
118	Kirby Consulting Group (Ken Kirby)	In relation to the "Properly applied" in the 3rd sentence of Section 4.1.5 – This report does not address how one might determine whether risk analysis is "properly applied".	The phase, "Properly applied" was removed from the text.
119	Kirby Consulting Group (Ken Kirby)	In relation to the "reasonable" in the last sentence of the 1st paragraph of Section 4.1.6 – The assumptions used are reasonable to conduct a numerical demonstration of an approach that yields numerical results. This report does not demonstrate that the assumptions used are reasonable to make determinations of impact.	The work, "reasonable" was replaced with "necessary" in the text. Also, the following sentence was added to the end of the 1st paragraph of Section 4.1.6, "Similar assumptions will be required as part of the risk analysis conducted for Section 408 permit applications. All employed assumptions would need to be documented and substantiated by permit applicants."
120	Kirby Consulting Group (Ken Kirby)	Change "impacts" to"numerical differences" in Section 4.1.7.	The reference to "impacts" in Section 4.1.7 was changed to "potential impacts".
121	Kirby Consulting Group (Ken Kirby)	In relation to the "seems most appropriate" in the last sentence of Section 4.1.7 – Based on what?	The reference to "seems most appropriate" was changed to "seems appropriate considering that small exceedance probabilities with greater than 3 significant figures implies return periods in the excess of 1000 years."
122	Kirby Consulting Group (Ken Kirby)	Change "cumulative hydraulic impacts" to "cumulative modeled hydraulic changes" in the 3rd sentence of Section 4.2.1.	The reference to "cumulative hydraulic impacts" in the 3rd sentence of Section 4.2.1 was changed to "cumulative modeled hydraulic changes and potential impacts".
123	Kirby Consulting Group (Ken Kirby)	Change "...to define hydraulic impacts…" to "…to represent changes in modeled hydraulic conditions" in the 1st section of Section 4.2.2.	The reference to "to define hydraulic impacts" in the 1st section of Section 4.2.2 was changed to "evaluate modeled hydraulic changes and potential impacts".
124	Kirby Consulting Group (Ken Kirby)	Change "impacts" to "modeled changes' for the title of Step 2.c. of Attachment A.	The reference to "impacts" in the title for Step 2.c has been changed to "potential impacts".
125	Kirby Consulting Group (Ken Kirby)	Delete "impact" in the first sentence of Step 5.b of Attachment A.	The reference to "hydraulic impact" in first sentence of Step 5.b of Appendix A (formerly Attachment A) was changed to "potential hydraulic impact".
126	Kirby Consulting Group (Ken Kirby)	In relation to Step 5 of Attachment A - Some determination of model resolution would also be extremely useful.	The following was added to Step 5.a in Appendix A, "Model should have adequate resolution to define the hydraulic conditions necessary to evaluate proposed projects and identify impacts. The required resolution of the model will be project specific and depend on a variety of factors, including, available data and resources, and significance of impacts."
127	Kirby Consulting Group (Ken Kirby)	Change "Define" to "Estimate" in the title of Steps 6.d. thru 6.i. of Attachment A.	The reference to "Define" in the title of the initial Steps 6.d. thru 6.i. of Attachment A (attachments in report are now appendix. Appendix A has been revised to match Table 2 of the report) have been changed to "Estimate".

Number	Organization (Person)	Comment	Response
128	Kirby Consulting Group (Ken Kirby)	Change the title of Step 10 of Attachment A from "Impact Evaluation" to "Evaluate Numerical Changes".	The title for Step 10 (now Step 12) of Appendix A was changed from "Impact Evaluation" to "Identification of Potential Impacts".
129	Kirby Consulting Group (Ken Kirby)	Add "Compare the numerical differences in computational results against model resolution. If the modeled differences are valid given the precision of the models used, take computed results into next step to determine if impacts may occur." between the 1st and 2nd sentence for Step 10.a.	The following has been added to the need of Step 12 (formerly Step 10.a). "Potential impacts should be evaluated to assess their significance." This is consistent with the discussion presented in 2.12.
130	Kirby Consulting Group (Ken Kirby)	Change "An increase in AEP and decrease in CNP would be considered an impact." to "An increase (shown to be significant given the model resolution) in AEP and decrease in CNP would be considered a potential impact."	The following was added to then end of Step 12, "The significance of the potential impacts might be defined by such things as policies (Federal, State and Local), flood damage consequences, and model resolution."

Appendix F

Glossary

Assurance is the probability that a target stage will not be exceeded during the occurrence of a specified flood. For example, USACE requires that, for a levee system to be found in accordance with NFIP levee system evaluation requirements, it must have at least a 90 percent change of not being overtopped when subjected to the estimated 1% annual chance exceedance flood. Term selected to replace "conditional non-exceedance probability".

Annual Exceedance Probability (AEP) is the probability a random variable (e.g., flood discharge or stage) will occur in any given year considering the full range of annual possible flood discharge. For this study, the AEP was estimated using the top of levee elevation at each of the Index Locations with no levee failure prior to overtopping. Therefore, the AEP for this study corresponds to the probability of levee overtopping in any given year considering the full range of possible annual floods.

Conditional Non-Exceedance Probability (CNP) is the likelihood of containing a flood event of a specific exceedance probability within a specified target stage (replaced by Assurance).

Deterministic Analysis a technical analysis approach that is accomplished using single values for key variables as opposed to using a probability distribution of values for the key variables (which acknowledges and incorporates uncertainty).

Discharge-Exceedance Probability is the relationship of peak discharge to the probability of that discharge being exceeded in any given year.

Early Implementation Projects (EIP) are project included in the Central Valley Flood Protection Plan (CVFPP), which provides a system-wide approach for managing floods within the Sacramento and San Joaquin River Valleys.

Exceedance Probability Event is the probability that a specific event will occur in any given year. For example, the 0.01 exceedance probability event has one chance in a hundred or a one percent chance of occurring in any given year.

Expected Value is the mean or average value. For normal probability density function the expected, median, and mode are the same.

Freeboard is the increment of levee height added to the design flood height to increase the likelihood of the design event being contained without the levee overtopping.

Index Locations are locations within the system where potential hydraulic impacts will be evaluated.

Mean is the average value of a set of numbers. The first moment statistic of a Log Pearson Type III analytical discharge-probability function, representing the average of the logarithms of peak discharge values.

Median is the value where there is a 0.5 probability that the actual value is less than that value. The middle value of an ordered list.

Normal Distribution is a two-parameter probability distribution defined by the mean and standard deviation. A symmetrical "bell shaped" curve applicable to many kinds of data sets where values are equally likely to be greater than or less than the mean.

Order Statistics is a statistical procedure for defining the sample errors of events that define a graphical frequency function. Order statistics are used to define the uncertainty (error limit curves) about a graphical frequency function defined by Weibull plotting positions (ordered events) for a specified equivalent record length. A normal distribution is used to define the errors.

Potential Impacts are defined in this study as an increase in the AEP and a reduction in assurance (CNP) for the risk analysis approach and an increase in the water surface elevation for the deterministic analysis approach.

Risk is the measure of the probability and severity of undesirable consequences.

Risk Analysis is a decision-making framework that is comprised of three tasks: risk assessment, risk management, and risk communication.

Risk and Uncertainty Analysis is a risk analysis that explicitly, and analytically, incorporates consideration of uncertainty of parameters and functions used in the analysis to determine the undesirable consequences.

Standard Deviation is a statistic used as a measure of the variation in a distribution, equal to the square root of the sum of the squares of the deviations from the arithmetic mean divided by the number of values minus one. The second moment statistic of a Log Pearson Type III analytical discharge-probability function calculated using the mean logarithm and logarithms of peak discharge values.

Uncertainty is a measure of imprecision of knowledge of variables and functions used in risk analysis. Uncertainty may be represented by a specific probability distribution with associated parameters, or sometimes expressed simply as standard deviation.