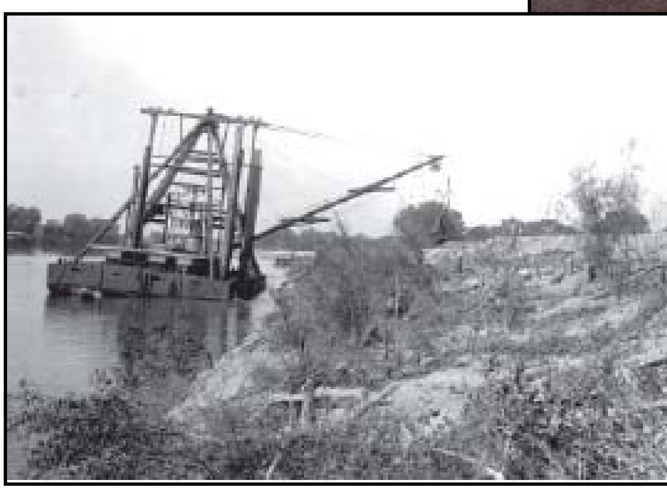
American River Watershed Project

Post-Authorization Change Report

American River Watershed

Common Features Project
Natomas Basin
Sacramento and Sutter Counties, California



SAFCA
Sacramento Area Flood Control Agency

Central Valley Flood Protection Board — Public Safety and Flood Management — State of California

US Army Corps of Engineers®
Sacramento District

APPENDIX H - ECONOMICS

October 2010

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EXECUTIVE SUMMARY

FOREWORD

This Appendix presents the economic analysis for the Natomas Post-Authorization Change, Interim Reevaluation Report. The study area is the Natomas Basin in the city of Sacramento. This Basin is surrounded by levees and is a "closed" ring levee system. The Interim National Economic Development (NED) Plan has been identified as one which includes making improvements to the entire levee system, which, for analytical and technical purposes, is comprised of nine geotechnical levee reaches (NAT A, NAT B, NAT C on the Sacramento River; NAT D on the Natomas Cross Canal; NAT E on the Pleasant Grove Canal; NAT F, NAT G, and NAT H on the Natomas East Main Drainage Canal; and NAT I on the American River). The Interim NED Plan produces average annual benefits of approximately $443 million, has a benefit-to-cost ratio of 6.5 to 1, and reduces flood risk from about a 1 in 5 chance of flooding to about a 1 in 67 chance of flooding in any given year.

It is important to point out that the cumulative reach-by-reach analysis presented in the following chapters has its limitations, mostly related to the modeling tools and the assumed engineering data used to perform the economic analysis. Significant limitations are:

- HEC-FDA was the economic model used to perform the analysis. While HEC-FDA is an approved Corps of Engineers planning model, it was not developed for and does not have the inherent functionality to analyze flooding within a systems context. Currently, the Corps does not have a certified model that addresses dependent inter-relational performance throughout a system. The economic analysis presented herein, however, does attempt to use a systems approach to characterize the flood risk in the Basin by manipulating data outside of HEC-FDA and applying this data within HEC-FDA. This analytical process is described in detail in Chapter 6, *With-Project Analysis*. A main objective of the approach was to perform a cumulative reach-by-reach analysis in order to show the reduction in flood risk to the Basin with each additional levee reach improvement; however, it does not go unrecognized that the reach-by-reach results presented in Chapters 6, 7a, and 7b may differ from those results that may be obtained from a model developed specifically to analyze flooding problems from a systems perspective. While the analytical approach described in this Appendix was necessitated by the lack of availability of a systems model, it is important to note that the Corps of Engineers is currently developing a model (FRM) that will be able to evaluate flood risk (probability of flooding and consequences of flooding) based on a systems approach.

- The economic analysis was completed prior to datum conversion from NGVD 29 to NAVD 88. Within the context of HEC-FDA modeling, this may have introduced additional uncertainty in terms of levee height deficiency and the true impact (or non-impact) of overtopping, which in turn could have affected the cumulative reach-by-reach analysis presented in Chapter 6. In particular, the methodical approach relies partly on HEC-FDA-computed annual exceedance probability (AEP) values, which is the chance of flooding in any given year, to determine the order of levee reach improvements; AEP for each reach and under different conditions is computed based on water surface elevation data that may be more uncertain in some reaches than in others. In instances where the AEP of reaches are particularly close, changes to one of the uncertainty drivers could alter the “order” of levee reach improvements.

The data and modeling tools used to perform the economic analysis may well have affected the order of reach improvements or the grouping of fixes presented in Table ES-7 of this Executive Summary and in Chapters 6, 7a, and 7b of this Appendix. It does not, however, affect the reality that the Natomas Basin is a “closed” ring levee system, whereby flood protection is only as good as its weakest link.

Chapter 6 describes the analytical approach and methodically depicts how flood risk in the Basin is improved as segments of the ring levee surrounding the Basin are improved, until finally the complete ring levee is improved; Chapter 7a introduces costs and shows the net benefit and benefit-to-cost analyses of improvements to the ring levee; Chapter 7b shows the net benefit and benefit-to-cost analyses using the Natomas @Risk Model (N@RM), which expands on the HEC-FDA analysis by incorporating additional assumptions regarding human behavior factors.

ES.1 OVERVIEW

Previous project delivery team (PDT) study efforts for the Natomas Basin area were conducted under a Natomas General Reevaluation Report (GRR). Initial findings (e.g., increased costs and scope of levee improvements for the Natomas Basin) from some of these efforts coupled with findings (e.g., potential through- and under seepage issues with the Sacramento River east levees downstream of the American River, which could lead to failure and major flooding in the city of Sacramento) from other hydraulic and geotechnical studies resulted in the Natomas Basin study efforts being included in a broader American River Watershed Common Features GRR so that potential FRM issues could be more fully addressed from a system approach and to reduce flood risk to the entire city of Sacramento (including the Natomas Basin). An ARWCF GRR document was completed in 2009; an F3 Conference was held in March of 2009.

Subsequent to the F3 Conference, it was decided that work for the Natomas Basin would be fast-tracked and the Basin area would be studied separately from the rest of the ARWCF project area. The study would be conducted under a Post-Authorization Change (PAC) and would be documented in a Natomas Post-Authorization Change Report (NPACR).

This Economic Appendix to the Natomas Post-Authorization Change Report (NPACR) documents the economic analysis performed for the Natomas Basin economic impact area (EIA). The analysis documented in this appendix addresses flood risk (probability of flooding and consequences of flooding) in the Natomas Basin, expected benefits associated with potential flood risk management (FRM) alternatives, and residual risk associated with these potential alternatives.

ES.2 PURPOSE AND SCOPE OF ECONOMIC ANALYSIS

The purpose of this Economic Appendix to the NPACR is to present the economic analysis performed for the Natomas Basin economic impact area. This appendix describes the methodologies, assumptions, data and results of the analysis, and summarizes the flood risk under the without-project condition, the residual flood risk associated with potential alternatives, and the economic benefits associated with these alternatives. This appendix also describes the benefit-to-cost and net benefit analyses performed to determine feasibility and optimization of various alternatives, respectively.

This Economic Appendix is intended to:

- Document the current hydrologic data used in the economic analysis for the Natomas Basin impact area under both the without-project and with-project conditions
- Document the current hydraulic floodplains and HEC-FDA hydraulic input data used in the economic analysis for the Natomas Basin impact area under both the without-project and with-project conditions
- Document the current geotechnical HEC-FDA input data (i.e., geotechnical levee functions which show the relationship between water surface on the river versus the probability of levee failure, or "geotechnical risk and uncertainty curves" (GRU) as they

are referred to throughout this appendix) used in the economic analysis for the Natomas Basin impact area under both the without-project and with-project conditions

- Document the economic methodologies, major assumptions, models, and data used in the economic analysis for the Natomas Basin impact area under both the without-project and with-project conditions
- Document the economic damage/benefit categories considered in the economic analysis for the Natomas Basin impact area under both the without-project and with-project conditions
- Document the results (detailed HEC-FDA output files and EAD/AEP results) of the HEC-FDA model runs for the Natomas Basin impact area under both the without-project and with-project conditions
- Document the screening-level cost estimates used to perform the net benefit and benefit-to-cost analyses
- Describe the approach used to perform the with-project benefits analysis and document the results of the net benefit and benefit-to-cost analyses used to determine plan optimization and feasibility
- Describe additional analyses that will be conducted for future studies and which were not considered in this NPACR

ES.3 WITHOUT-PROJECT DAMAGES

The Natomas Basin encompasses parts of both Sutter and Sacramento counties in California. The impact area is bounded by the Natomas Cross Canal to the north, the Natomas East Main Drainage Canal (NEMDC) to the east, the American River to the south, and the Sacramento River to the west.

For the NPACR, without-project damages and with-project benefits were based on potential damages to residential structures and contents, non-residential (commercial, industrial, public, and farm) structures and contents, and automobiles. Other damage/benefit categories, including agricultural/crops, traffic disruption, and emergency costs, will be addressed in the upcoming GRR.

There are approximately 23,000 structures in the Natomas Basin. Structure counts are presented in Table ES-1. Total value of damageable property (structures and contents) is displayed in Table ES-2 and is approximately $8.5 billion.

Table ES-1
Structure Count
Natomas Basin

STRUCTURE COUNT BY DAMAGE CATEGORY	
Damage Category	**Structure Count**
Commercial	303
Farm	21
Industrial	156
Public	85
Residential	22,265
TOTAL	**22,830**

Table ES-2
Total Value of Damageable Property by Category
Structures and Contents
Values in $Millions, October 2010 Price Level

CATEGORY	VALUE OF DAMAGEABLE PROPERTY		
	Structures	**Contents**	**Total**
Commercial	681	308	989
Farm	6	7	13
Industrial	458	249	707
Public	440	275	715
Residential	4,076	2,038	6,114
TOTAL	**5,661**	**2,877**	**8,538**

Single-event damages for the 2-, 10-, 25-, 50-, 100-, 200-, and 500-year flood events were computed in the economic model (HEC-FDA) and are presented in Table ES-3. The damages shown are based on flooding from a levee breach along the Natomas Cross Canal (NCC). The consequences from a breach are greatest from a breach on the NCC than from any of the other water sources (Sacramento River, Pleasant Grove Creek Canal, Natomas East Main Drainage Canal, and American River).[1] Potential damages from a breach on the NCC range from $6.3 billion for the 2-yr event to close to $7.0 billion for the 500-year event; Figure ES-1 displays the event floodplains from a breach on the NCC. There is extremely deep (darkest blue indicates greater than 20 feet of flooding) and extensive flooding in the Basin from a breach on the NCC.

[1] Nine geotechnical reaches (economic index points) were delineated for the analysis. A levee breach from any of these nine index points produced a unique suite of floodplains (2-yr to 500-yr). Single-event damages from a breach on the NCC were the greatest for all events, while damages from a breach on the Natomas East Main Drainage Canal (NEMDC) were the lowest.

Table ES-3
Without-Project Single-Event Damages
Damages Based on Levee Breach from Natomas Cross Canal (NCC)
Values in $Millions, October 2010 Price Level

DAMAGE CATEGORY	NATOMAS REACH D SINGLE-EVENT WITHOUT-PROJECT FLOOD DAMAGES						
	2-yr	**10-yr**	**25-yr**	**50-yr**	**100-yr**	**200-yr**	**500-yr**
Residential	4,133	4,386	4,444	4,495	4,513	4,519	4,520
Commercial	760	814	832	849	857	868	875
Industrial	530	585	596	609	619	627	637
Public	537	597	604	639	647	650	651
Farm	9	10	11	11	11	11	12
Auto Losses	333	339	339	339	339	339	339
TOTAL	**6,302**	**6,731**	**6,826**	**6,942**	**6,986**	**7,014**	**7,034**

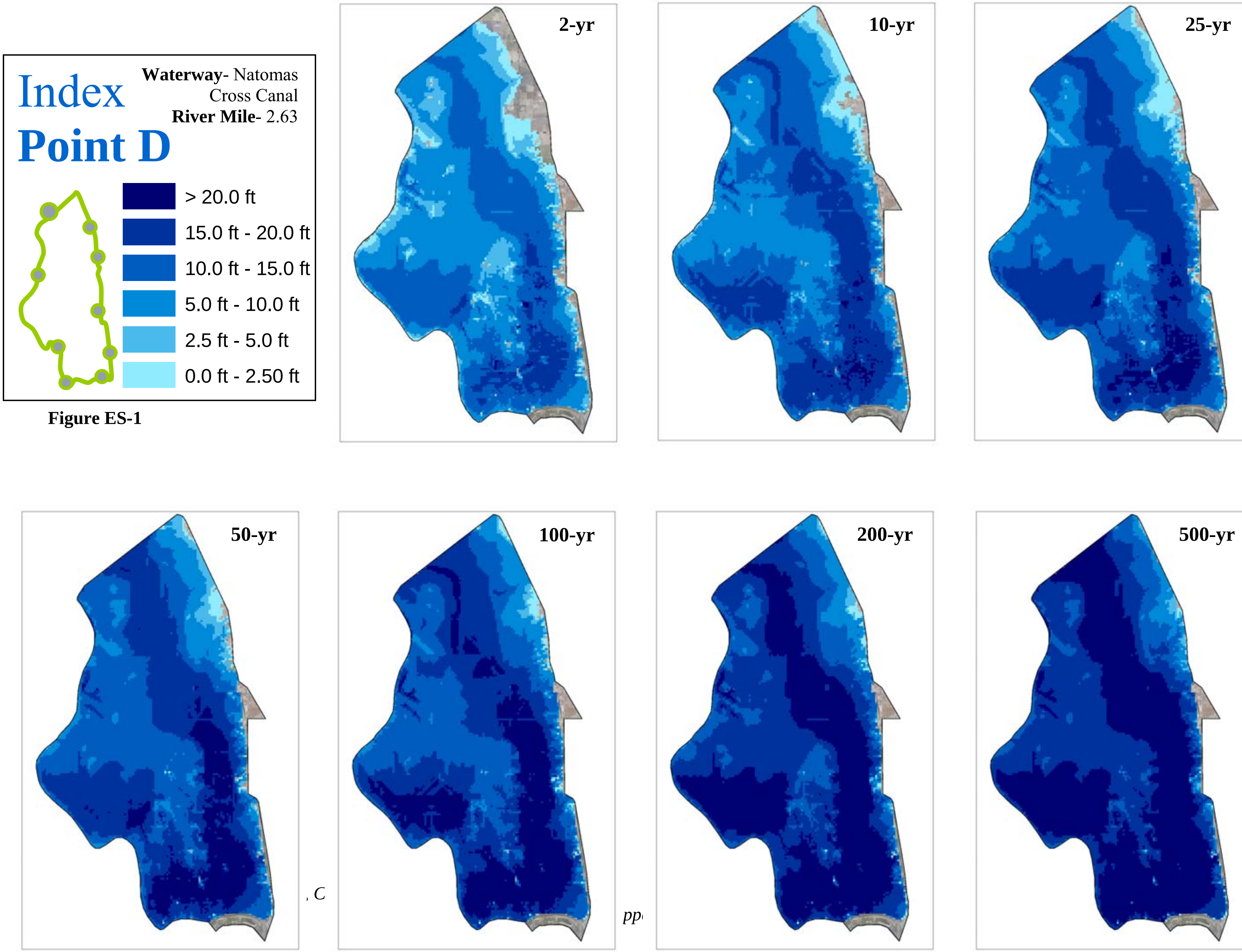
Index
Point D
Waterway- Natomas Cross Canal
River Mile- 2.63
> 20.0 ft
15.0 ft - 20.0 ft
10.0 ft - 15.0 ft
5.0 ft - 10.0 ft
2.5 ft - 5.0 ft
0.0 ft - 2.50 ft
2-yr
10-yr
25-yr
50-yr
100-yr
200-yr
500-yr

Figure ES-1

Without-project EAD is estimated to be approximately $462 million and is shown in Table ES-4 below.

Table ES-4
Without-Project Expected Annual Damages (EAD) by Category
Values in $Millions, October 2010 Price Level

STRUCTURE & CONTENTS	WITHOUT-PROJECT EAD
Total	**462**

ES.4 WITH-PROJECT DAMAGES AND DAMAGES REDUCED

A with-project benefit analysis was performed based on levee improvement (by geotechnical reach) around the basin; these improvements included fixing levees in place as well as levee raises in reaches where necessary. The levee reach improvements are:

- No Improvement -- Without-Project
- Fix Reach D
- Fix Reach D+A
- Fix Reach D+A+E
- Fix Reach D+A+E+B
- Fix Reach D+A+E+B+C
- Fix Reach D+A+E+B+C+H
- Fix Reach D+A+E+B+C+H+G
- Fix Reach D+A+E+B+C+H+G+F
- Fix Reach D+A+E+B+C+H+G+F+I
- Fix All + Raise D,B,E,F
- Fix All + Raise D,B,E,F,A,C,I,G
- Fix All + Raise All

Table ES-5 displays the with-project residual damages and benefits for each alternative. Each alternative is comprised of specific methods of fixes (measures) for each reach. Additionally, two categories of alternatives were identified for plan formulation purposes – a “fix-in-place” and “adjacent levee” alternative. Generally speaking, each measure can be part of both a “fix-in-place” and “adjacent levee” alternative as the salient factor that determines how a measure is categorized is dictated mostly by where the measure is physically located. From a geotechnical performance point of view, whether a measure is labeled “fix-in-place” or “adjacent levee” does not change its geotechnical performance (i.e., a measure has the same geotechnical performance no matter how it’s categorized), and therefore, benefits for each measure (method of fix) and benefits between the two categories of alternative evaluated, are the same. This can be seen in Table ES-5.

Table ES-5
With-Project Residual Damages and Benefits by Levee Reach Improvement
Damages/Benefits in $Millions, October 2010 Price Level

LEVEE REACH IMPROVEMENT	ALTERNATIVE TYPE	EXPECTED ANNUAL DAMAGES	RESIDUAL DAMAGES	DAMAGES REDUCED (BENEFITS)
Without-Project	Adjacent Levee Fix-in-Place	462	--	--
Fix D	Adjacent Levee Fix-in-Place	--	341	121
Fix D+A	Adjacent Levee Fix-in-Place	--	330	132
Fix D+A+E	Adjacent Levee Fix-in-Place	--	299	163
Fix D+A+E+B	Adjacent Levee Fix-in-Place	--	101	361
Fix D+A+E+B+C	Adjacent Levee Fix-in-Place	--	60	402
Fix D+A+E+B+C+H	Adjacent Levee Fix-in-Place	--	32	430
Fix D+A+E+B+C+H+G	Adjacent Levee Fix-in-Place	--	24	438
Fix D+A+E+B+C+H+G+F	Adjacent Levee Fix-in-Place	--	19	443
Fix D+A+E+B+C+H+G+F+I	Adjacent Levee Fix-in-Place	--	19	443
Fix All + Raise D,B,E,& F	Adjacent Levee Fix-in-Place	--	10	452
Fix All + Raise D,B,E,F, A,C,I,& G	Adjacent Levee Fix-in-Place	--	8	454
Fix All + Raise All	Adjacent Levee Fix-in-Place	--	2	460

It can be seen from Table ES-5 that Fix all reaches – D, A, E, B, C, H, G, F, and I) does not provide any additional benefit. Any additional benefit of fixing I is only achieved when levees in other reaches are raised. This is because fixing NAT I without raising levees in other reaches at the same time does not improve the probability of flooding in the Basin.

ES.5 PROJECT PERFORMANCE

Project performance can be measured by annual exceedance probability (AEP), long-term risk, and conditional non-exceedance probability (CNP). These were computed in HEC-FDA using hydrologic, hydraulic, and geotechnical engineering data. Table ES-6 presents the AEP results for each alternative.

Table ES-6
Project Performance Statistics by Levee Reach Improvement

GROUP	AEP
Without-Project	.21
Fix D	.21
Fix D+A	.18
Fix D+A+E	.12
Fix D+A+E+B	.04
Fix D+A+E+B+C	.04
Fix D+A+E+B+C+H	.015
Fix D+A+E+B+C+H+G	.015
Fix D+A+E+B+C+H+G+F	.015
Fix D+A+E+B+C+H+G+F+I	.015
Fix All + Raise D,B,E,& F	.008
Fix All + Raise D,B,E,F, A,C,I,& G	.006
Fix All + Raise All	.001

Table ES-6 shows that Basin-wide AEP is reduced with each improvement. Fixing all levees (no raises) around the Basin results in an AEP of about .015. Additional levee raises throughout the Basin improves AEP correspondingly.

ES.6 NET BENEFIT ANALYSIS

Average annual benefits for each levee reach improvement were determined by taking the difference between without-project EAD and with-project EAD (Table ES-5). Net benefits were determined by taking the difference between average annual benefits and average annual costs.

For purposes of preliminarily screening of improvements, total project first costs and interest during construction (IDC) were estimated for the various measures (methods of fixes) in each reach and by alternative type ("fix-in-place" or "adjacent levee"). First costs and IDC were added together to derive total investment costs. Investment costs were then amortized assuming a 50-year period of analysis and an interest rate of 4.375%.

Table ES-7 displays the average annual benefits and average annual costs, benefit-to-cost ratios by levee reach improvement. Figure ES-2 visually displays the net benefits of each improvement in graphical form, and shows that net benefits continue to increase until the 11th levee reach improvement, where the cost of improving the levee are greater than the additional benefits; The 11th improvement includes levee raises in A, C, I, and G in addition to levee raises in D, B, E, and F. It should be noted that net benefits do increase from the first set of levee raises to the final raises, where levee raises occur in all reaches.

Figure ES-1
October 2010 Price Level

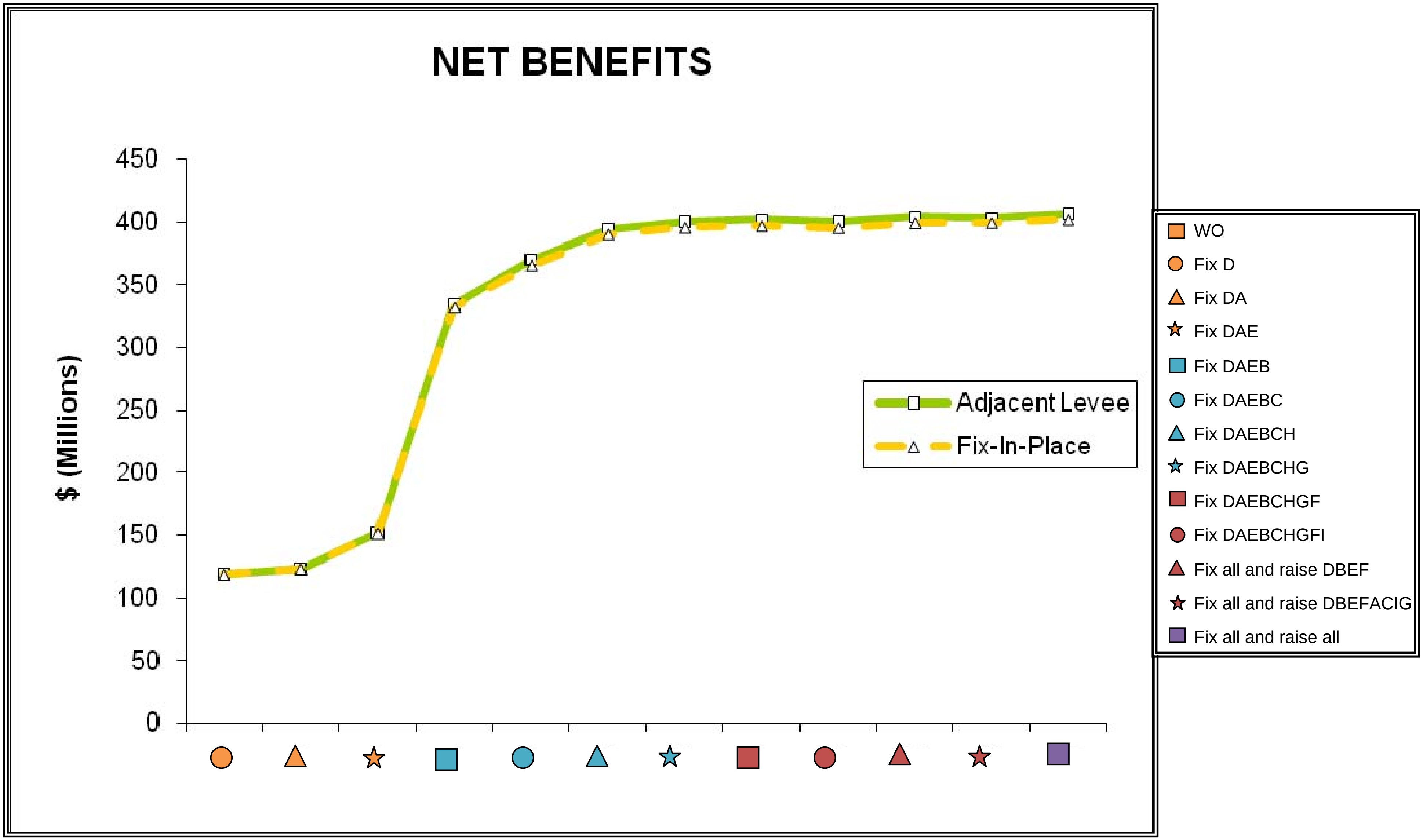

Table ES-7
Net Benefits and Benefit-to-Cost Ratio
October 2010 Price Level

Levee Reach Improvement	ALTERNATIVE TYPE	EXPECTED ANNUAL DAMAGES	ANNUAL BENEFITS	ANNUAL COST	NET BENEFITS	B/C RATIO
WITHOUT-PROJECT	-	462	-	-	-	-
FIX D	Adjacent Levee	341	121	2.0	119	61.7
	Fix-in-Place			2.0	119	61.7
FIX D, A	Adjacent Levee	330	132	8.3	124	15.9
	Fix-in-Place			8.6	123	15.4
FIX D, A, E	Adjacent Levee	299	163	11.5	152	14.2
	Fix-in-Place			12.0	151	13.6
FIX D, A, E, B	Adjacent Levee	101	361	26.7	334	13.5
	Fix-in-Place			29.2	332	12.4
FIX D, A, E, B, C	Adjacent Levee	60	402	31.7	370	12.7
	Fix-in-Place			36.0	366	11.2
FIX D, A, E, B, C, H	Adjacent Levee	32	430	35.6	394	12.1
	Fix-in-Place			39.9	390	10.8
FIX D, A, E, B, C, H, G	Adjacent Levee	24	438	37.8	400	11.6
	Fix-in-Place			42.4	396	10.3
FIX D, A, E, B, C, H, G, F	Adjacent Levee	19	443	41.3	402	10.7
	Fix-in-Place			46.1	397	9.6
FIX D, A, E, B, C, H, G, F, I	Adjacent Levee	19	443	42.7	400	10.4
	Fix-in-Place			47.6	395	9.3
FIX ALL + RAISE D, B, E, F	Adjacent Levee	10	452	48.1	404	9.4
	Fix-in-Place			52.7	399	8.6
FIX ALL + RAISE D, B, E-2, F, G, I, A, C	Adjacent Levee	8	454	51.1	403	8.9
	Fix-in-Place			54.6	399	8.3
FIX ALL + RAISE ALL	Adjacent Levee	2	460	53.5	407	8.6
	Fix-in-Place			58.1	402	7.9

ES.7 CONCLUSION

The Natomas Basin is considered a "closed" ring levee system, whereby flood protection is only as good as its weakest link. Table ES-8 is a condensed version of Table ES-7. Table ES-8 displays the risk remaining after improvements to groups of specific levee reaches. The purpose of the table is to highlight the notion that the Natomas Basin is a "closed" ring levee system as well as to show the reduction in flood risk with each levee reach improvement in terms of the chance of flooding and the consequences of flooding.

Table ES-8
Residual Risk and Unit of Measurement
October 2010 Price Level

Unit of Measurement	Improvement	Expected Annual Damages (EAD) In $Millions	Residual Damages In $Millions	Annual Exceedance Probability (AEP)
N/A	No fixes	462	--	.21
3 of 9 reaches	Fix D, A, E	--	299	.12
6 of 9 reaches	Fix D, A, E, B, C, H	--	32	.015
COMPLETE SYSTEM	Fix All Reaches	--	19	.015
COMPLETE SYSTEM	Fix all and raise some	--	10	.008
COMPLETE SYSTEM	Fix all and raise some	--	8	.006
COMPLETE SYSTEM	Fix all and raise all	--	2	.001

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LIST OF ABBREVIATIONS AND ACRONYMS

AEP	**Annual Exceedance Probability**
AR	**American River**
ARWCF	**American River Watershed Common Features**
ARN	**AR North Basin**
ARS	**AR South Basin**
C&I	**Commercial and Industrial**
CIP	**Controlling Index Point**
CF	**Common Features**
cfs	**cubic feet per second**
CNP	**Conditional Non-Exceedance Probability**
CVP	**Central Valley Project**
EA	**Environmental Assessment**
EAD	**Expected Annual Damages**
Appendix	**Economic Appendix**
EGM	**Economic Guidance Memorandum**
EIA	**Economic Impact Area**
EIR	**Environmental Impact Report**
EIS	**Environmental Impact Statement**
EQ	**Environmental Quality**
ERR	**Economic Reevaluation Report**
FDR	**Floor Damage Reduction**
FEMA	**Federal Emergency Management Agency**
FIA	**Federal Insurance Administration**
FRM	**Flood Risk Management**
GIS	**Geographic Information Systems**
GRR	**General Reevaluation Report**
GRU	**Geotechnical Risk & Uncertainty**
HEC-FDA	**Hydrologic Engineering Center Flood Damage Analysis model**
H&H	**Hydrology and Hydraulics**
I-5	**Interstate 5**
IDC	**Interest During Construction**
IP	**Index Point**
IWR	**Institute for Water Resources**
JFP	**Joint Federal Project**
LRR	**Limited Reevaluation Report**
MFR	**Multiple-Family Residence**
MH	**Mobile Home**
NA1	**No Action 1 Condition**
NA2	**No Action 2 Condition**
NA3	**No Action 3 Condition**
NADA	**National Auto Dealer Association**
Natomas	**A suburb within the Sacramento city limits, just north of downtown Sacramento and in the Natomas Basin.**
NCC	**Natomas Cross Canal**
NED	**National Economic Development**
NEMDC	**Natomas East Main Drainage Canal**
NPACR	**Natomas Post-Authorization Change Report**
OSE	**Other Social Effects**
PAC	**Post Authorization Change**
Report	
PDT	**Project Delivery Team**
PMF	**Probable Maximum Flood**
Reclamation	**U.S. Department of the Interior, Bureau of Reclamation**
RED	**Regional Economic Development**
RM	**River Mile**
ROI	**Region of Influence**
SAFCA	**Sacramento Area Flood Control Agency**
SFR	**Single-Family Residence**
SIR	**Supplemental Information Report**
SP	**Selected Plan**
SR	**Sacramento River**
TOL	**Top of Levee**
USACE	**U.S. Army Corps of Engineers**
WO1	**Without-Project Condition 1**
WO2	**Without-Project Condition 2**
WO3	**Without-Project Condition 3**
WOPC	**Without-Project Condition**
WRDA	**Water Resources Development Act**
WSE	**Water Surface Elevation**
WSP	**Water Surface Profile**

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CHAPTER 1
INTRODUCTION

1.1 NATOMAS POST-AUTHORIZATION CHANGE REPORT (NPACR)

Previous project delivery team (PDT) study efforts for the Natomas Basin area were conducted under a Natomas General Reevaluation Report (GRR). Initial findings (e.g., increased costs and scope of levee improvements for the Natomas Basin) from some of these efforts coupled with findings (e.g., potential through- and under seepage issues with the Sacramento River east levees downstream of the American River, which could lead to failure and major flooding in the city of Sacramento) from other hydraulic and geotechnical studies resulted in the Natomas Basin study efforts being included in a broader American River Watershed Common Features GRR so that potential FRM issues could be more fully addressed from a system approach and to reduce flood risk to the entire city of Sacramento (including the Natomas Basin). An interim ARWCF GRR document evaluating without-project conditions was completed in 2009; an F3 Conference was held in March of 2009.

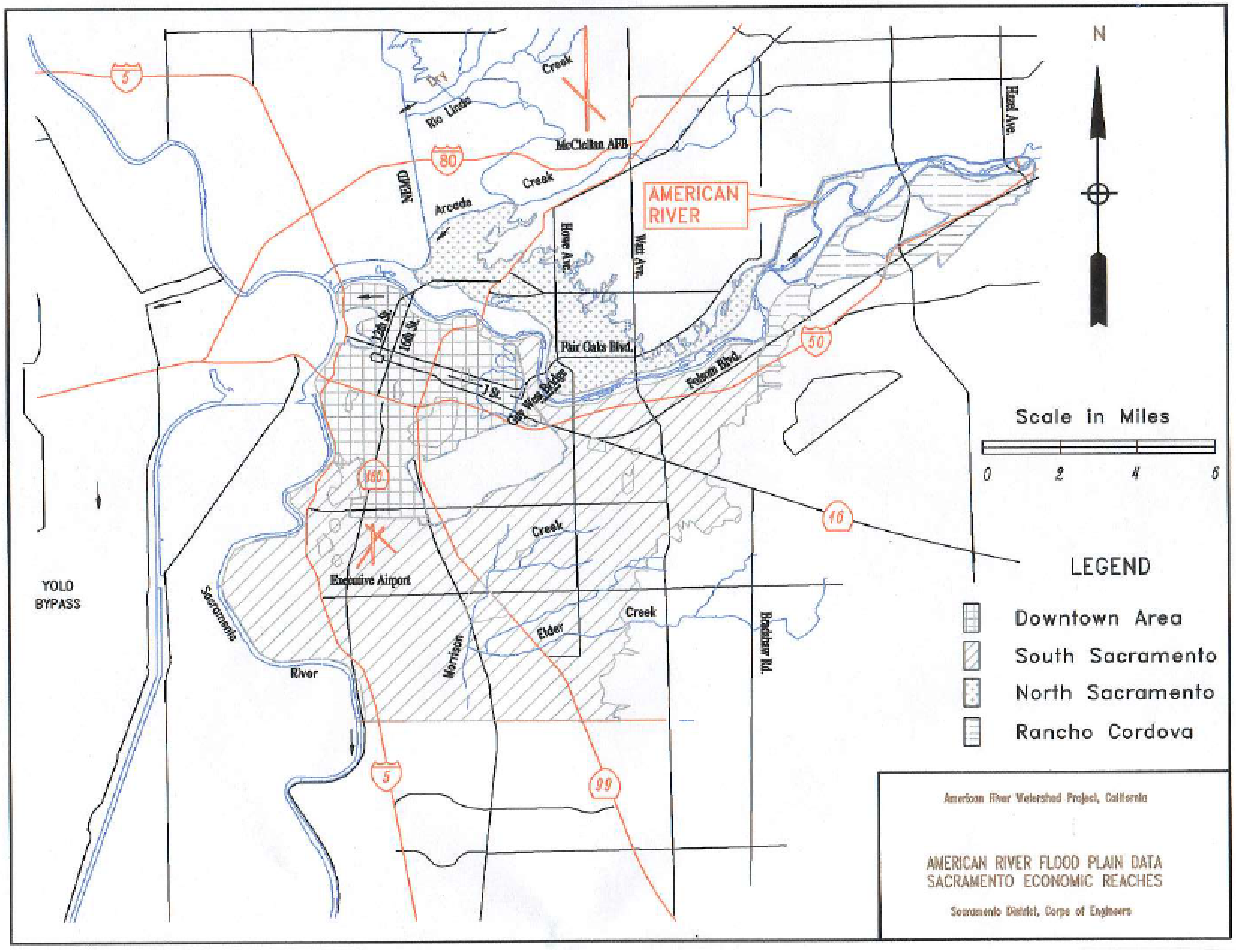
Subsequent to the F3 Conference, it was decided that work for the Natomas Basin would be fast-tracked and the Basin area would be studied separately from the rest of the ARWCF project area. The study would be conducted under a Post-Authorization Change (PAC) and would be documented in a Natomas Post-Authorization Change Report (NPACR).

This Economic Appendix to the Natomas Post-Authorization Change Report (NPACR) documents the economic analysis performed for the Natomas Basin economic impact area (EIA). The analysis documented in this appendix addresses flood risk (probability of flooding and consequences of flooding) in the Natomas Basin, expected benefits associated with potential flood risk management (FRM) alternatives, and residual risk associated with these potential alternatives.

1.2 BACKGROUND – AMERICAN RIVER WATERSHED

In order to provide a broader picture of the flood-related issues facing the Sacramento metropolitan area as well as to provide a more complete context in which to understand the flooding issues associated with the Natomas Basin, a brief background and flooding history of the entire ARWCF study area is described in the following paragraphs. For reference purposes, Figure 1-1 shows the ARWCF study area, including the Natomas Basin area.

Figure 1-1
MAP OF ENTIRE ARWCF STUDY AREA



The American River Watershed drains about 2,100 square miles northeast of Sacramento and includes portions of Placer, El Dorado, and Sacramento counties. Runoff from this basin flows through Folsom Reservoir and passes through Sacramento within a system of levees. Folsom Dam and Reservoir, located on the American River about 25 miles east of the city of Sacramento, form a multipurpose water project. The project was constructed by the U.S. Army Corps of Engineers (USACE) and is operated by the U.S. Department of the Interior, Bureau of Reclamation (Reclamation) as part of the Central Valley Project (CVP). The reservoir has a normal full-pool storage capacity of 975,000 acre-feet with a minimum seasonally designated flood control storage space of 400,000 acre-feet.

In February 1986, major storms in Northern California caused record flood flows in the American River Watershed. Outflows from Folsom Reservoir, together with high flows in the Sacramento River, caused water levels to rise above the safety margin on levees protecting the Sacramento area. The effects of the 1986 storms raised concerns over the adequacy of the existing flood control system. This in turn led to a series of study authorizations and investigations into the need to provide additional flood protection to the Sacramento area. The major reports documenting completed investigations are summarized in Section 2. Some of the key milestones in this process included:

- **1986** – Severe storms in Northern California raise concern over level of flood protection in watershed
- **1988** – Continuing Appropriations Act funds American River Watershed Investigation
- **1989** – Sacramento Area Flood Control Agency (SAFCA) is formed
- **1991** – American River Watershed Investigation Feasibility Report and Environmental Impact Statement/Environmental Impact Report (EIS/EIR) recommends levee improvements at Natomas and a detention dam at Auburn
- **1993** – Defense Appropriations Act authorized Natomas levee improvements proposed in the 1991 Feasibility Report and directs USACE to conduct new flood risk management (FRM) studies, including flood management at Folsom Dam, rejecting the proposed detention dam at Auburn
- **1996** – American River Watershed, California, Supplemental Information Report (SIR) and EIS/EIR identifies three plans to reduce flood risk: Folsom Dam Modifications, Stepped Release Plan, and Auburn Detention Dam Plan, which was identified as the National Economic Development (NED) Plan
- **1996** – Water Resources Development Act (WRDA) of 1996 again rejects proposed detention dam at Auburn but authorizes additional levee improvements that were common to all three plans (referred to as "Common Features") in the 1996 SIR
- **1997** – Severe storms again highlight flooding risk in the watershed
- **1998** – SAFCA releases Folsom Dam Modification Report, New Outlets Plan, that presents alternatives to lower the spillways under the Folsom Dam Modifications Plan from the 1996 SIR

- **1999** – WRDA of 1999 authorizes the Folsom Modification Project as identified in the 1996 SIR and as modified by SACFA and also directs the USACE to conduct further FRM studies
- **2001** – Common Features Limited Reevaluation Report (LRR) identifies improvements providing additional benefits and project performance to the Lower American River. Section 366 of WRDA 1999 further modifies the WRDA 1996 authorization in regard to Common Features with specific direction related to levee modifications. Work directed in this section of WRDA is important to the current effort because it would allow for Folsom Dam to increase outflows to 160,000 cubic feet per second (cfs) for a sustained time (currently being evaluated) without a high probability of levee failure along the Lower American River.
- **2002** – American River Watershed, California, Long-Term Study and EIS/EIR recommend raising Folsom Dam by 7 feet (referred to as "Folsom Modification Project").
- **2003** – Energy and Water Development Appropriations Act for 2004 authorizes a 7-foot raise of Folsom Dam
- **2003** – Folsom Dam Modification Project LRR and Environmental Assessment (EA)/EIS reconcile conflicts between the authorized Folsom Modification Project and recommendations in the 2002 Long-Term Study Feasibility Report
- **2005** – Energy and Water Development Appropriations Act for 2006 directs the USACE and Reclamation to collaborate on FRM planning by the USACE and dam safety efforts by Reclamation at Folsom Dam.
- **2005** – The limitations of the existing flood control system in the Sacramento area and the need to increase the level of flood protection receive increased public attention in the aftermath of the 2005 Gulf Coast hurricanes.
- **2007** – American River Watershed Project, California, Folsom Modification and Folsom Dam Raise Projects, Post Authorization Change (PAC) Report documents recommended changes to two authorized projects: the Folsom Modification Project and the Folsom Dam Raise Project, and evaluates a Joint Federal Project (JFP) that addresses both FRM and dam safety objectives.
- **2007** – American River Watershed Project, California; Folsom Modification and Folsom Dam Raise Projects; Economic Reevaluation Report (ERR) documents the analysis of potential damages associated with flood risk and the economic benefits and project performance statistics associated with alternative FRM alternatives at Folsom Dam for the American River Watershed. The analysis revised the PAC report with a current inventory and an increased emphasis on the Regional Economic Development (RED) and Other Social Effects (OSE) accounts.

The new floodplain inventory for the ERR analysis was a primary aspect of the update from the PAC analysis. (Another important difference between the PAC and ERR was that the ERR considered the RED and OSE accounts in addition to the NED account.) The revised inventory included an expanded floodplain area and additional economic impact areas. These allowed for more precise and accurate economic modeling using the HEC-FDA program. Additionally, the economic modeling used for the 2007 ERR incorporated new non-residential content damage curves and new stage-damage curves, which were computed within the HEC-FDA program. Computing stage-damage curves directly within HEC-FDA eliminated the need to use additional, external software (@RISK) to compute stage-damage curves with uncertainty.

- **2009** – American River Watershed, Common Features GRR, Without-project (F3) Economic Appendix was completed for the larger Sacramento study area.

Unlike in the ERR, which only considered flooding from the American River, the GRR also considered flooding from the Sacramento River and therefore evaluated expected annual flood damages for the Natomas Basin impact area. The GRR also used updated hydrologic, hydraulic, and geotechnical data, a current version of the HEC-FDA program, and the same economic inventory developed for the 2007 ERR. The Economic Appendix to the GRR described the methodologies, data, assumptions, and results of the economic analysis and summarized the without-project flood risk (probability of flooding and consequences of flooding) for 18 economic impact areas and for multiple without-project conditions. These results were presented at an F3 conference in March 2009. The full ARCF GRR is being completed concurrently with this NPACR. The GRR, when completed, will include analysis of the flood risk for the three major areas within the Lower American River Watershed study area – the American River North and American River South areas, as well as the Natomas Basin area.

1.3 PURPOSE AND SCOPE

The purpose of this Economic Appendix to the NPACR is to present the economic analysis performed for the Natomas Basin economic impact area. This appendix describes the methodologies, assumptions, data and results of the analysis, and summarizes the flood risk under the without-project condition, the residual flood risk associated with potential alternatives, and the economic benefits associated with these alternatives. This appendix also describes the benefit-to-cost and net benefit analyses performed to determine feasibility and optimization of various alternatives, respectively.

This Economic Appendix is intended to:

- Document the current hydrologic data used in the economic analysis for the Natomas Basin impact area under both the without-project and with-project conditions
- Document the current hydraulic floodplains and HEC-FDA hydraulic input data used in the economic analysis for the Natomas Basin impact area under both the without-project and with-project conditions
- Document the current geotechnical HEC-FDA input data (i.e., geotechnical levee functions which show the relationship between water surface on the river versus the probability of levee failure, or "geotechnical risk and uncertainty curves" (GRU) as they are referred to throughout this appendix) used in the economic analysis for the Natomas Basin impact area under both the without-project and with-project conditions

- Document the economic methodologies, major assumptions, models, and data used in the economic analysis for the Natomas Basin impact area under both the without-project and with-project conditions
- Document the economic damage/benefit categories considered in the economic analysis for the Natomas Basin impact area under both the without-project and with-project conditions
- Document the results (detailed HEC-FDA output files and EAD/AEP results) of the HEC-FDA model runs for the Natomas Basin impact area under both the without-project and with-project conditions
- Document the screening-level cost estimates used to perform the net benefit and benefit-to-cost analyses
- Describe the approach used to perform the with-project benefits analysis and document the results of the with-project benefit, net benefit, and benefit-to-cost analyses used to determine plan optimization and feasibility
- Describe additional analyses that will be conducted for future studies and which were not considered in this NPACR

1.4 ORGANIZATION AND CONTENTS

Chapter 1 of this appendix provides an overview of the authorizations, investigations, and resulting reports leading up to the Natomas Post-Authorization Change Report (NPACR). The chapter also outlines the purpose and scope of the economic analysis, and provides an overview of the organization and contents of the NPACR Economic Appendix.

Chapter 2 provides background information on economic analyses documented in prior reports that evaluated FRM benefits on the American and Sacramento Rivers.

Chapter 3 describes the Natomas Basin impact area and provides a detailed compilation of the structure inventory and valuations (structures and contents) used as the base inventory for the economic analysis.

Chapter 4 describes the economic and risk analysis methodologies used in this NPACR, outlines the major assumptions used in the economic analysis, and summarizes the engineering data (hydrologic, hydraulic, and geotechnical) and economic data (e.g., economic uncertainties, depth-percent damage functions) used in the economic analysis; this chapter also outlines the NED damage/benefit categories considered in the analysis.

Chapter 5 provides a detailed report of the HEC-FDA results for each index point under the without-project condition; these results include expected annual damages (EAD), annual exceedance probability (AEP), and single-event damages, all of which were used to guide the subsequent with-project benefit analysis documented in Chapter 6; the delineation of the Natomas Basin impact area into two separate impact area (major and minor) is also explained.

Chapter 6 summarizes the HEC-FDA base model results (per reach/index point) for the various with-project geotechnical fixes, outlines the order of fixes (Levee Reach Improvements) selected based on the without-project and with-project HEC-FDA base model results, describes the conceptual approach used to perform the with-project benefit analysis, explains in detail the steps taken and factors considered to perform the with-project analysis, and reports the results of each levee reach improvement in terms of Basin-wide AEP, residual EAD, and annual benefits.

Chapter 7A presents the net benefit and benefit-to-cost analyses using the HEC-FDA results as documented in Chapters 5 and 6. Chapter 7a summarizes the costs used in the net benefit analysis and reports the net benefits and benefit-to-cost ratios for each levee reach improvement. **It is important to note that the net benefit and benefit-to-cost analyses and results reported in Chapter 7A are not the "final" results used as the basis for plan formulation. Chapter 7B presents the net benefits and benefit-to-cost analyses and results used for the basis for plan formulation.**

Chapter 7B presents the with-project net benefit, and benefit-to-cost analyses and results used as the basis for plan formulation; these results are also what are reported in the Executive Summary of this Appendix. The results documented in Chapter 7B were obtained through "post-processing" of the HEC-FDA output presented in Chapters 5, by repeating the steps of the with-project analysis as described in Chapter 6, and by taking the costs used in the net benefit and benefit-to-cost analyses documented in Chapter 7A. This "post-processing" of the HEC-FDA output was completed in order to adjust expected annual damages and benefits to account for rational human behavior. A model was developed to account for human behavior in the form of assumptions regarding a rebuild period and a loss of inventory stock in the floodplain after a flood event occurs in the Natomas Basin. The model was developed and the EAD and benefit adjustments were made in response to agency technical review (ATR) comments.

Chapter 8 describes the residual risk associated with future development in the Natomas Basin.

Chapter 9 describes any future analyses that will be conducted in the GRR, including those associated with additional NED benefit categories (e.g., emergency costs, traffic disruption costs, and airport-related transportation costs) as well as those related to the Regional Economic Development (RED) and Other Social Effects (OSE) accounts.

Chapter 10 lists any references used to write this economic appendix.

Enclosure 1 contains the without-project floodplain plates. Suites of floodplains comprising the 2-yr to 500-yr flood events are presented for each of the nine Natomas Basin index points used in the economic analysis.

Enclosure 2 includes the HEC-FDA input data used in the analysis as well as the more detailed HEC-FDA output results not contained within the main economic appendix.

Enclosure 3 includes the Economic Memorandum for Record (MFR) that documents the sensitivity analysis performed subsequent to the ARCF F3 Conference regarding upstream levee performance and human intervention assumptions and their effects on the economic analysis.

Enclosure 4 includes information on the utility program used to convert FLO-2D output data into an HEC-FDA-importable format.

Enclosure 5 includes an information paper that describes the technique used to incorporate additional hydraulic stage uncertainty within the HEC-FDA model when only exceedance probability-stage curves are used.

Enclosure 6 contains cost tables used for the preliminary screening of alternatives; these tables include more detailed cost information than what is presented in Chapter 7a, *Net Benefit and Benefit-to-Cost Analyses*.

Enclosure 7 contains the documentation provided to the USACE Planning Center of Expertise (PCX)/Model Certification for Flood Risk Management (FRM) in San Francisco. This documentation was created to obtain approval for use of the @Risk model.

Enclosure 8 contains information on the dollar-per-square foot values used as the basis to compute depreciated replacement values for both residential and non-residential structure types. These values were developed by Clark-Wolcott, Inc., Real Estate Analysts and Consultants.

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CHAPTER 2
ECONOMIC ANALYSIS IN PRIOR REPORTS

Section 1.1 of this appendix provided a summary timeline of major study and project authorizations and investigations associated with the American River Watershed Study. Much of the economic data in previous American River Watershed planning reports trace their beginnings to the initial 1991 American River Watershed Investigation Feasibility Report. The following sections of this chapter describe changes in economic analysis methodologies, data, and conclusions from each study. Many of the studies described below did not evaluate the Natomas Basin area. However, general knowledge of the analyses, results, and recommendations associated with previous American River Watershed studies will help to place into perspective how the Natomas Basin flooding issues have come into play in relation to the flooding issues facing the Sacramento metropolitan region as a whole.

2.1 AMERICAN RIVER WATERSHED INVESTIGATION FEASIBILITY REPORT, 1991

The recommended plan in the 1991 feasibility report was a detention dam at Auburn providing more than 500,000 acre-feet of flood storage and reducing the probability of flooding in Sacramento to a 1-in-200 chance in any given year (using pre-risk based evaluation methodologies). This project was not authorized by Congress and two projects to follow were adopted to help reduce flood damages in the Sacramento Area. These were the SAFCA North Area Levee Project (Natomas) and Re-operation of Folsom Dam from 400,000 acre-foot fixed space to a variable 400,000/670,000 acre-feet. The basic floodplain and economic inventory data from this study was used for developing the economic databases for all subsequent studies up to but not including the ERR.

Only limited data developed for this 1991 Feasibility Report was used in the 2007 ERR, 2009 ARCF GRR, and this current NPACR analysis. The nonresidential structural depth-percent damage functions developed for the long duration flooding conditions from this 1991 study were used in modifying the Federal Emergency Management Agency (FEMA) curves in the 2007 ERR, 2009 GRR, and this NPACR. All other data was dropped in favor of either more detailed and/or current information.

2.2 AMERICAN RIVER WATERSHED SUPPLEMENTAL INFORMATION REPORT (SIR), 1996

The 1996 SIR was the first document to use risk analysis for determining economic benefits on the American River. The SIR identified three final alternatives: the Stepped Release, the Folsom Modifications, and the Detention Dam plans. The Detention Dam, which reduced the probability of flooding along the American River to less than a 1-in-500 chance of flooding in any given year, was determined to be the NED Plan but was not recommended in the Chief's report. Instead, the less controversial Common Features was authorized. This alternative included 'features' that were part of all three final alternatives and would not preclude selection of anyone of the three alternatives in the future. Completion of the Common Features was expected at the time to provide Sacramento with '100-year protection,' terminology no longer used in the USACE guidance.

In 1999, the WRDA authorized additional levee improvements to supplement the 1996 Common Features and authorized a modified version of the Folsom Modifications Plan identified in the 1996 SIR. WRDA 99 also authorized additional study of FRM measures beyond the Folsom Modifications.

For economic analysis, three documents resulted from this authorization:

- Common Features LRR, completed in 2001
- American River Long-Term Study, completed in 2002
- Folsom Modifications LRR, revised November 2003

The Common Features was important in defining the future without-project condition for the ERR study. The levee failure probabilities are based on the completion of the ARCF project. Both the Long-Term Study and the Folsom Modifications are relevant in defining the final array of alternatives to include dam outlets and potential dam raises. But the economic, hydrologic, hydraulic, and geotechnical inputs applied in these prior studies were not used in the economic model for the ERR. In 2008, the need to reevaluate the ARCF due to changes in problem identification, and increasing scope and cost became apparent. Therefore, as a part of the 2009 ARCF GRR, the benefits and associated performance of the recommended plan for the ERR without the ARCF in place were analyzed.

2.3 AMERICAN RIVER WATERSHED COMMON FEATURES LRR, 2001

With completion of the Common Features Project, it is estimated that the outflows from Folsom Dam could be increased to as much as 160,000 cfs for a sustained time without a high probability of levee failure along the American River. The improvements include raising a small portion of the left-bank levee upstream of Mayhew Drain, raising a small portion of the right-bank levee downstream of Howe Avenue, installing gates and pumps to the Mayhew Drain area, and performing additional levee work to improve conditions in the Natomas Basin.

In the LRR, the analysis split the Common Features into two areas:

- The Lower American River levee improvements, which is functional, and enables the American River to pass the 100-year event
- The Natomas Basin area, which required significant reformulation and development of a GRR; the 2009 ARCF GRR was expanded to include the Natomas Basin area.

The Lower American River first costs were estimated in the 2001 LRR at $158 million, with $14.2 million in annual benefits and $12.7 million in annual costs. The additional net benefits for the Lower American area were $1.6 million, with a benefit-to-cost ratio of 1.1 to 1, and an annual exceedance probability (AEP) of 0.0099.

The 2001 LRR served as the basis for the levee performance assumptions in the ERR. But, because the economic, hydrologic, hydraulic, and geotechnical inputs are not the same, direct comparison of the damages, benefits, and project performance between the Common Features 2001 LRR, the 2007 ERR, and the still-to-be completed GRR is not practical.

2.4 AMERICAN RIVER WATERSHED LONG-TERM STUDY, 2002

The purpose of the Long-Term Study was to address the residual flood risk remaining once the Folsom Modifications was completed. The study looked at an array of FRM alternatives that include dam raises ranging from 3.5 feet to 12 feet. The Long-Term Study determined that a 7-foot raise of Folsom Dam, which would provide both additional FRM improvements and dam safety improvements by enabling the facility to pass 100 percent of the probable maximum flood (PMF), would be the optimal (non-Auburn Dam) economic solution.

Recommendations from the 2002 Long-Term Study that were authorized by Congress in the Energy and Water Development Appropriations Act for fiscal year 2004 included raising the dam by 7 feet (mini-raise), spillway modifications at L.L. Anderson Dam, a permanent bridge downstream from Folsom Dam, and modification of emergency release operations to permit surcharge. First costs for this project were estimated at around $249 million, with $128 million allocated to FRM. Annual FRM benefits of $19 million and annual FRM costs of $10 million provided a benefit-to-cost ratio of 1.9 to 1. This project was estimated at the time to reduce flooding to a 0.0057 AEP[2].

As with other studies before the ERR, the inputs used in the economic modeling for the Long-Term Study were not used in economic modeling for the ERR. Of relevance to the still-to be-completed ARCF GRR will be the two potential project components evaluated in the ERR, the 3.5-foot and the 7.0-foot dam raises. In the ARCF GRR, the 3.5-foot raise will be analyzed by comparing two separate without-project conditions.[3] The GRR will evaluate the benefits of the raise and will confirm whether or not the additional improvements are still justified under the changed without-project conditions.

2.5 AMERICAN RIVER WATERSHED FOLSOM MODIFICATIONS LRR, 2003

The 2003 LRR reconciled conflicts between the authorized Folsom Modifications Project elements and recommendations in the 2002 Long-Term Study. As directed by Congress in WRDA 1999, the plan identified in the 2002 Long-Term Study included raising Folsom Dam, modifying downstream levee improvements, and implementing other elements necessary to meet current Federal dam safety standards. These authorized features, which make up the Folsom Dam Raise Project, carry design implications for the previously authorized Folsom Modifications Project.

[2] In the Long-Term Study, advanced forecast releases were evaluated as part of the alternatives that would have an impact on project performance. With the consideration of advance release, project performance (as measured by AEP) increased to 0.0047. Advance release was dropped as part of the evaluation for the ERR.

[3] In the upcoming ARCF GRR, a without-project condition, which assumes that the Authorized Common Features (ACF) and Folsom Modifications are in place, will be evaluated. This condition will be compared to a separate without-project condition, which assumes that the ACF, Folsom Modifications, and the 3.5 foot mini-raise are in place.

The 2003 LRR refined the elements related to increasing release capacity to be consistent with gate modifications in the 2002 Long-Term Study. These changes included the following:

- Construct two new upper-tier outlets
- Enlarge the four existing upper-tier outlets to 9 feet, 4 inches, by 14 feet, and the four existing lower-tier outlets to 9 feet, 4 inches, by 12 feet
- Modify the existing main spillway stilling basin

In addition, for the surcharge storage aspect of the project, the three emergency spillway tainter gates would be replaced with larger gates, as authorized, but the design would permit future expansion of these gates should the Folsom Dam Raise Project be authorized and implemented.

The Folsom Modifications revised economics report (November 2003) identified the recommended project as new and enlarged existing outlets capable of releases of 115,000 cubic feet per second (cfs) and improvements allowing for the use of surcharge storage up to Elevation 474 feet. First costs for this project were estimated at around $214 million with annual benefits of $32 million and annual costs of $16 million providing a benefit-to-cost ratio of 2.0 to 1. This project was estimated at the time to reduce the annual exceedance probability of flooding to 0.0071.

During the construction proposal process, the cost estimates exceeded the fully funded authorized costs (Section 902 limit). Consequently, dam operations and performance and alternate structural methods to achieve the FRM improvements provided by the outlet modifications were reexamined. Subsequent studies also found that modification of the two outboard lower-tier outlets was infeasible, and offered only a marginal increase in performance.

The ERR evaluated LRR construction measures (eight of the total 10 outlets described) that were included as alternatives evaluated in the ERR. The GRR will evaluate the additional benefits of the Folsom Dam modifications (outlined in the 2007 ERR) by comparing two separate without-project conditions.[4]

2.6 AMERICAN RIVER WATERSHED PAC REPORT, 2007

The purpose of the PAC report was to document changes to two authorized projects: the Folsom Modifications Project and the Folsom Dam Raise Project. Both projects share an objective of improving flood management on the Lower American River, primarily through structural modifications to the existing Folsom Dam.

In the PAC report, project elements from both the Folsom Modifications and the Long-Term Study were considered not only for the purpose of flood risk management but also for dam safety. During the design refinements for Folsom Modifications, it was believed that due to significant increases in the cost estimates that the authorized project may not be optimal or even economically feasible. During this preliminary analysis, it appeared that adding operational gates

[4] In order to evaluate the benefits of the Folsom Modifications, one without-project condition, which assumes that the ACF is in place, will be compared to another without-project condition, which assumes that the ACF and Folsom Modifications are in place.

to the proposed Reclamation dam safety auxiliary spillway may provide a more efficient way to meet two project purposes.

The Folsom Dam Joint Federal Project (JFP) was intended to meet not only the goals of the USACE but also the Bureau of Reclamation and the local sponsor as well; its analysis became one of the main focuses of the PAC. As mentioned, the PAC economic analysis included elements of three authorizations, the Folsom Modifications, the Dam Raise, and Reclamation's dam safety project. The combined project's objectives in terms of economic outputs and project performance were: (1) Reduce flood damages as effectively and efficiently as possible within a limited schedule and without complete reformulation, (2) safely pass the 200-year design flow event without levee failure (based on design non-risk-based criteria), and (3) pass the PMF without placing the dam structure in danger of failure.

The PAC and ERR evaluated a final array of four action alternatives. Alternative C, as described below, was the recommended plan from both studies. Alternative C included an auxiliary spillway containing six submerged tainter gates, a 3.5-foot dam raise, and three emergency spillway gate replacements. The recommended plan is summarized in Table 2-1 below.

Table 2-1
Benefits, Costs, and Project Performance In
The 2007 Post Authorization Change Report

SUMMARY CRITERIA	RECOMMENDED PLAN
Performance	
Passes PMF	Yes
Probability of Flooding AEP	0.0054
Design Flood Event (non-risked-based criteria)	240
First Cost (FRM only, $ millions)	788
Annual Cost (FRM only, $ millions)	40.0
Annual Benefits (FRM, $ millions)	107.1
Net Benefits (FRM, $ millions)	67.1
Benefit-Cost Ratio	2.7
Residual Damages ($ millions)	91.1
Percent Damage Reduction	54

Note: Values in October 2006 prices.
AEP = annual exceedance probability
FRM = flood risk management

2.7 AMERICAN RIVER WATERSHED ERR REPORT, 2007

The main purpose of the ERR was to affirm that the recommended plan from the PAC was economically feasible and was the most efficient among the array of alternatives considered. The focus of the ERR was to revise the economics and the HEC-FDA model (including hydrologic and hydraulic data) in hopes of obtaining a more accurate estimate of flood risk for the study area.

The 2007 ERR quantified NED benefits based on 2007 local conditions. Many factors contributed to the improvement of the economic analysis in the 2007 ERR as compared to previous analyses. These include more data, more precise data, improved methodologies, and additional analyses. Some of these are described below:

- The 2007 ERR HEC-FDA economic model contained a new economic inventory; the structures and contents of the new 2007 floodplain were inventoried and valued; locality-specific non-residential contents were valued; ground surveys were conducted for a sample of single-family residential (SFR) structures and a field survey was conducted for 100 percent of the multiple-family residential (MFR), public, commercial, and industrial structures; depreciation and building quality data were collected through numerous field visits; the total value of structures and contents potentially at risk was estimated at more than $58 billion while expected annual damages (EAD) for the without-project condition were estimated at $277 million. (This value does not include the Natomas Basin area.)

- Stage-damage curves with uncertainty were computed directly within the HEC-FDA model and utilized newly-developed non-residential content damage curves.

- Whereas in the 1991 American River Watershed Investigation Feasibility Report only one floodplain was used in the analysis, the analysis for the 2007 ERR used seven event-based floodplains.

- The 2007 ERR modeled 17 economic impact areas (Natomas Basin was not included); the increase in the number of impact areas allowed for more precise and accurate HEC-FDA modeling.

- A new methodology that allowed for the direct import of geo-referenced floodplain data originating from the hydraulic engineering models (HEC-RAS and FLO-2D) directly into the HEC-FDA model was used; this enabled the computation of stage-damage curves directly within HEC-FDA instead of using an external software program to compute stage-damage curves.

- For the ERR, an expert elicitation panel was convened to identify non-residential structure categories and estimate their content values. Nineteen non-residential categories were identified. Content values (dollar per square foot) were computed and depth-percent damage curves were developed for each structure category.

- A Regional Economic Development (RED) analysis was completed for the 2007 ERR, which provided detailed insights into the most likely regional impacts of the 200-yr and

500-yr flood events in the Sacramento region. The RED analysis was completed using the IMPLAN model.

- An Other Social Effects (OSE) analysis was completed for the 2007 ERR, which described the potential effects of the Selected Plan (SP) on the Sacramento County urban area as well as the potential effects of hypothetical 200-yr and 500-year flood events (from the American River) on the Sacramento County urban area.

The 2007 ERR evaluated the same four alternatives that were evaluated for the PAC. These are described in more detail below. The recommended plan for the ERR was Alternative C. Benefits are shown in Table 2-2 and Figure 2-1 below.

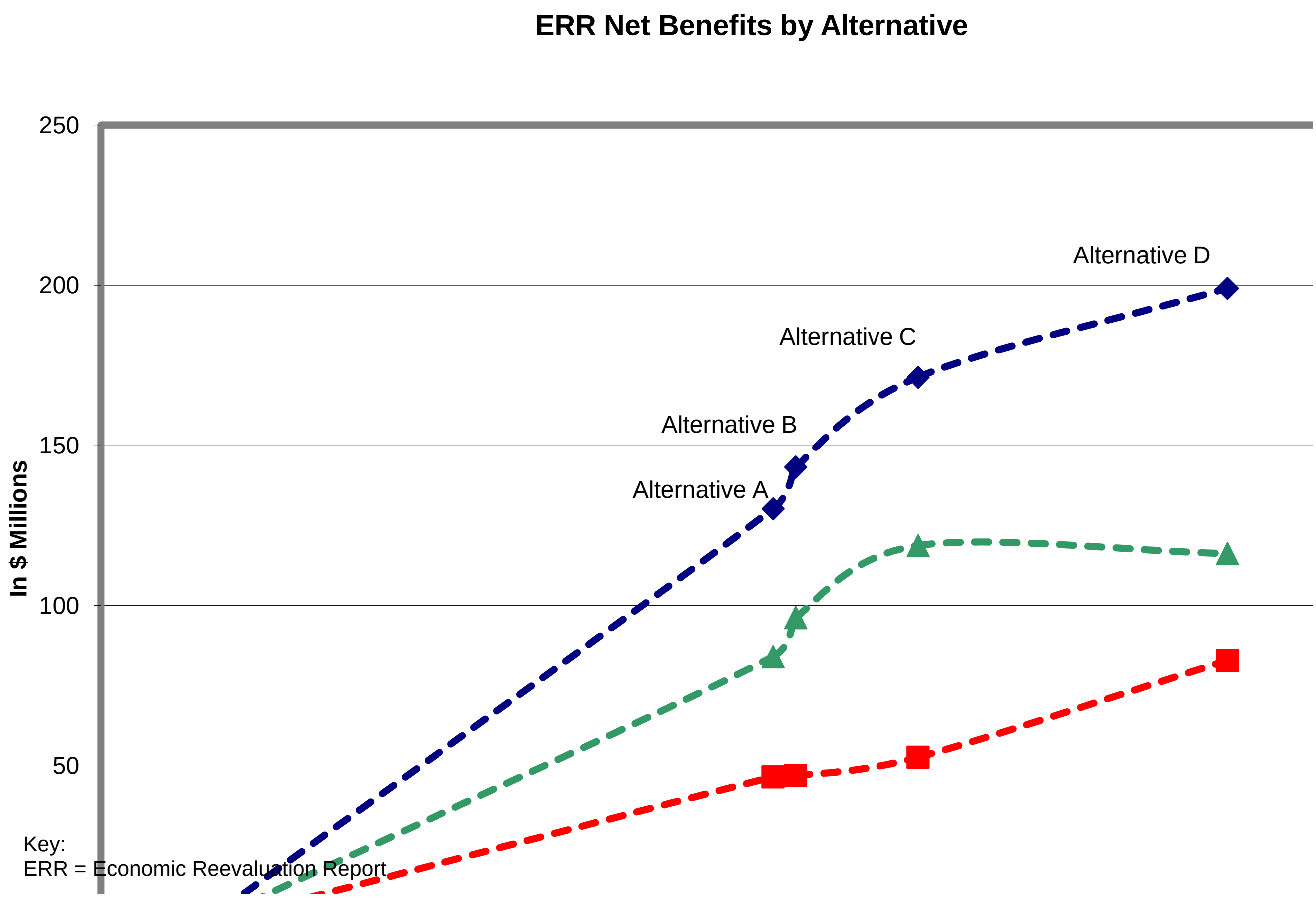
- Alternative A – Eight Main Dam Outlets and Fuseplug Spillway
- Alternative B – Six Submerged Tainter Gate Auxiliary Spillway
- Alternative C – Six Submerged Tainter Gate Auxiliary Spillway, 3.5-Foot Dam Raise, and Three Emergency Spillway Gate Replacements
- Alternative D – Six Submerged Tainter Gate Auxiliary Spillway, 7-Foot Dam Raise, and Eight Emergency and Service Spillway Gate Replacements

Table 2-2
ERR Benefit-to-Cost Analysis per Alternative

ITEM	ALT A	ALT B	ALT C	ALT D
Total Project First Costs	650.4	918.1	1,042.1	1,555.6
Annual Benefits (2018-2067)	98.1	116.3	143.8	172.2
Annual Benefits-During Construction (2012-2017)	32.6	26.9	29.9	26.9
Total Annual Flood Damage Reduction Benefits	130.7	143.2	173.7	199.1
Annual Costs	46.6	62.3	68.0	98.2
Savings in Avoided Dam Safety Annual Costs[1]	0	-15.3	-15.3	-15.3
Net Flood Damage Reduction Annual Costs	46.6	47.0	52.7	82.9
Net Benefits	84.1	96.2	121.0	116.2
Benefits to Cost Ratio	2.8	3.0	3.3	2.4

Notes:
1) Values are in millions and are based on October 2007 prices, a 50-year period of analysis, and a 4.875 percent interest rate
2) Alternatives B, C, and D will eliminate the need for construction of the dam safety only fuseplug as part of the future without-project condition. The $15.3 million reduction in dam safety annual costs was taken as a savings from the net flood risk management annual costs.

Figure 2-1
NET BENEFIT, ANNUAL BENEFIT, AND ANNUAL COST CURVES



2.8 AMERICAN RIVER WATERSHED GRR REPORT

The ARCF GRR Report is currently being completed as a separate document from the NPACR. The GRR, part of which was completed in March of 2009 to document the without-project condition(s), will continue to focus on the major areas within the Lower American River Watershed, including the American River North Basin, the American River South Basin, and the Natomas Basin, the focus of this report.

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CHAPTER 3
NATOMAS BASIN AND ECONOMIC INVENTORY BASE DATA

3.1 AMERICAN RIVER COMMON FEATURES STUDY AREA

The without-project analysis completed in 2009 as part of the GRR included 18 economic impact areas (EIA) within three major basins: the American River – North (4 impact areas) basin, the American River – South (13 impact areas) basin, and the Natomas Basin (which is its own impact area). Table 3-1 below lists all of the impact areas included in the 2009 analysis and Figure 3-1 shows the entire ARCF study area delineated by the 18 impact areas.

Table 3-1
Economic Impact Areas by Basin

Economic Impact Area	Total Acres	Total Square Miles
AR-NORTH		
ARD 13: American River Drive	5,220	8.2
AE 14: Arden/Expo	6,080	9.5
NS 15: North Sacramento	3,750	5.8
DC 16 Dry Creek	9,290	14.5
Total Basin	**24,340**	**38.0**
AR-SOUTH		
PG 1: Pocket/Greenhaven	4,160	6.5
FM 2: Fruitridge/Meadowview	13,270	20.7
LP 3: Land Park	4,100	6.4
DS 4: Downtown Sacramento	3,830	6.0
ES 5: East Sacramento	3,800	5.9
RCA 6a: Rancho Cordova West	6,110	9.5
RCA 6b: Rancho Cordova East		
GR 7: Gold River	1,870	2.9
SF 8: South I-50/Florin/Watt	13,500	21.1
FS 9: Florin South	10,420	16.3
MA 10: Mather North	8,550	13.4
RMT 11: Rosemont	9,220	14.4
SM 17: South of Morisson Creek	67,540	105.5
Total Basin	**146,370**	**228.6**
NATOMAS		
Natomas	53,570	83.7
Total Basin	**53,570**	**83.7**
TOTAL AREA (All Basins)	**224,280**	**350.3**

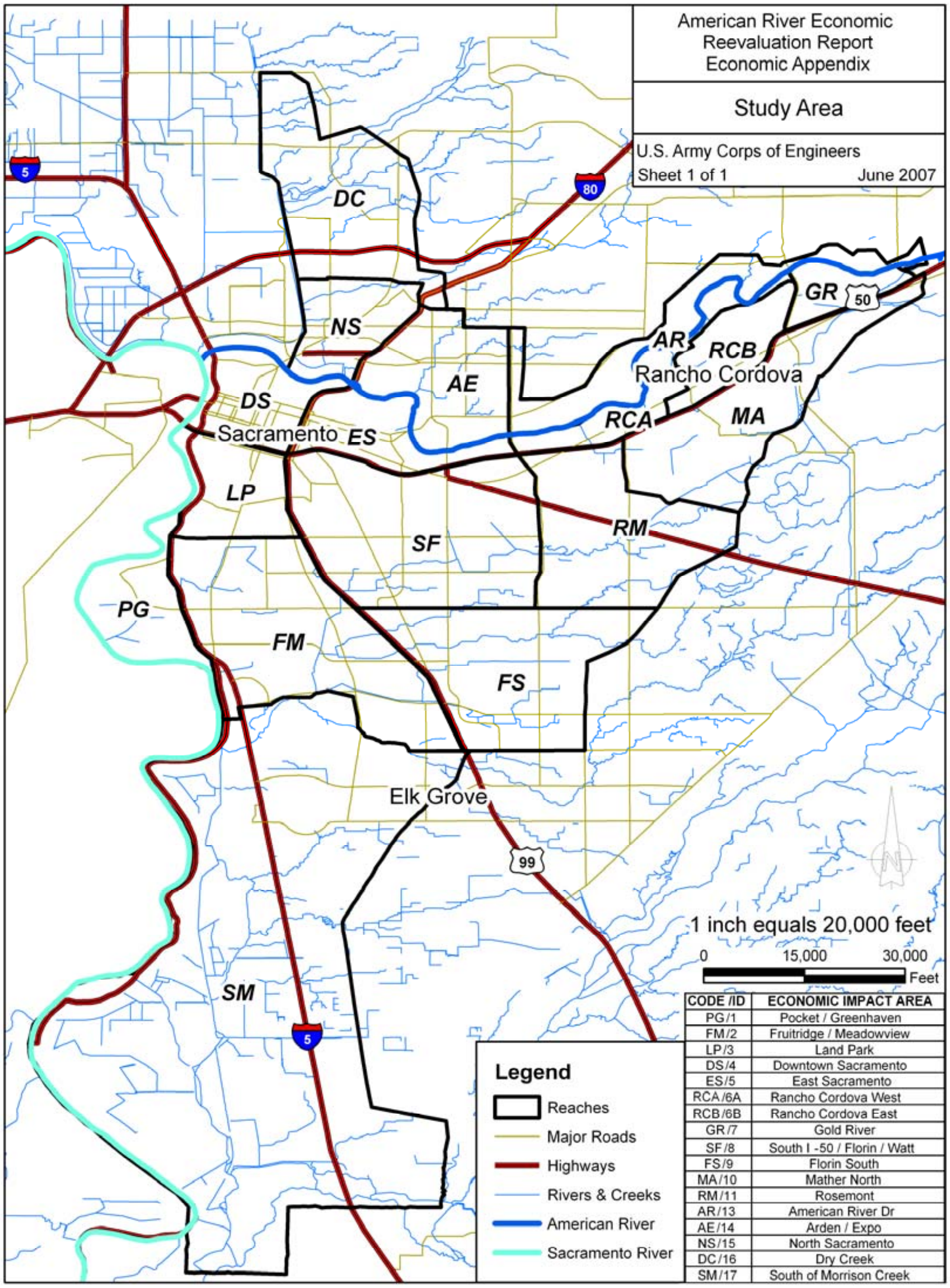

Figure 3-1
Economic Impact Areas

Together, Table 3-1 and Figure 3-1 allows for the comparison of size between impact areas and basins, especially as it pertains to the Natomas Basin area, which is the focus of this report. The data show that the Natomas Basin accounts for approximately 25% of the total ARCF study area. The sections that follow will describe in detail the economic inventory, structure and content valuations, and floodplains associated with the Natomas Basin impact area.

3.1.1 Natomas Basin Economic Impact Area

As was mentioned previously, the focus of this report is the Natomas Basin area. The other basins will be evaluated in a separate GRR.

Natomas Basin encompasses parts of both Sutter and Sacramento counties in California. The impact area is bounded by the Natomas Cross Canal to the north, the Natomas East Main Drainage Canal (NEMDC) to the east, the American River to the south, and the Sacramento River to the west. The area is currently not protected from the one percent chance event and therefore lies within the Federal Emergency Management Agency's (FEMA) 100-year flood plain. In 2008, the federal government issued a construction moratorium which effectively restricted development in the Basin until the levees are improved and the area can be re-mapped as being outside the 100-year floodplain.

Beginning around 1998, the area north of Interstate 80 experienced rapid development, including single-family residential (SFR) and multi-family residential (MFR) structures as well as commercial, industrial, and public structures. The area continued to experience significant development up until 2008 as more people moved to the area, which offered both relative housing affordability and convenience to employment centers.

Figure 3-2 shows a typical residential community in the North Natomas area.

Figure 3-2
Photo of Typical North Natomas Neighborhood

3.2 ECONOMIC INVENTORY – COLLECTION OF BASE DATA

For the Natomas Basin impact area, a base geographic information system (GIS) inventory with parcel attribute data was provided by the local sponsor for both Sacramento and Sutter counties. Building attribute data were used to determine land use and valuation of structures and contents. Numerous field visits were taken to collect the base inventory data; data was collected using standard USACE practices. The following sections describe the data collection process in more detail.

3.2.1 Field Inventory Characteristics

Field sheets containing the base inventory data were taken to the field along with aerial maps for identification. Characteristics observed in the field were recorded on the field sheets, including:

A) ***Stories:*** The number of floors or stories found in the building.

B) ***Foundation:*** The estimated difference between the average ground elevation and the first floor of the structure.

C) ***Building Use:*** While the base data included a specification of land use, field verification was required to correlate building use to more specific residential and non-residential structure occupancy types. Under the more general residential, commercial, industrial, and public categories typically used in USACE studies, the following specific occupancy types were identified.

For residential structures:

1) ***SFR:*** This category may include detached single family homes, half-plexes, duplexes, and townhouses with four units or less per parcel.
2) ***MFR:*** This category may include apartments, townhouses, and attached multiple units.
3) ***MH:*** This category may include mobile homes and mobile home parks.

For non-residential structures:

4) ***COM-OFF:*** office buildings
5) ***COM-RET:*** typical retail stores
6) ***COM-FOOD:*** retail stores that sell perishable food items
7) ***COM-REST:*** restaurants, fast food establishments
8) ***COM-MED:*** medical, dental, hospitals, care facilities, veterinary
9) ***COM-SHOP:*** large shopping centers, box stores, shopping malls
10) ***COM-SERV:*** auto repair, service and maintenance shops
11) ***IND-WH:*** warehouses, storage, transportation centers
12) ***IND-LT:*** small tool shops, light manufacture
13) ***IND-HV:*** heavy manufacture, large plants

14) ***PUB-GOV:*** government buildings, county, city, state and federally owned offices
15) ***PUB-SCH:*** schools, elementary, middle, high, colleges and day care/pre-school facilities
16) ***PUB-CH:*** churches
17) ***PUB-REC:*** recreation, assembly- clubs theaters
18) ***FARM:*** nonresidential outbuildings and sheds, family farm residences and light production facilities.

D) ***Class:*** This characteristic corresponds with classifications from the Marshall and Swift (M&S) Valuation Service. Each of the five classifications corresponds to a grade of construction for use in the structure valuation.

1) ***A:*** primary characteristic- steel reinforced frame
2) ***B:*** reinforced concrete frame
3) ***C:*** Masonry
4) ***D:*** Wood Frame
5) ***S:*** Metal frame-prefabricated

E) ***Type:*** This characteristic represents the quality of construction for the observed structure. Different land use categories have slightly different groupings but can include the following:

1) ***Excellent***
2) ***Very Good***
3) ***Good***
4) ***Average***
5) ***Fair***
6) ***Low Cost***

F) ***Condition***: This characteristic is a subjective measure of the remaining life of the structure. This is not a measure of the actual age as many older structures may have been restored and may have had improvements made to extend its remaining life. The estimated percentage of remaining value was recorded to account for depreciation. The basic groupings for assignment of condition during the field observations included:

1) ***New:*** (no signs of deterioration, all new components) 100% remaining life
2) ***Excellent:*** around 95%
3) ***Very Good:*** basic wear and tear- move in condition- fully functional 90 to 95%
4) ***Good:*** some minor maintenance required 80 to 90 %
5) ***Fair:*** showing signs or wear 70 to 80 %
6) ***Poor:*** 50 to 70%
7) ***Other:*** abandoned or condemned

3.2.2 Assignment of Non-SFR Square Footage

For all residential structures classified as SFR, Sacramento County provided detailed information regarding square footage of the buildings. This included total square footage, basement square footage, 2nd-floor square footage, and garage square footage; this same data was not available for the non-residential and MFR categories. For many of the larger buildings and in some of the commercially dense areas, the county provided GIS data that included digitized building footprints. This GIS data was used to identify each structure's square footage. For those buildings not included in the GIS data, high-resolution aerial photographs were used in conjunction with GIS to measure the building footprint. In both cases, the measured first floor square footages were used along with the number of damageable floors (limited to no more than three floors) to estimate the maximum possible damageable square footage for structure valuation purposes.

3.3 VALUE OF DAMAGEABLE PROPERTY IN NATOMAS BASIN

The total value of damageable property (structures and contents) within the Natomas Basin impact area is estimated at $8.5 billion. Table 3-2 below displays the total value of damageable property by category.

Table 3-2
Total Value of Damageable Property by Category
Structures and Contents
Values in $Millions, October 2010 Price Level

CATEGORY	VALUE OF DAMAGEABLE PROPERTY		
	Structures	Contents	Total
Commercial	681	308	989
Farm	6	7	13
Industrial	458	249	707
Public	440	275	715
Residential	4,076	2,038	6,114
TOTAL	**5,661**	**2,877**	**8,538**

3.3.1 Structure Valuation

All structures were valued based upon a function of square footage, estimated cost per square foot (from the Marshall & Swift Valuation Handbook), and estimated depreciation. Values per square foot were based on building use, class, and type as outlined in Marshall and Swift Valuation Handbook[5]. Depreciated replacement values of structures are listed by category in Table 3-3 below.

Table 3-3
Total Value of Damageable Property – Structures
Values in $Millions, October 2010 Price Level

VALUE OF DAMAGEABLE PROPERTY (STRUCTURES) BY DAMAGE CATEGORY	
Damage Category	**Structure Value**
Commercial	681
Farm	6
Industrial	458
Public	440
Residential	4,076
TOTAL	**5,661**

[5] Structure valuations were based on replacement cost estimates developed by Clark-Walcott, Inc., Real Estate Analysts and Consultants specifically for structures in the Natomas Basin. Clark-Wolcott, Inc. developed replacement cost estimates on a dollar-per-square foot basis for 39 different residential and non-residential structure types using data and methods published by the Marshall and Swift Valuation Service. Base Clark-Walcott, Inc. dollar-per-square foot data were then adjusted by USACE SPK to account for depreciation, which was then applied to the square footage of a structure to derive structure value. The base Clark-Walcott, Inc. data is presented in Enclosure 8.

The total value of structures (excluding the value of their contents, which is presented in Sections 3.4 and 3.5) is approximately $ 5.7 billion or nearly 67% of the $8.5 billion total. These values represent all structures within the Natomas Basin impact area.

3.3.2 Content Valuation

Non-residential and residential content values are presented in Table 3-4 below. Sections 3.4.1 and 3.4.2 provide more details about non-residential and residential content valuation, respectively.

Table 3-4
Total Value of Damageable Property – Contents
Values in $Millions, October 2010 Price Level

CONTENT VALUE BY DAMAGE CATEGORY	
Damage Category	**Content Value**
Commercial	308
Farm	7
Industrial	249
Public	275
Residential	2,038
TOTAL	**2,877**

3.3.3 Non-Residential Content Valuation

An expert elicitation was performed to develop content values and content depth-percent damage curves for specific occupancy types (as listed in section 3.2.1 above) for the 2007 ERR. The results of that expert elicitation were used for the 2009 GRR as well as for this NPACR. The values and curves were developed specifically for structures in the American River Watershed study area. In total, there were 22 different occupancy types with values ranging from $22 to $235 per square foot with uncertainty.

In the 2009 GRR content values for non-residential structures were generated as a function of building use, damageable square footage, and content value per square footage (by the 22 different categories). These same values were carried forward to this NPACR analysis. Total non-residential content value is estimated to be approximately $839 million.

Additional information related to the depth-percent damage curves used for the NPACR analysis can be found in Chapter 5, *Without-Project Analysis*.

3.3.4 Residential Content Valuation

For SFR residential structures, depth-percent damage curves developed by the USACE Institute for Water Resources (IWR) and presented in Economic Guidance Memorandum (EGM) 04-01, were used. Since the percentage damages in these generic depth-percent damage curves were developed as a function of structure value, it was unnecessary to explicitly derive content values for input into the HEC-FDA model; the model computes content damages by applying the percentages in the content-percent damage curves to structure values. For reporting purposes and to estimate content value for residential structures, a content-to-structure value ratio of 50% was used, which is consistent with the ratio used in prior American River studies. Total residential content value is estimated to be approximately $2.0 billion.

3.4 STRUCTURE COUNT

Table 3-5 below displays the total number of structures within the Natomas Basin impact area and which are at risk of flooding. Structure counts are broken down by major category. It is estimated that there is close to 23,000 structures in the Natomas Basin impact area.

Table 3-5
Total Structure Count

STRUCTURE COUNT BY DAMAGE CATEGORY	
Damage Category	**Structure Count**
Commercial	303
Farm	21
Industrial	156
Public	85
Residential	22,265
TOTAL	**22,830**

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CHAPTER 4
ECONOMIC METHODOLOGIES AND MAJOR ASSUMPTIONS

4.1 CONSISTENCY WITH REGULATIONS AND POLICIES

This economic analysis was performed in accordance with standards, procedures, and guidance of the USACE. The *Planning Guidance Notebook* (ER 1105-2-100, April 2000, with emphasis on Appendix D, Economic and Social Considerations, Amendment No. 1, June 2004) serves as the primary source for evaluation methods of FRM studies and was used as reference for this analysis. Additional guidance for risk analysis was obtained from EM 1110-2-1619, *Engineering and Design – Risk-Based Analysis for Flood Damage Reduction Studies* (August 1996) and ER 1105-2-101, *Planning Risk-Based Analysis for Flood Damage Reduction Studies* (Revised January 2006).

4.2 PRICE LEVEL, PERIOD OF ANALYSIS, AND DISCOUNT RATE

Unless otherwise noted, all values in this document are presented in October 2010 prices. Costs and benefits of the various alternatives were evaluated over a 50-year period of analysis. For common comparison, all costs and benefits over the period of analysis were converted to present values using the current federal discount rate of 4.375 percent. The base year of 2016 was identified as the year that all alternatives considered would be completed and fully functional, providing a full level of project benefits. The base year is important as it guides, at least conceptually during this phase of the study, the construction period and timing of project costs assumed for computation of interest during construction (IDC).

4.3 METHODOLOGIES

The following sections describe the methodologies and data application techniques used to perform the economic analysis. These include methodologies and techniques pertaining to the analysis framework (multiple index points, floodplain assignments), the application of modeling results and data (hydrologic, hydraulic, and geotechnical analyses) used for the economic analysis, and the application of economic data (uncertainties, depth-percent damage curves) used in the HEC-FDA model.

4.3.1 Using Multiple Index Points to Analyze Multiple-Source Flooding

In the 2009 GRR economic analysis, without-project expected annual damages for the Natomas Basin impact area was based on engineering data (HEC-FDA input data and floodplains) at one index point location, which was located on the Sacramento River at river mile 79. This was (and still is) known as the NAT C index point. For this NPACR analysis, nine index points were selected around the Basin with the intent to better facilitate the evaluation of a with-project analysis and to perform a more accurate net benefit analysis which identifies a plan that optimizes benefits from a national perspective.

4.3.1.1 Rationale for Methodology

The Natomas Basin can flood from four sources: the Natomas Cross Canal (NCC) to the north, the Natomas East Main Drainage Canal (NEMDC) to the east, the American River to the south, or the Sacramento River to the west, each with varying probabilities depending on the source. Multiple sources of flooding in the Basin make it difficult to estimate expected annual damages (EAD) and annual exceedance probability (AEP) on a basin-wide basis using currently available computer models. Additional analytical complexity is introduced if one considers the probability of flooding along a particular flooding source also varies (i.e., not only is the probability of flooding between various water sources not uniform but the probability of flooding along a specific water source is also not uniform), and that the same area is flooded from levee breaches at different locations but at varying magnitudes (i.e., different floodplains) depending on the location of the breach.

In the past and in similar studies with multiple-source flooding, EAD for an economic impact area was computed based either on 1) composite floodplains using one index point or 2) weighted averages of separate EAD results using multiple index points. These methods have tended to overstate without-project damages. In addition, using a single index point, as was done for the 2009 GRR (F3 without-project analysis for the Natomas Basin), produces a less accurate net benefit analysis of an array of alternatives as net benefits would be based on engineering improvements at only one representative index point, instead of engineering improvements at a representative sample of index points around the entire Basin based on improvements along all sources of flooding.

4.3.1.2 Natomas Basin Index Points

In order to better estimate without-project damages and to facilitate a more accurate analysis of potential alternatives, nine index points (reaches) around the Basin were identified by the project delivery team (PDT) and used in the economic analysis. Figure 4-1 displays the general location of each index point around the Basin. Table 4-1 below describes the location of the nine index points.

Figure 4-1 General Location of Natomas Basin Index Points

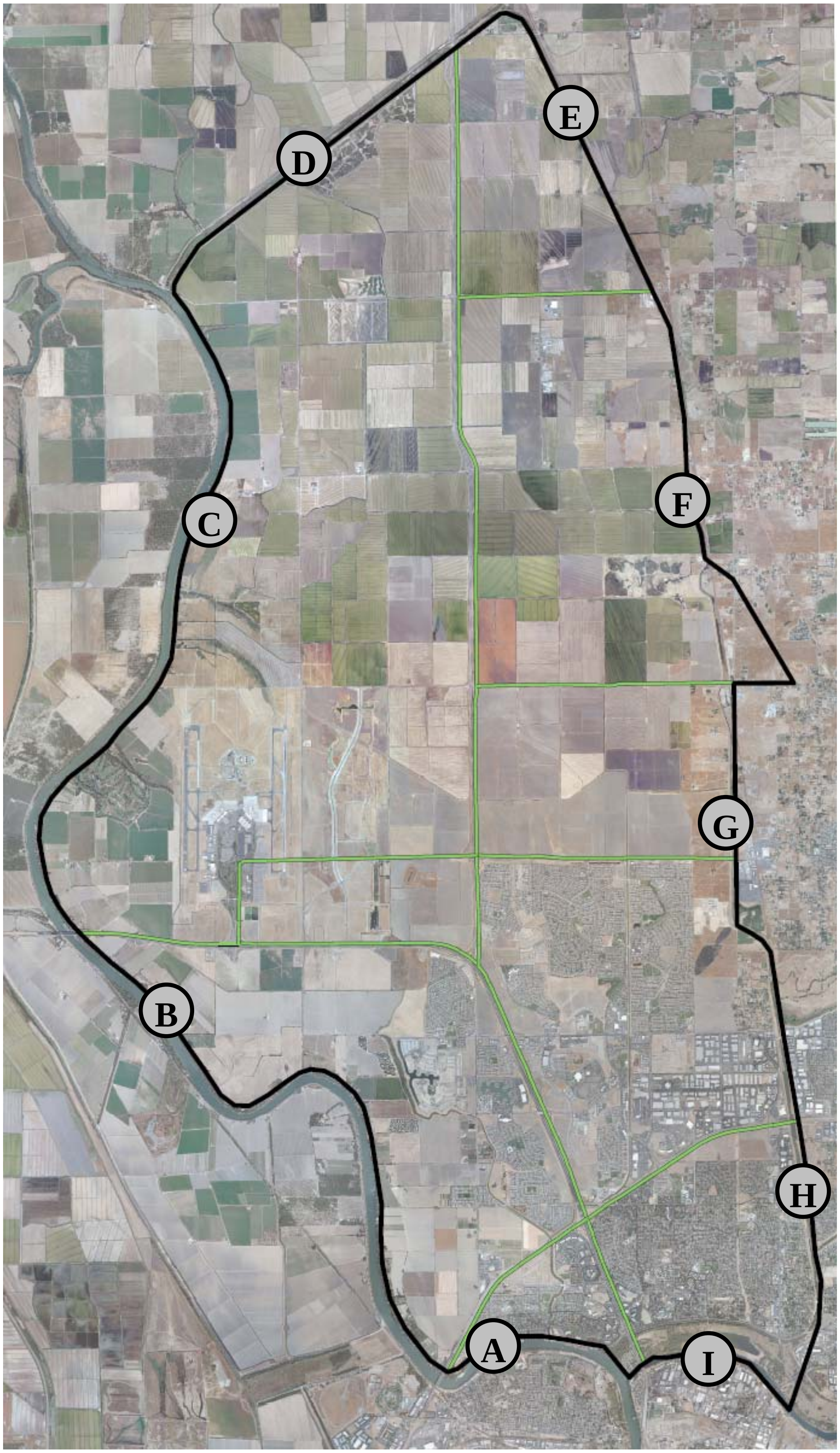


Table 4-1
Natomas Basin Index Points

INDEX POINT	WATERWAY	RIVER MILE (RM)
A	Sacramento River	62.75
B	Sacramento River	69.25
C	Sacramento River	79.00
D	Natomas Cross Canal (NCC)	2.63
E	Natomas East Main Drainage Canal (NEMDC)	Pleasant Grove Canal (PGCC)
F	Natomas East Main Drainage Canal (NEMDC)	12.62
G	Natomas East Main Drainage Canal (NEMDC)	8.59
H	Natomas East Main Drainage Canal (NEMDC)	4.32
I	American River	1.00

More detail on how the nine index points were applied in the economic analysis is provided in Chapter 5, *Without-Project Analysis -- HEC-FDA Base Modeling Results*, and Chapter 6, *With-Project Analysis.*

4.3.2 Application of Engineering Data in the Economic Analysis

The following sub-sections describe briefly the engineering model and data used for input into the economic analysis and HEC-FDA economic model. More details can be found in the appropriate engineering appendix (Appendix B – Hydrology, Appendix C – Hydraulics, and Appendix F – Geotechnical).

4.3.2.1 Hydrologic Engineering Data and Application in HEC-FDA

The Sacramento District Water Management Section provided all hydrologic data used in the HEC-FDA modeling. This includes the equivalent record length for each index point (A through I) and frequency-discharge curves for index points B, C, and I. For index points A, D, E, F, G, and H, only frequency-stage curves (and not frequency-discharge curves) were provided; only frequency-stage curves were developed due to backwater effects in these areas, which made it difficult to model discharges along these reaches. (The hydrologic data was provided to the Hydraulic Design Section for use in channel modeling using the HEC-RAS program; frequency-stage curves were then developed and provided to the Economics & Risk Analysis Section by the SPK Hydraulic Design Section for use in the HEC-FDA models.) Data and curves for each index point and for both without-project and with-project conditions were provided. These data and curves can be found in Enclosure 1, *HEC-FDA Input Data and Output Results*.

4.3.2.2 Hydraulic Engineering Data and Application in HEC-FDA

The SPK Hydraulic Design Section used the HEC-RAS model to determine stages in the channel, to model levee breakout locations, and to develop breakout hydrographs; the Hydraulic Design Section used the FLO-2D model to determine water surface elevations in the floodplain (i.e., develop suites of floodplains). More details about the data and assumptions used by the Hydraulic Design Section for their HEC-RAS and FLO-2D modeling efforts can be found in Appendix C.

In the 2009 GRR without-project (F3) analysis for the Natomas Basin impact area, a suite of floodplains was generated for only one index point (NAT C); for this NPACR analysis, a suite of floodplains was generated for each of the nine index points. For each index point, the Hydraulic Design Section provided data for input into the HEC-FDA model. These datasets that were used in the HEC-FDA modeling include:

- Frequency-discharge-stage curves (with uncertainty) for the without-project condition (WOPC); the WOPC assumed in this analysis is described in this chapter under the section entitled, *Major Assumptions*.

- Frequency-discharge-stage curves (with uncertainty) for the with-project condition, including levee raises within the project area.

- Frequency-stage curves that were used for the floodplain analysis; these curves were used in HEC-FDA for computation of the stage-damage curves. Section 4.3.3 describes in more detail the process of using this frequency-stage data to compute stage-damage curves in HEC-FDA.

- Formatted FLO-2D data for direct import into HEC-FDA as a water surface profile (or suite of floodplains). These floodplains and the process used to generate and format them for direct import into HEC-FDA are described in more detail in Section 4.3.3.

4.3.2.3 Hydraulic Engineering Stage Uncertainty Data and Application in HEC-FDA

As was discussed in section 4.3.2.1, exceedance probability-stage curves (instead of exceedance probability-discharge and stage-discharge curves) were developed for most of the nine index points due to the effects on discharges backwater has at these index point locations. These effects on discharges, which result in non-monotonic stage-discharge curves (flows don't increase with increasing stages), would make it impossible to use these curves in the HEC-FDA model, which requires monotonic stage-discharge curves. Exceedance probability-stage curves were developed for index points NAT A on the Sacramento River, NAT D on the Natomas Cross Canal (NCC), and NAT E, NAT F, G, and H on the Natomas East Main Drainage Canal (NEMDC)[6].

Using only exceedance probability-stage curves in HEC-FDA resolves the issue of non-monotonic stage-discharge curves, but this approach only captures hydrologic uncertainty (via equivalent record length) and neglects to explicitly capture typical hydraulic in-channel stage uncertainty (e.g., channel roughness) within HEC-FDA. In order to explicitly address hydraulic stage uncertainty within HEC-FDA, several non-standard techniques were applied in HEC-FDA using exceedance probability-stage curves and stage uncertainty data provided by the SPK Hydraulic Design Section.

A methodology paper describing these non-standard techniques is provided as Enclosure 5 in this Economic Appendix. While this methodology paper was developed specifically to address downstream stage uncertainty as it relates to upstream levee performance assumptions, the same general approach can be used to account for stage uncertainty related to other hydraulic factors. Therefore, it is important to note that Enclosure 5 is included mainly as a reference and to inform potential readers of this document that there exists a non-standard technique that can be applied in HEC-FDA to reasonably account for additional stage uncertainty; this NPACR economic analysis applied the same technique described in Enclosure 5 to capture typical stage uncertainties which cannot be captured by using only frequency-stage curves; for this NPACR analysis, this technique was not applied to account for uncertainty in stages due to potential upstream levee failures.

To account for additional hydraulic stage uncertainty within HEC-FDA using only the exceedance probability-stage curves and stage uncertainty data (i.e., standard deviation of stages per frequency event) provided by the Hydraulic Design Section, the following techniques were used in HEC-FDA:

- All three available discharge and stage relationships (exceedance probability-discharge, stage-discharge, and transform flow curves) in HEC-FDA were used but defined only in terms of stage.
- Exceedance probability-stage curves were entered using the graphical option set for discharge but stages were entered in place of flow.
- The transform flow option was used to explicitly address stage uncertainty by entering stage standard deviations by probability event instead of inflow-outflow.

[6] NAT E is technically located on the Pleaseant Grove Canal, which is essentially connected to the Natomas East Main Drainage Canal (NEMDC) in the north. Only for reporting purposes in this Appendix, references made to the location of the NAT E index point will be to the NEMDC.

- The stage-discharge curve was entered in HEC-FDA as a “dummy” curve, where stage would equal stage.

More details about this technique and a description of HEC-FDA sensitivity runs completed to validate this technique can be found in Enclosure 5.

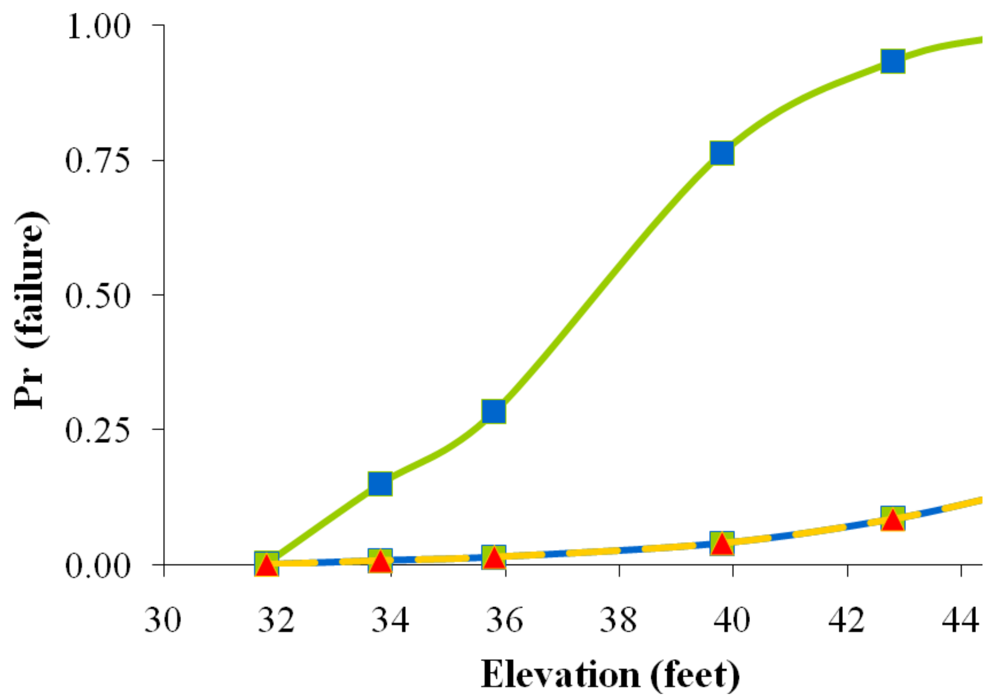
4.3.2.4 Geotechnical Engineering Data and Application

As explained in previous sections of this report, for the 2009 GRR F3 Natomas Basin economic analysis only one index point was used (NAT C) and only one geotechnical risk and uncertainty curve (GRU) was entered into the HEC-FDA model as part of the AEP and EAD computations. For this NPACR, nine index points were used in the analysis resulting in nine without-project GRU curves and 18 with-project GRU curves. (There were between one and three with-project GRU curves for each geotechnical reach/index point.) Figure 4-2 below is one example of the GRU curves (without-project and with-project) used for the NAT D reach/index point. Enclosure 2 presents the complete set of GRU curves used in the economic analysis; Appendix F describes in detail the development of these GRU curves; and Chapter 6, *With-Project Analysis*, lists by index point and water source the method of geotechnical fix, with each fix represented by a unique GRU curve.

Figure 4-2

Without-Project & With-Project
Geotechnical Risk & Uncertainty Curve

NATOMAS BASIN REACH D



Elevation	Probability of Failure		
	WO	SB/SCB CWP (F)	SB/SCB CWP
31.8	0.00269	0.00000	0.00000
33.8	0.15000	0.00736	0.00736
35.8	0.28324	0.01401	0.01401
39.8	0.76297	0.03982	0.03982
42.8	0.93273	0.08504	0.08504
44.8	0.98191	0.13115	0.13115

One reason for including nine index points/reaches in the NPACR analysis was to better facilitate the with-project benefits analysis and to address the reality that the Basin is at risk from flooding from multiple sources, but to different degrees. In fact, the without-project GRU curves, on first glance, reveal that the levee reaches around the Basin do differ in terms of existing conditions and the flood protection provided. Once the without-project GRU curves are applied in the economic analysis and integrated with the hydrologic and hydraulic data, HEC-FDA results highlight the differences in expected performance of the levee reaches around the Basin. The without-project HEC-FDA modeling results for each reach/index point are presented in Chapter 5, *Without-Project Analysis*.

4.3.3 Economic HEC-FDA Model and Application of Floodplain Data

The Hydrologic Engineering Center's HEC-FDA model (version 1.2.4) was used to perform the economic damage and benefits analyses. More detailed descriptions about the capabilities of HEC-FDA model and how it was used are provided in the following sub-sections.

4.3.3.1 The HEC-FDA Economic Model

The HEC-FDA model was used to integrate the engineering data (hydrologic, hydraulic, and geotechnical), compute stage-damage curves using specially-formatted hydraulic FLO-2D output data, and compute initial AEP and EAD results under both without-project and with-project conditions. The HEC-FDA model was also used to conduct the with-project benefits analysis using the information provided by the initial HEC-FDA modeling results.

4.3.3.2 Application of Floodplain Data

Floodplains were developed by the SPK Hydraulic Design Section using the FLO-2D model, which produces interior water surface elevations by grid cell; the Hydraulic Design Section used a 400 foot by 400 ft grid cell size. Suites of FLO-2D floodplains (2-year to 500-year frequency events) were developed for use in the without-project condition for each of the nine index points. The Hydraulic Design Section developed the Natomas Basin floodplains assuming certain project components on the American River would be constructed and operational, including the Authorized Common Features, Joint Federal Project, and Folsom Dam mini-raise; development of floodplains also assumed that the American River could safely pass 160,000 cubic feet per second.

Importing the FLO-2D data into the HEC-FDA models required file modification. The FLO-2D files were modified so that the HEC-FDA program could import them as a HEC-RAS water surface profile (WSP) output file. Instead of using river station numbers like in a typical HEC-RAS WSP, assignment of water surface elevations by frequency event were completed using grid cell numbers (output of FLO-2D); the grid cell assignments represent actual floodplain water surface elevations by frequency event rather than in-channel water surface elevations. Once the formatted FLO-2D floodplains (WSP) were imported into HEC-FDA, a row was inserted at the top of the WSP which included the in-channel (HEC-RAS) stages associated with the index point (for a particular reach). This step allowed for the linkage between the two-dimensional floodplain data (FLO-2D data imported into HEC-FDA) and the in-channel

HEC-RAS stages. Importing formatted FLO-2D data and assigning water surface elevations to grid cells eliminated the need for creating interior-exterior relationships, which is another way to link exterior (river) stages to interior (floodplain) stages within HEC-FDA.[7]

Additionally, since structures and depths of flooding (water surface elevations) in the WSPs are linked by grid cell number, this technique allowed for the computation of stage-damage curves within HEC-FDA and eliminated the need to use other models (e.g., @Risk) to compute stage-damage curves. Once computed, stages in the stage-damage curves are scaled by HEC-FDA using the in-channel (exterior) stages at the index point (first row of data inserted into WSP). The index point, then, links the floodplain data (via stage-damage curves) to the channel hydrology, hydraulic, and geotechnical data in the HEC-FDA model.[8] The process of inserting data into the first row of the WSP for computation of stage-damage curves is explained in the following sub-section.

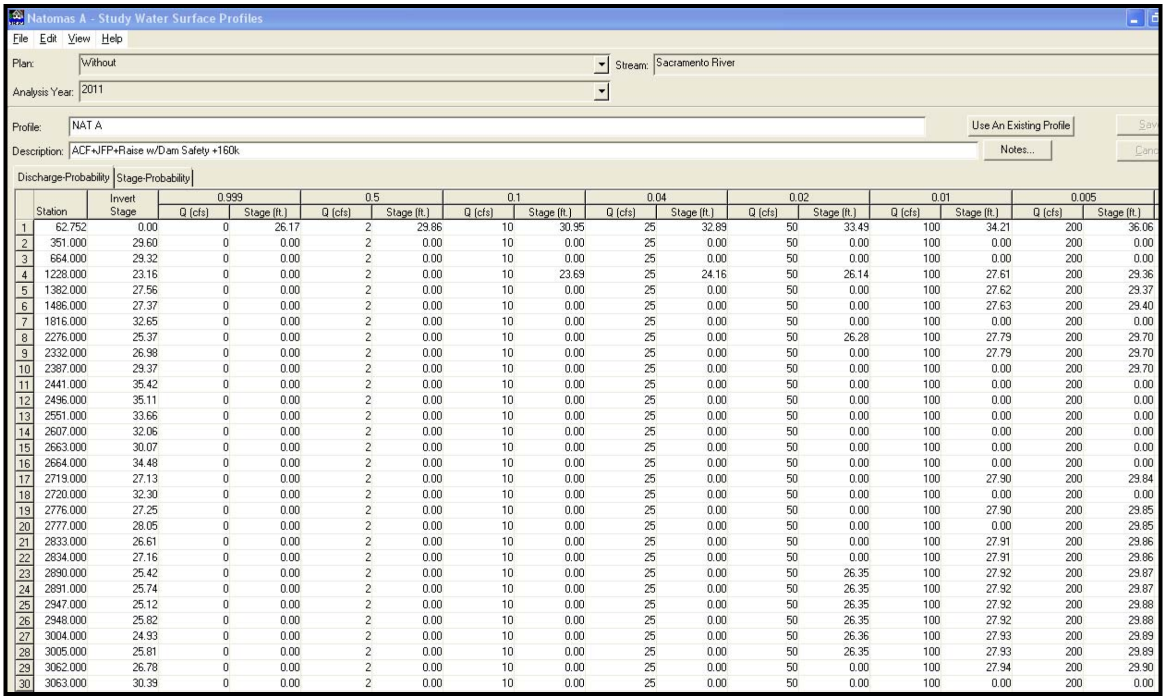
4.3.3.3 Computation of Stage-Damage Curves within the HEC-FDA Model

For each of the nine suites of floodplains (one at each index point), the Sacramento District's Hydraulic Design Section formatted the FLO-2D floodplain output data so that the floodplains could be directly imported into the HEC-FDA model as a water surface profile. The Hydraulic Design Section used the HECFDA utility (not to be confused with the HEC-FDA model) to format the FLO-2D data; this utility was developed by a consultant specifically to allow FLO-2D output data to be imported into the HEC-FDA model.[9] The formatted files contained every grid cell that contained a structure and the water surface elevations in each grid cell for each frequency event. The suite of floodplains (one for each index point) was used in HEC-FDA to compute stage-damage curves.

An example of the FLO-2D-formatted floodplain data that was imported into HEC-FDA for the NAT A index point is shown in Figure 4-3 below. As explained in sub-section 4.3.3.2, once the formatted data is imported, stage data is inserted into the first row of the water surface profile representing the HEC-RAS exterior stages (per frequency event) at the index point that were used by the Hydraulic Design Section to develop the floodplains. The first row of data is

[7] Since the floodplains used in the NPACR economic analysis were developed assuming that the American River could safely pass 160,000 flow, two sets of frequency-stage curves were entered into HEC-FDA to address the fact that the without-project condition for this NPACR does not make this same 160,000 flow assumption. This adjustment was made even though floodplains for the Natomas Basin impact area do not differ significantly under each scenario. This difference in assumptions was accounted for in HEC-FDA by using one set of HEC-RAS-developed frequency-stage curves (those used to develop the floodplains) to compute stage-damage curves in HEC-FDA and using another set of HEC-RAS-developed frequency-stage curves (those reflecting the without-project condition without assuming the safe passage of the 160,000 flow) to compute AEP/EAD in HEC-FDA at the index point. In effect, using two sets of frequency-stage curves in HEC-FDA shifts the frequencies at specific stages to account for the different underlying assumptions and scales the stages in the stage-damage curves to reflect the stages associated with the correct without-project condition being assumed for this NPACR. (The without-project condition assumed for this NPACR analysis is described in more detail under Section 4.4, *Major Assumptions*.)
[8] Note: The FLO-2D-based WSPs are used only to compute stage-damage curves within HEC-FDA. None of the exceedance probability-discharge functions or stage-discharge functions were retrieved from the WSP.
[9] The HECFDA utility is a stand-alone FORTRAN program used specifically to format FLO-2D model output data (grid element ground elevation and water surface elevation) into the HEC-FDA file format. The HECFDA user guidelines, which explains in more detail the steps involved in formatting the FLO-2D output data, is provided as Enclosure 4 to this Economic Appendix.

required in order to be able to 1) properly scale stages in association with the computation of the stage stage-damage curves in HEC-FDA and 2) link exterior (river) stages to damages in the floodplain for expected annual damage (EAD) calculations in HEC-FDA. It is important to note that the discharge values listed under each frequency event in the WSP/FLO-2D data are placeholder ("dummy") values only and are not used by the HEC-FDA program in its computation of stage-damage curves.



	Station	Invert Stage	0.999		0.5		0.1		0.04		0.02		0.01		0.005	
			Q (cfs)	Stage (ft.)	Q (cfs)	Stage (ft.)	Q (cfs)	Stage (ft.)	Q (cfs)	Stage (ft.)	Q (cfs)	Stage (ft.)	Q (cfs)	Stage (ft.)	Q (cfs)	Stage (ft.)
1	62.752	0.00	0	26.17	2	29.86	10	30.95	25	32.89	50	33.49	100	34.21	200	36.06
2	351.000	29.60	0	0.00	2	0.00	10	0.00	25	0.00	50	0.00	100	0.00	200	0.00
3	664.000	29.32	0	0.00	2	0.00	10	0.00	25	0.00	50	0.00	100	0.00	200	0.00
4	1228.000	23.16	0	0.00	2	0.00	10	23.69	25	24.16	50	26.14	100	27.61	200	29.36
5	1382.000	27.56	0	0.00	2	0.00	10	0.00	25	0.00	50	0.00	100	27.62	200	29.37
6	1486.000	27.37	0	0.00	2	0.00	10	0.00	25	0.00	50	0.00	100	27.63	200	29.40
7	1816.000	32.65	0	0.00	2	0.00	10	0.00	25	0.00	50	0.00	100	0.00	200	0.00
8	2276.000	25.37	0	0.00	2	0.00	10	0.00	25	0.00	50	26.28	100	27.79	200	29.70
9	2332.000	26.98	0	0.00	2	0.00	10	0.00	25	0.00	50	0.00	100	27.79	200	29.70
10	2387.000	29.37	0	0.00	2	0.00	10	0.00	25	0.00	50	0.00	100	0.00	200	29.70
11	2441.000	35.42	0	0.00	2	0.00	10	0.00	25	0.00	50	0.00	100	0.00	200	0.00
12	2496.000	35.11	0	0.00	2	0.00	10	0.00	25	0.00	50	0.00	100	0.00	200	0.00
13	2551.000	33.66	0	0.00	2	0.00	10	0.00	25	0.00	50	0.00	100	0.00	200	0.00
14	2607.000	32.06	0	0.00	2	0.00	10	0.00	25	0.00	50	0.00	100	0.00	200	0.00
15	2663.000	30.07	0	0.00	2	0.00	10	0.00	25	0.00	50	0.00	100	0.00	200	0.00
16	2664.000	34.48	0	0.00	2	0.00	10	0.00	25	0.00	50	0.00	100	0.00	200	0.00
17	2719.000	27.13	0	0.00	2	0.00	10	0.00	25	0.00	50	0.00	100	27.90	200	29.84
18	2720.000	32.30	0	0.00	2	0.00	10	0.00	25	0.00	50	0.00	100	0.00	200	0.00
19	2776.000	27.25	0	0.00	2	0.00	10	0.00	25	0.00	50	0.00	100	27.90	200	29.85
20	2777.000	28.05	0	0.00	2	0.00	10	0.00	25	0.00	50	0.00	100	0.00	200	29.85
21	2833.000	26.61	0	0.00	2	0.00	10	0.00	25	0.00	50	0.00	100	27.91	200	29.86
22	2834.000	27.16	0	0.00	2	0.00	10	0.00	25	0.00	50	0.00	100	27.91	200	29.86
23	2890.000	25.42	0	0.00	2	0.00	10	0.00	25	0.00	50	26.35	100	27.92	200	29.87
24	2891.000	25.74	0	0.00	2	0.00	10	0.00	25	0.00	50	26.35	100	27.92	200	29.87
25	2947.000	25.12	0	0.00	2	0.00	10	0.00	25	0.00	50	26.35	100	27.92	200	29.88
26	2948.000	25.82	0	0.00	2	0.00	10	0.00	25	0.00	50	26.35	100	27.92	200	29.88
27	3004.000	24.93	0	0.00	2	0.00	10	0.00	25	0.00	50	26.36	100	27.93	200	29.89
28	3005.000	25.81	0	0.00	2	0.00	10	0.00	25	0.00	50	26.35	100	27.93	200	29.89
29	3062.000	26.78	0	0.00	2	0.00	10	0.00	25	0.00	50	0.00	100	27.94	200	29.90
30	3063.000	30.39	0	0.00	2	0.00	10	0.00	25	0.00	50	0.00	100	0.00	200	0.00

Figure 4-3
FLO-2D Output Data Formatted and Imported into HEC-FDA, NAT A Index Point

4.4 MAJOR ASSUMPTIONS

Some of the major, fundamental assumptions used throughout this NPACR economic analysis are described in the following sub-sections. Major assumptions, generally those that may have a significant impact on the Natomas Basin economic analysis, include those made in regard to the without-project condition, upstream levee performance, potential for human intervention in the project area, index point locations and derivation of floodplains based on these index points, future hydrologic, hydraulic, and geotechnical levee conditions, and future development in the Natomas Basin.

4.4.1 Without-Project Condition – 2009 GRR and 2010 NPACR

Six conditions were developed to analyze the American River South, American River North, and Natomas Basins in the 2009 GRR; for this NPACR, only one without-project condition was used to evaluate the Natomas Basin since, for the most part, the Natomas Basin area is not affected by changes on the American River associated with assumptions pertaining to completed project components. The conditions used for the 2009 GRR are re-visited in sub-section 4.4.1.1 below;

the without-project condition assumed for this NPACR analysis is described in sub-section 4.4.1.2.

4.4.1.1 2009 GRR Conditions

For the 2009 GRR, three without-project conditions and three no-action conditions were developed for the analysis. They were labeled as follows: WO1, WO2, and WO3 for the without-project conditions and NA1, NA2, and NA3 for the no-action conditions. These conditions were delineated based on the complex and long history of the American River Watershed projects and with the intent to reveal, through the changing flood protection level and expected consequences associated with each condition, the nature of the authorized flood risk management solutions associated with the Watershed. The analysis of additional conditions was also necessary in order to properly formulate projects for the on-going GRR. The conditions delineated for the GRR were:

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- **Without Project Conditions**: The without-project conditions (WOPC) all assume that none of the components of the Common Features (CF) project has been implemented. The differences between the WOPCs are:

  - WO1: Conditions as they would be in 2010 if there were no CF components in place (most of which are constructed). Folsom operational storage would remain the current 400,000/670,000 cfs variable.
  - WO2: Same as above with the addition of the Joint Federal Project which addresses both dam safety and flood risk management issues through Folsom Dam modifications (described as alternative B in the PAC and ERR.) It is projected that the JFP will be completed by 2014.The WO2 condition shows how the ERR recommended plan would perform with a different without project condition (no Common Features) as its analysis base.
  - WO3: Same as above with the addition of the 3.5 foot Folsom Dam and Reservoir raise. It is projected that the 3.5 foot raise will be completed by 2016.This condition shows how the raise would perform with a different without-project condition as its analysis base. The comparison of this condition to WO1 gives the change in performance and benefits associated with all of the current plans to change Folsom Dam and Reservoir (without the Common Features components in place).

- **No-Action Conditions**: These conditions assume that the CF components that have been completed or are anticipated to be completed and which require no additional federal authorization are in place.
  - NA1: Conditions as they would be in 2010 with all (WRDA 96/99) CF components in place that can be completed without additional authorization.
  - NA2: Same as NA1 with the addition of the JFP from the ERR.
  - NA3: Same as NA2 with the addition of the 3.5 foot Folsom Dam and Reservoir raise. This condition is comparable to the ERR recommended plan. The comparison of this condition to NA1 gives the change in performance and benefits associated with all of the current plans to change Folsom Dam and Reservoir. The comparison of any with-project alternatives to this condition will provide the remaining benefits possible, the change in residual flood damages, and the change in expected performance that the Sacramento metropolitan area can expect to experience with additional improvements above those already authorized on the Lower American River.

As it turns out, only the WO1, WO3, and NA3 conditions ended up being analyzed in the 2009 GRR. For the on-going GRR, only the WO1, NA1, NA2 (with and without dam safety), and NA3 conditions will be carried forward.

4.4.1.2 2010 NPACR Without-Project Condition

In both the 2009 GRR the only without-project condition assumed for the Natomas Basin impact area was the NA3 condition. This without-project condition, which assumes that the authorized Common Features components, the JFP, and the mini-raise are in place, is also assumed for this NPACR.

4.4.2 Upstream Levee Performance

In the 2009 GRR, the assumption of no upstream levee breaches, commonly used in USACE engineering analyses, was made; hence, only levee overtopping, and no levee breaches, was considered upstream of the project area.

Subsequent to the GRR F3 conference in March 2009, and in association with addressing the relatively high AEP and EAD values that were being reported for the Natomas Basin impact area associated with the NAT C index point (Sacramento River, river mile 79), additional sensitivity analyses pertaining to upstream levee breaches were conducted to see its effect on AEP and EAD values. In these sensitivity analyses, the hydraulic frequency-stage curves were adjusted based on historical flood events to account for possible upstream levee breaches; these modified curves were then used in HEC-FDA to see its effects on AEP and EAD. The analysis found that adjustments to the frequency-stage curves produced only relatively minimal changes to AEP and EAD results. The Economic Memorandum for Record that describes the sensitivity analyses is provided as Enclosure 3 in this Economic Appendix. Further details concerning upstream levee performance assumptions can also be found in Appendix C, Hydraulics.

For this NPACR, no upstream levee breaches were assumed in the hydraulic engineering analysis and are not reflected in the exceedance-probability-stage curves used in the economic analysis.

4.4.3 Potential for Human Intervention and the GRU Curves

As mentioned in sub-section 4.4.2, the 2009 GRR analysis brought into question the reasonableness of the high AEP and EAD results that were being reported for the Natomas Basin impact area. Directly related to this were the effects the GRU curves were having on the AEP and EAD results. Subsequent to the F3 conference, economic sensitivity analyses were performed using modified GRU curves to see the effect these curves would have on AEP and EAD. The GRU curves were modified by the SPK Geotechnical Sciences Section to reflect the possibility of human intervention during the smaller exceedance probability events, where the assumption of human intervention on the levees can be considered reasonable as there is historical precedent whereby efforts to stabilize levees have occurred during past flood events in the Natomas Basin impact area.

Based on the modifications made to the GRU curves to reflect the potential for human intervention, the economic sensitivity analyses suggested that only a relatively minimal effect to AEP and EAD could be attributable to these GRU curve modifications. More detail about how the GRU curves were modified to account for potential human intervention can be found in Appendix F, *Geotechnical*; more detail about the economic sensitivity analyses can be found in Enclosure 3 of this Appendix.

For this NPACR, GRU curves (without-project and with-project) used in the economic analysis do not account for the potential for human intervention.

4.4.3 Index Point Locations and Derivation of Floodplains

The Natomas Basin impact area is at risk of flooding from the American River, the Sacramento River, the Natomas Cross Canal, and the Natomas East Main Drainage Canal. For the 2009 GRR economic analysis, floodplains were developed based on breakouts from only one index point (NAT C) on the Sacramento River, a location that had been previously selected for prior Natomas Basin studies. For this NPACR analysis, suites of floodplains were developed based on nine index points located on each of the flooding sources in order to better characterize the without-project condition and facilitate the formulation and evaluation of with-project alternatives.

4.4.4 Future Development in Natomas Basin

In the Natomas Basin impact area significant residential and non-residential construction occurred up until the area was re-mapped (and considered to be within the 100-year floodplain) and a 2008 construction moratorium came into effect. Significant development is expected to continue within the Basin over the next few decades if FRM improvements are made which will remove the area from the FEMA 100-year floodplain and lift the existing building moratorium.

To be consistent with the WRDA 90 Section 308 guidance, none of the growth expected to occur once the 2008 construction moratorium is lifted will be considered in the damage/benefit analysis (future without-project condition). However, future development within the Natomas Basin impact area will be considered in terms of describing future residual risk. This residual risk will be characterized in this NPACR analysis by describing additional event damages and population at risk associated with each alternative.

4.4.6 Future Conditions for Hydrology, Hydraulics, and Geotechnical

For the NPACR the basic assumption is that the hydrology, hydraulics, and geotechnical would remain the same between the existing and future without-project conditions. Future hydrologic, hydraulics, and geotechnical engineering HEC-FDA data inputs were assumed to be the same as existing base conditions. For HEC-FDA modeling purposes, these relationships were set equal under both existing and future without-project conditions.

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CHAPTER 5
WITHOUT-PROJECT ANALYSIS – HEC-FDA BASE MODELING RESULTS

Chapter 5 presents the HEC-FDA base modeling results used to inform and guide the with-project analysis documented in Chapter 6; the HEC-FDA modeling completed for each reach and documented in this chapter "sets the stage" for the with-project analysis. Analyzing expected annual damages (EAD) and annual exceedance probability (AEP) for each reach/index point was a necessary step in the analytical process in order to gain information (e.g., EAD, AEP, single-event damages) regarding the overall risk (probability of flooding and consequences of flooding) associated with each reach independently of one another; the results also allowed for the determination of the risk of flooding associated with each reach on a relative basis, that is, which reaches consists of levees that provide the least protection from flooding (or has the greatest risk of flooding) and which reaches consists of levees that provide the most protection from flooding. This initial analysis provided sufficient information to establish the baseline without-project condition (EAD and AEP) used for the with-project analysis documented in Chapter 6. This baseline without-project condition used for the with-project analysis is presented at the end of this chapter.

5.1 MULTIPLE INDEX POINTS AND SINGLE IMPACT AREA

In the without-project economic analysis conducted as part of the 2009 ARWCF GRR, only one index point (NAT C on the Sacramento River near the confluence with the Natomas Cross Canal) was used to evaluate the without-project condition. For this NPACR, nine economic index points, which represent nine different geotechnical reaches, were selected around the Basin in order to better facilitate the evaluation of alternatives and support the economic with-project analysis. The locations of the nine index points were presented in Chapter 4, *Economic Methodologies and Major Assumptions.*

The use of nine index points for economic evaluation purposes necessarily resulted in nine sets of without-project hydrologic/hydraulic HEC-FDA input data, nine suites of without-project floodplains, and nine without-project GRU curves. What did not change between the 2009 analysis and this NPACR, at least during the initial stages of this current economic analysis, was that the entire Basin was considered as one impact area having the same economic structure inventory.[10] Having nine different index points and only one impact area resulted in reach/index point-specific without-project AEP and EAD results, which are presented in the following subsections. Nine HEC-FDA models were set-up to model each reach/index point. Evaluation of the AEP and EAD results from this initial HEC-FDA modeling showed the risk associated with flooding on a reach-by-reach basis; this initial, "building block" modeling was a necessary step

[10] The Basin was eventually split into two impact areas based on the results of the initial HEC-FDA without-project modeling for each reach/index point. The delineation of two impact areas is described later in this chapter.

and provided valuable information for making decisions associated with the Basin-wide with-project analysis, which is presented in Chapter 6, *With-Project Analysis*.

5.2 WITHOUT-PROJECT FLOODPLAINS

Floodplains were developed by the Sacramento District's Hydraulic Design Section using the FLO-2D hydraulic model, which provides interior water surface elevations by grid cell. Without-project floodplains were developed for the 2-, 10-, 25-, 50-, 100-, 200-, and 500-year probability events for each index point. The suites of floodplains associated with each index point are presented in Enclosure 1; these plates show the extent and depths of flooding associated with levee breaches at each index point for each event. Additional details regarding the floodplains and their development can be found in Appendix C, *Hydraulics*.

5.3 HYDROLOGIC, HYDRAULIC, AND GEOTECHNICAL DATA

As described in Chapter 4, *Economic Methodologies and Major Assumptions*, key engineering relationships used in the economic analysis include exceedance probability-stage functions (NAT A, NAT D, NAT E, NAT F, NAT G, NAT H) or exceedance probability-discharge and stage-discharge functions (NAT B, NAT C, NAT I); geotechnical risk and uncertainty (GRU) curves were developed for all reaches/index points. All of the HEC-FDA input data can be found in Enclosure 2 of this Appendix.

5.4 ECONOMIC INVENTORY VALUATION BY EVENT FLOODPLAIN

Chapter 4 presented the structure count and total value of damageable property within the Natomas Basin impact area. For each index point, Table 5-1 displays the total number of structures and the total value of these structures that fall within a specific event floodplain. The data in Table 5-1 show that most of the structures in the Natomas Basin are at risk from flooding. The table also allows for the comparison of the flooding risk (in terms of the number of structures affected and the value of property at risk) associated with a breach at one reach/index point versus a breach at another reach/index point. It can be clearly seen from this table that the number of structures and value of property at risk from a levee breach at NAT F or NAT G are significantly lower than from a breach at the other reaches/index points.

Table 5-1
Number of Structures and Value of Property at Risk
October 2010 Price Level

REACH/ INDEX PT	EVENT FLOODPLAIN	NUMBER OF STRUCTURES	STRUCTURE VALUE	CONTENT VALUE	TOTAL VALUE
A	25-yr	20,964	5,255,941	2,649,709	7,905,650
	100-yr	22,313	5,619,278	2,854,929	8,474,207
	500-yr	22,543	5,658,982	2,876,400	8,535,382
B	25-yr	21,229	5,304,540	2,686,974	7,991,514
	100-yr	22,574	5,617,342	2,853,797	8,471,139
	500-yr	22,828	5,659,545	2,876,682	8,536,227
C	25-yr	22,706	5,644,853	2,869,222	8,514,075
	100-yr	22,828	5,659,633	2,876,726	8,536,359
	500-yr	22,830	5,660,504	2,877,154	8,537,658
D	25-yr	22,828	5,660,504	2,877,154	8,537,658
	100-yr	22,830	5,660,504	2,877,154	8,537,658
	500-yr	22,830	5,660,504	2,877,154	8,537,658
E	25-yr	16,184	4,075,581	1,992,676	6,068,257
	100-yr	17,453	4,291,210	2,104,792	6,396,002
	500-yr	19,594	4,765,657	2,347,633	7,113,290
F	25-yr	1,096	213,063	105,249	318,312
	100-yr	5,969	1,884,830	919,943	2,804,773
	500-yr	16,043	3,863,171	1,890,689	5,753,860
G	25-yr	3,141	973,369	477,315	1,450,684
	100-yr	9,279	2,431,106	1,187,646	3,618,752
	500-yr	16,313	3,947,895	1,933,051	5,880,946
H	25-yr	14,292	3,552,158	1,728,885	5,281,043
	100-yr	17,931	4,402,568	2,157,145	6,559,713
	500-yr	20,995	5,260,235	2,652,132	7,912,367
I	25-yr	21,335	5,335,584	2,696,741	8,032,325
	100-yr	22,412	5,642,219	2,867,606	8,509,825
	500-yr	22,551	5,659,545	2,876,682	8,536,227

5.5 DEPTH-PERCENT DAMAGE FUNCTIONS

The depth of flooding is the primary factor in determining potential damages to structures, contents, and automobiles. Depth-percent damage functions were used in the HEC-FDA model to estimate the percent of value lost for these categories. Residential depth-damage curves (structures and contents) were taken from Economic Guidance Memorandum (EGM) 04-01, *Generic Depth-Damage Relationships for Residential Structures*, for use on both single-family and multi-family residential structures. Structures were identified as 1-story, 2-story, or split-level. Mobile home curves were taken from the May 1997 Final Report, *Depth Damage Relationships in Support of Morganza to the Gulf, Louisiana Feasibility Study*. Non-residential curves (structures) were based on the same 1997 Morganza study (USACE New Orleans District) and were used for the Natomas Basin, where inundation depths are deep and flooding durations are long (greater than three days). In 2007 non-residential content depth-percent damage curves were developed based on the expert elicitation for each of the 22 categories outlined in Chapter 3; these curves were developed specifically for building types in the Sacramento Metropolitan area and were used for this NPACR analysis.

The complete set of depth- percent damage functions with their corresponding uncertainties can be found in Enclosure 2. Tables 5-2 to 5-7 show the depths-percent damage functions for residential and non-residential damage categories (without uncertainty).

Table 5-2
Residential Curves

CATEGORY		DEPTH OF FLOODING ABOVE THE FIRST FLOOR IN FEET							
		-4.0	-1.0	0.0	1	3	5	10	15
1 Story	Structure	0%	3%	13%	23%	40%	53%	73%	80%
	Content	0%	2%	8%	13%	22%	29%	38%	40%
2 Story	Structure	0%	3%	9%	15%	26%	36%	56%	68%
	Content	0%	1%	5%	9%	16%	21%	32%	37%
Split	Structure	0%	6%	7%	9%	17%	29%	63%	84%
	Content	0%	2%	3%	5%	11%	20%	46%	61%
1 Story w/base	Structure	5%	19%	26%	32%	46%	59%	80%	81%
	Content	6%	13%	16%	19%	25%	30%	39%	39%
2 Story w/base	Structure	5%	14%	18%	22%	32%	42%	65%	76%
	Content	5%	10%	12%	14%	18%	22%	34%	49%
Split w/base	Structure	5%	14%	19%	23%	33%	44%	65%	69%
	Content	4%	9%	12%	14%	18%	22%	26%	26%
Mobile Home-Short Duration	Structure	0%	6%	10%	45%	46%	66%	66%	66%
	Content	0%	0%	0%	38%	69%	90%	90%	90%
Mobile Home-Long Duration	Structure	0%	6%	10%	45%	96%	96%	96%	96%
	Content	0%	0%	0%	85%	99%	99%	99%	99%

Table 5-3
Non Residential Structure Curves

CATEGORY	DEPTH OF FLOODING ABOVE THE FIRST FLOOR IN FEET						
	-1.0	0	1	3	5	10	15
1 Story Short Duration	0	7	16	28	31	46	50
2 Story Short Duration	0	5	10	18	22	38	38
1 Story Long Duration	0	7	22	31	32	54	86
2 Story Long Duration	0	5	15	22	23	46	80

Table 5-4
Non Residential Content Curves – 1 Story – Short Duration

CATEGORY	DEPTH OF FLOODING ABOVE THE FIRST FLOOR IN FEET						
	-1.0	0	1	3	5	10	15
Food Stores	0	0	29	96	100	100	100
Furniture-Retail	0	0	80	96	100	100	100
Grocery Store	0	0	32	89	100	100	100
Hotel-Full Service	0	0	23	90	100	100	100
Medical	0	0	33	89	100	100	100
Office	0	0	35	90	100	100	100
Restaurant	0	0	30	96	100	100	100
Rest-Fast Food	0	0	23	90	100	100	100
Retail	0	0	80	96	100	100	100
Service-Auto	9	10	23	67	100	100	100
Shopping Centers	0	0	33	72	100	100	100
Heavy	0	0	16	56	92	100	100
Light	0	0	35	75	96	100	100
Warehouse	0	0	23	69	96	100	100
Churches	0	0	33	85	99	99	100
Government	0	0	35	90	100	100	100
Recreation	0	0	38	95	100	100	100
Schools	0	0	22	67	88	100	100
Farms	0	0	30	76	100	100	100

Table 5-5
Non Residential Content Curves – 2 Story – Short Duration

CATEGORY	DEPTH OF FLOODING ABOVE THE FIRST FLOOR IN FEET						
	-1.0	**0**	**1**	**3**	**5**	**10**	**15**
Food Stores	0	0	25	50	50	50	100
Furniture-Retail	0	0	42	50	50	50	100
Grocery Store	0	0	27	49	50	50	100
Hotel-Full Service	0	0	20	50	50	50	100
Medical	0	0	28	49	50	50	100
Office	0	0	29	50	50	50	100
Restaurant	0	0	25	50	50	50	100
Rest-Fast Food	0	0	20	50	50	50	100
Retail	0	0	19	36	50	50	100
Service-Auto	8	8	19	37	50	50	100
Shopping Centers	0	0	28	40	50	50	100
Heavy	0	0	14	31	46	50	100
Light	0	0	30	41	48	50	100
Warehouse	0	0	20	38	48	50	100
Churches	0	0	28	47	49	50	100
Government	0	0	30	50	50	50	100
Recreation	0	0	32	49	50	50	100
Schools	0	0	18	37	44	50	100

Table 5-6
Non Residential Content Curves – 1 Story – Long Duration

CATEGORY	DEPTH OF FLOODING ABOVE THE FIRST FLOOR IN FEET						
	-1.0	0	1	3	5	10	15
Food Stores	0	0	78	100	100	100	100
Furniture-Retail	0	0	98	100	100	100	100
Grocery Store	0	0	87	100	100	100	100
Hotel-Full Service	0	0	88	100	100	100	100
Medical	0	0	75	100	100	100	100
Office	0	0	97	100	100	100	100
Restaurant	0	0	91	100	100	100	100
Rest-Fast Food	0	0	88	100	100	100	100
Retail	0	0	80	100	100	100	100
Service-Auto	10	10	74	100	100	100	100
Shopping Centers	0	0	96	100	100	100	100
Heavy	0	0	33	77	100	100	100
Light	0	0	88	99	100	100	100
Warehouse	0	0	84	100	100	100	100
Churches	0	0	73	99	99	99	100
Government	0	0	97	100	100	100	100
Recreation	0	0	98	100	100	100	100
Schools	0	0	88	100	100	100	100
Farms	0	0	56	100	100	100	100

Table 5-7
Non Residential Content Curves – 2 Story – Long Duration

CATEGORY	DEPTH OF FLOODING ABOVE THE FIRST FLOOR IN FEET						
	-1.0	**0**	**1**	**3**	**5**	**10**	**15**
Food Stores	0	0	38	56	56	67	100
Furniture-Retail	0	0	47	56	56	67	100
Grocery Store	0	0	42	56	56	67	100
Hotel-Full Service	0	0	42	56	56	67	100
Medical	0	0	36	56	56	67	100
Office	0	0	46	56	56	67	100
Restaurant	0	0	44	56	56	67	100
Rest-Fast Food	0	0	42	56	56	67	100
Retail	0	0	38	56	56	67	100
Service-Auto	5	5	35	56	56	67	100
Shopping Centers	0	0	46	56	56	67	100
Heavy	0	0	40	56	56	67	100
Light	0	0	42	56	56	67	100
Warehouse	0	0	40	56	56	67	100
Churches	0	0	35	55	55	66	100
Government	0	0	45	56	56	68	100
Recreation	0	0	47	56	56	67	100
Schools	0	0	42	56	56	67	100
Farms	0	0	27	56	56	67	100

5.6 AUTOMOBILE LOSSES

Damages to automobiles were developed based on a function of average value, number of vehicles, estimated evacuation rate, depth of flooding, and depth-percent damages loss. Values were determined for average used cars ($14,925)[11] and new cars ($28,500) based on information from the National Auto Dealer Association (NADA). The number of cars per residential unit (1.93) was based on the total number of automobiles and trucks registered in the Sacramento Area (source: California Department of Finance) divided by the number of households. Automobile counts for car dealerships were based on discussions with local dealers (who also verified values were within a reasonable range) and comparisons with spot inventories from aerial photos. New car values were used to determine value of vehicles at risk at full service new car dealerships and used car values for both residential units and small used car dealerships. It

[11] For the analysis and results documented in Chapters 5, 6, and 7a, the values used to compute vehicle damages is $14,925. However, comments received through agency technical review recommended using a lesser value of $7,988, which is the value published by the Bureau of Transportation Statistics, unless regional vehicle data supported the higher value of $14,925. For the analysis presented in Chapter 7b, damages are based on the lower value of $7,988; the damages and benefits results reported in Chapter 7b serve as the "final" economic results used for the net benefit and benefit-to-cost analyses and for plan formulation purposes.

was assumed that, based on short evacuation time[12], about 50% of residential-based vehicles will be removed from the flood area prior to the event and only 20% will be removed from dealerships. Depth-percent damage functions for automobiles were based on averages from curves developed by the Institute for Water Resources (IWR) and provided in EGM 09-04, *Generic Depth-Damage Relationships for Vehicles*. These curves were developed for five vehicle categories (sedans, pickups, SUV, sports, and mini-vans) and are displayed in Table 5-8 below. The curve used for this analysis is displayed in the last column.

[12] The 50% assumption (percentage of autos moved out of the floodplain) used for automobiles was made based on the potential short warning time, the large number of people who live in the Basin, the relatively small number of major routes (highways) for evacuation, and EGM 09-04 which recommends a removal rate of 50.6% for areas where the warning time is less than 6 hours.

Table 5-8
Vehicle Depth-Percent Damage Curve

PERCENT DAMAGE TO VEHICLES												
	Sedans		Pickups		SUVs		Sports		Mini Vans		HEC-FDA	
Depth Above Grnd	Percent Dam	Std Dev	Percent Dam	Std Dev	Percent Dam	Std Dev	Percent Dam	Std Dev	Percent Dam	Std Dev	Percent Dam	Std Dev
.5	7.60%	2.42%	5.20%	3.02%	0.00%	11.28%	1.40%	19.22%	0.00%	9.11%	2.80%	9.00%
1	28.00%	1.84%	20.30%	2.53%	13.80%	8.76%	29.20%	16.81%	17.80%	6.82%	21.80%	7.40%
2	46.20%	1.51%	34.40%	2.33%	30.60%	6.67%	52.80%	13.17%	38.30%	5.33%	40.50%	5.80%
3	62.20%	1.45%	47.50%	2.38%	45.80%	5.24%	72.20%	8.47%	56.80%	4.88%	56.90%	4.50%
4	76.00%	1.57%	59.60%	2.57%	59.40%	4.78%	87.40%	3.61%	73.30%	5.34%	71.10%	3.60%
5	87.60%	1.74%	70.70%	2.81%	71.40%	5.36%	98.40%	6.12%	87.80%	6.23%	83.20%	4.50%
6	97.00%	1.92%	80.80%	3.04%	81.80%	6.61%	100%	13.80%	100%	7.20%	91.90%	6.50%
7	100%	2.06%	89.90%	3.21%	90.60%	8.17%	100%	13.80%	100%	7.20%	96.10%	6.90%
8	100%	2.06%	98.00%	3.32%	97.80%	9.88%	100%	13.80%	100%	7.20%	99.20%	7.30%
9	100%	2.06%	100%	3.36%	100%	11.70%	100%	13.80%	100%	7.20%	100%	7.60%
10	100%	2.06%	100%	3.36%	100%	11.70%	100%	13.80%	100%	7.20%	100%	7.60%

5.7 ECONOMIC UNCERTAINTIES

The valuation of residential and non-residential structures and contents along with automobile losses were estimated with uncertainty. In the estimation of structure value, three variables were considered to have a possible range of values: $ per square foot, building square footage, and percent of estimated depreciation. Using a triangular distribution to describe the range of these three variables, a Monte Carlo simulation was run on typical structures by category and the mean and standard deviations were compared to derive coefficients of variation (COV) for structure values by category. Content value uncertainties were based on data from the aforementioned expert elicitation. The program Best Fit was used to determine what would be a reasonable distribution, and using the model data, a normal distribution best described uncertainty in structure and content valuation. These uncertainty parameters for valuation were imported into the HEC-FDA program. The uncertainties for structure and content values by category are shown in Table 5-9 below.

Table 5-9
UNCERTAINTY IN STRUCTURE AND CONTENT VALUE

USE CATEGORY	UNCERTAINTY IN VALUE (INPUT TO HEC-FDA)	
	Structure SD/Mean	Content SD/Mean
Residential (SFR & MFR)	17%	12%
Mobile Homes	14%	12%
Office 2-Story	17%	14%
Office 1-Story	17%	16%
Retail	17%	18%
Retail-Furniture	17%	20%
Auto Dealerships	12%	12%
Hotel	12%	16%
Food Stores	21%	27%
Restaurants	19%	3%
Restaurants-Fast Food	19%	13%
Medical	13%	46%
Hospitals	21%	46%
Shopping Centers	20%	23%
Large Grocery Stores	20%	4%
Service (Auto)	17%	4%
Warehouse	17%	31%
Light Ind.	21%	19%
Heavy Ind.	21%	31%
Government	31%	16%
Schools	15%	33%
Religious	19%	40%
Recreation	19%	13%
Farms	20%	8%
Automobiles	15%	N/A

Several factors contributed to the uncertainty associated with automobile damages. These factors include the average unit value, the number of vehicles per residence/dealership assumed, and the evacuation rate. It was assumed that the average number or automobiles per residential unit was 2 and the evacuation rate was 50%. An average value of an automobile was calculated to be $14,930. (As was previously noted, this value was reduced to $7,988.) While uncertainty in these variables was not considered, uncertainty in the percent damage (Table 5-9) by depth (as reflected in the depth-percent damage curve) was taken into account.

Uncertainty in first floor elevation was also included in the model. During the field inventory, first floor estimations were made by visual inspection and assigned to structures in one half-foot increases. For example, the average SFR built on slab without any fill might be listed as ground elevation + 0.5 foot to 1.0 foot; raised foundations either 1.5, 2 or 2.5 feet. Based on this level of precision, it was assumed that 0.5 foot standard error would capture the potential uncertainty in this first floor elevation adjustment.

The uncertainty associated with the percent damages at specific depths of flooding for automobiles and structures/contents were entered into the HEC-FDA model. Residential structure and content depth-percent damage curves are normally distributed and include standard deviations of percent damages by depth of flooding. Non-residential content depth-percent damage curves are triangularly distributed and include a minimum, most likely, and maximum percent damage by depth of flooding. These curves with their corresponding uncertainties are shown in section 5.5 above.

5.8 WITHOUT-PROJECT SINGLE-EVENT DAMAGES

Single-event without-project damages for the 2-, 10-, 25-, 50-, 100-, 200-, and 500-year events were computed in HEC-FDA using the economic inventory, flooding depths, and depth-percent damage functions. Table 5-10 displays damages by event on a reach/index point-specific basis. Tables 5-11 through 5-19 display the damages by event and damage category for each reach/index point. It is important to note that the values in these tables represent single-event damages based on flooding the same impact area (the entire Natomas Basin) and structure inventory but from different sources (index points); damages, therefore, cannot be summed across reaches/index point as this would result in double counting.

Single-event damages for structures and contents and for both residential and non-residential categories were calculated with uncertainty in HEC-FDA. Single-event automobile damages with uncertainty were also estimated. The single-event damage results indicate that flooding from NAT D for all frequency events results in the most severe consequences with damages ranging from $6.9 billion for a 2-year event to $7.0 billion for a 500-year event.

Table 5-10
Single-Event Without-Project Damages by Reach/Index Point

REACH/INDEX POINT	NATOMAS BASIN SINGLE-EVENT WITHOUT-PROJECT DAMAGES (VALUES IN $ MILLIONS, OCTOBER 2010 PRICE LEVELS)						
	2-yr	10-yr	25-yr	50-yr	100-yr	200-yr	500-yr
NAT A	3,815	4,983	5,122	5,739	6,196	6,502	6,739
NAT B	3,733	5,176	5,199	5,673	6,113	6,408	6,775
NAT C	5,194	6,386	6,540	6,759	6,836	6,954	7,010
NAT D	6,302	6,731	6,826	6,942	6,986	7,014	7,034
NAT E	2,002	2,955	3,384	3,587	3,743	3,913	4,261
NAT F	0	44	78	134	191	259	3,049
NAT G	222	573	615	1,054	1,616	1,971	3,068
NAT H	36	904	2,773	3,388	3,923	4,524	5,098
NAT I	3,806	5,163	5,389	5,998	6,427	6,671	6,813

Table 5-11
Single-Event Without-Project Damages
NAT A

DAMAGE CATEGORY	NAT A SINGLE-EVENT WITHOUT-PROJECT DAMAGES (VALUES IN $ MILLIONS, OCTOBER 2010 PRICE LEVEL)						
	2-yr	**10-yr**	**25-yr**	**50-yr**	**100-yr**	**200-yr**	**500-yr**
Residential	2,573	3,279	3,373	3,752	4,062	4,246	4,388
Commercial	492	598	615	697	757	794	825
Industrial	338	404	420	483	523	563	590
Public	170	409	414	486	515	553	588
Farm	1	3	3	5	8	9	10
Auto Losses	241	291	296	316	331	336	339
TOTAL	**3,815**	**4,983**	**5,122**	**5,739**	**6,196**	**6,502**	**6,739**

Table 5-12
Single-Event Without-Project Damages
NAT B

DAMAGE CATEGORY	NAT B SINGLE-EVENT WITHOUT-PROJECT DAMAGES (VALUES IN $ MILLIONS, OCTOBER 2010 PRICE LEVEL)						
	2-yr	**10-yr**	**25-yr**	**50-yr**	**100-yr**	**200-yr**	**500-yr**
Residential	2,371	3,384	3,398	3,702	4,008	4,197	4,411
Commercial	453	614	619	685	734	774	824
Industrial	317	421	423	476	515	551	591
Public	361	456	457	489	518	543	600
Farm	2	4	5	6	7	9	10
Auto Losses	229	297	298	314	330	334	339
TOTAL	**3,733**	**5,176**	**5,199**	**5,673**	**6,113**	**6,408**	**6,775**

Table 5-13
Single-Event Without-Project Damages
NAT C

DAMAGE CATEGORY	NAT C SINGLE-EVENT WITHOUT-PROJECT DAMAGES (VALUES IN $ MILLIONS, OCTOBER 2010 PRICE LEVEL)						
	2-yr	**10-yr**	**25-yr**	**50-yr**	**100-yr**	**200-yr**	**500-yr**
Residential	3,628	4,183	4,277	4,402	4,451	4,499	4,519
Commercial	668	770	788	820	833	851	866
Industrial	460	548	565	588	597	611	626
Public	482	542	564	600	605	643	649
Farm	5	9	10	10	11	11	11
Auto Losses	311	334	336	339	339	339	339
TOTAL	**5,194**	**6,386**	**6,540**	**6,759**	**6,836**	**6,954**	**7,010**

Table 5-14
Single-Event Without-Project Damages
NAT D

DAMAGE CATEGORY	NAT D SINGLE-EVENT WITHOUT-PROJECT DAMAGES (VALUES IN $ MILLIONS, OCTOBER 2010 PRICE LEVEL)						
	2-yr	**10-yr**	**25-yr**	**50-yr**	**100-yr**	**200-yr**	**500-yr**
Residential	4,133	4,386	4,444	4,495	4,513	4,519	4,520
Commercial	760	814	832	849	857	868	875
Industrial	530	585	596	609	619	627	637
Public	537	597	604	639	647	650	651
Farm	9	10	11	11	11	11	12
Auto Losses	333	339	339	339	339	339	339
TOTAL	**6,302**	**6,731**	**6,826**	**6,942**	**6,986**	**7,014**	**7,034**

Table 5-15
Single-Event Without-Project Damages
NAT E

DAMAGE CATEGORY	NAT E SINGLE-EVENT WITHOUT-PROJECT DAMAGES (VALUES IN $ MILLIONS, OCTOBER 2010 PRICE LEVEL)						
	2-yr	**10-yr**	**25-yr**	**50-yr**	**100-yr**	**200-yr**	**500-yr**
Residential	1,172	1,915	2,250	2,409	2,521	2,651	2,875
Commercial	325	409	449	464	479	497	551
Industrial	260	301	317	327	336	343	368
Public	122	139	152	155	169	173	199
Farm	0	0	1	2	2	2	2
Auto Losses	123	190	216	229	237	247	265
TOTAL	**2,002**	**2,955**	**3,384**	**3,587**	**3,743**	**3,913**	**4,261**

Table 5-16
Single-Event Without-Project Damages
NAT F

DAMAGE CATEGORY	NAT F SINGLE-EVENT WITHOUT-PROJECT DAMAGES (VALUES IN $ MILLIONS, OCTOBER 2010 PRICE LEVEL)						
	2-yr	**10-yr**	**25-yr**	**50-yr**	**100-yr**	**200-yr**	**500-yr**
Residential	0	41	68	118	164	225	1,903
Commercial	0	0	0	0	0	0	448
Industrial	0	0	0	0	0	0	347
Public	0	0	4	4	10	10	150
Farm	0	0	0	0	0	0	1
Auto Losses	0	3	6	11	17	24	200
TOTAL	**0**	**44**	**78**	**134**	**191**	**259**	**3,049**

Table 5-17
Single-Event Without-Project Damages
NAT G

DAMAGE CATEGORY	NAT G SINGLE-EVENT WITHOUT-PROJECT DAMAGES (VALUES IN $ MILLIONS, OCTOBER 2010 PRICE LEVEL)						
	2-yr	**10-yr**	**25-yr**	**50-yr**	**100-yr**	**200-yr**	**500-yr**
Residential	192	316	319	560	909	1,150	1,990
Commercial	0	99	129	247	283	321	434
Industrial	0	106	109	159	243	258	302
Public	10	19	24	32	90	121	140
Farm	0	0	0	0	0	0	0
Auto Losses	20	33	34	55	90	121	202
TOTAL	**222**	**573**	**615**	**1,054**	**1,616**	**1,971**	**3,068**

Table 5-18
Single-Event Without-Project Damages
NAT H

DAMAGE CATEGORY	NAT H SINGLE-EVENT WITHOUT-PROJECT DAMAGES (VALUES IN $ MILLIONS, OCTOBER 2010 PRICE LEVEL)						
	2-yr	**10-yr**	**25-yr**	**50-yr**	**100-yr**	**200-yr**	**500-yr**
Residential	28	435	1,735	2,239	2,641	3,066	3,346
Commercial	3	216	416	459	511	576	616
Industrial	0	147	302	321	350	391	425
Public	0	54	140	152	174	213	414
Farm	0	0	0	1	1	2	3
Auto Losses	5	53	179	217	246	277	296
TOTAL	**36**	**904**	**2,773**	**3,388**	**3,923**	**4,524**	**5,098**

Table 5-19
Single-Event Without-Project Damages
NAT I

DAMAGE CATEGORY	NAT I SINGLE-EVENT WITHOUT-PROJECT DAMAGES (VALUES IN $ MILLIONS, OCTOBER 2010 PRICE LEVEL)						
	2-yr	10-yr	25-yr	50-yr	100-yr	200-yr	500-yr
Residential	2,555	3,400	3,547	3,928	4,201	4,347	4,430
Commercial	499	621	655	732	787	815	836
Industrial	334	424	441	507	557	584	598
Public	170	416	436	498	540	578	600
Farm	1	3	3	6	9	10	10
Auto Losses	246	299	307	327	335	338	339
TOTAL	**3,806**	**5,163**	**5,389**	**5,998**	**6,427**	**6,671**	**6,813**

5.9 HEC-FDA MODEL RESULTS BY REACH/INDEX POINT

The following subsections present the without-project expected annual damages (EAD) and annual exceedance probability (AEP) results. Without-project EAD was computed on a reach/index point-specific basis using the HEC-FDA model. The HEC-FDA model integrates the hydrologic, hydraulic, geotechnical and economic relationships with uncertainty to create exceedance probability-damage functions with uncertainty. Without-project EAD for each reach/index point is shown in Table 5-20; the EAD results for each reach/index point broken down by category are displayed in Table 5-21.

Depending on where the levee breach occurs, EAD ranges between $26 million and over one billion. The HEC-FDA results indicate that risk of flooding from NAT D (Natomas Cross Canal) is the worst: over one billion dollars in expected damages and a one-in-five chance of flooding in any given year. On the other hand, risk of flooding from NAT I is the lowest in terms of probability: about a 1 in 67 chance of flooding in any given year; the risk of flooding from NAT F is the lowest in terms of consequences: about $26 million in expected annual damages.

5.9.1 Expected Annual Damages (EAD)

Table 5-20 and 5-21 show the without-project expected annual damages results for each reach/index point. Table 5-20 shows total damages while Table 5-21 shows damages by category.

Table 5-20
Expected Annual Damages by Reach/Index Point (Oct 2010 Price Level)

PLAN	EXPECTED ANNUAL DAMAGES (EAD) IN $MILLIONS								
	Reach/Index Point								
	SR			NCC	PGCC/NEMDC				AR
	A	B	C	D	E	F	G	H	I
Without-Project	747	351	265	1,167	789	26	67	122	95

Notes: SR = Sacramento River, NCC = Natomas Cross Canal; PGCC = Pleasant Grove Creek Canal; NEMDC = Natomas East Main Drainage Canal; AR = American River

Table 5-21
EAD by Reach/Index Point and Damage Category (Oct 2010 Price Level)
Without-Project Condition (Per Reach/Index Point)

ECONOMIC REACH/INDEX POINT	EXPECTED ANNUAL DAMAGES (EAD) IN $MILLIONS								
	Reach/Index Point								
	SR			NCC	PGCC/NEMDC				AR
	A	B	C	D	E	F	G	H	I
Residential	468	227	172	758	518	20	41	77	62
Commercial	97	44	32	144	99	2	11	19	12
Industrial	65	30	23	102	69	1	8	12	8
Public	54	31	23	103	59	1	3	6	8
Farm	1	1	1	2	1	0	0	0	0
Automobiles	43	20	13	59	44	2	4	7	5
Total	747	351	265	1,167	789	26	67	122	95

Notes: SR = Sacramento River, NCC = Natomas Cross Canal; PGCC = Pleasant Grove Creek Canal; NEMDC = Natomas East Main Drainage Canal; AR = American River

5.9.2 Annual Exceedance Probability (AEP)

Table 5-22 below displays the AEP results on a reach-by-reach basis.

Table 5-22
Without-Project AEP by Reach/Index Point

PLAN	ANNUAL EXCEEDANCE PROBABILITY (AEP)								
	Natomas Basin Reach/Index Point								
	SR			NCC	PGCC/NEMDC				AR
	A	B	C	D	E	F	G	H	I
Without-Project	0.20	0.12	0.04	0.21	0.18	0.30	0.20	0.04	0.015

5.10 EVALUATION OF WITHOUT-PROJECT HEC-FDA RESULTS

Upon completion of the initial HEC-FDA modeling runs (per reach/index point) for the without-project condition, the results revealed that for index points NAT F and NAT G there was a relatively high probability of flooding but a relatively low consequence (EAD) of flooding as compared to the other index points. As shown in Tables 5-21 and 5-22, AEP and EAD for NAT F is .30 and approximately $26 million, respectively; AEP and EAD for NAT G is .20 and approximately $67 million, respectively.

The reach/index point-specific AEP and EAD results prompted a closer look at the underlying floodplain data, upon which damages are based on. Total single-event damages, which were computed in HEC-FDA, showed that on a relative basis (i.e., as compared to the other reaches/index points) damages resulting from levee breaches in NAT F or NAT G are significantly lower than damages resulting from levee reaches in the other reaches for all exceedance probability events. (See Tables 5-16 and 5-17.)

Evaluation of the without-project AEP, EAD, and single-event damages data together showed that even though NAT F and NAT G have relatively high AEPs, the consequences of flooding from breaches in those reaches do not become significant until the occurrence of bigger flood events. The main factors that explain the relatively low incurrence of damages up until the bigger flood events include a) relatively small floodplains up until the .01 to .005 probability events b) relatively low depths of flooding up until the .002 probability event and 3) relatively low number of structures affected by flooding up until about the .01 to .005 probability event. (See Enclosure 1 for NAT F and NAT G floodplains plates.)

The EAD and AEP results from the HEC-FDA "building block" models and subsequent evaluation of single-event damages for NAT F and NAT G helped to identify in more detail the flooding problem (risk and consequences) in the Natomas Basin impact area on a reach-by-reach (or index point-by-index point) basis and also provided valuable information in regard to the approach taken to perform the Basin-wide with-project benefit analysis. One of these approaches involved splitting the Basin into two impact areas, each with its own economic inventory. This is explained in the next section.

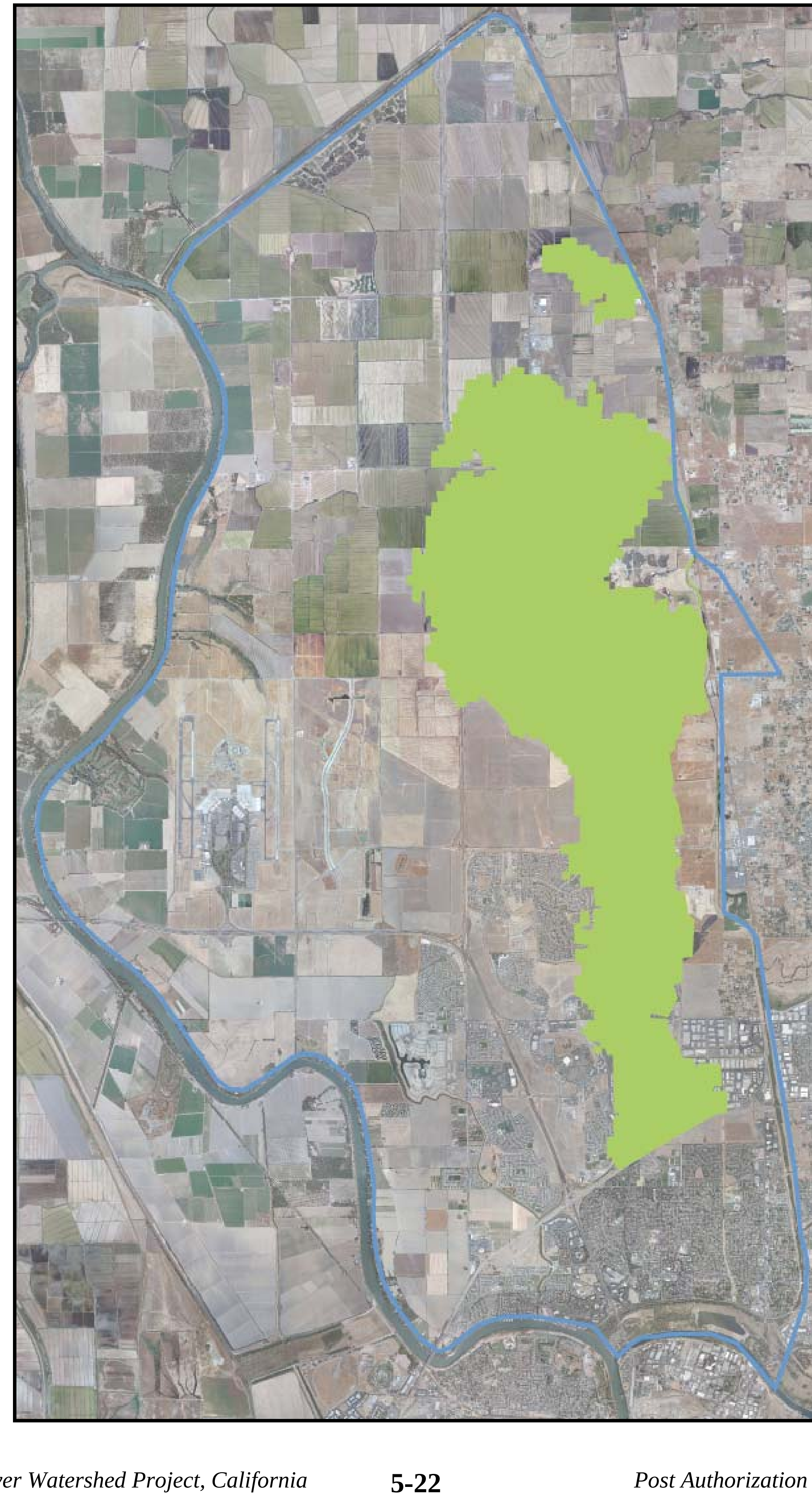
5.10.1 Impact Areas: "Major" and "Minor"

Based on the initial HEC-FDA without-project modeling results for each reach/index point, the Basin was split up into two impact areas for purposes of conducting the with-project benefit analysis documented in Chapter 6. By splitting the Basin into two impact areas – a "Major" impact area and a "Minor" impact area[13] – levee reach improvements around the Basin could be ordered by balancing the main factors of risk: the probability of flooding (as measured by AEP) and the consequences of flooding (as measured by EAD and single-event damages). Figure 5-1 shows the two impact areas. Chapter 6, *With-Project Analysis*, provides more details regarding the delineation of the Major and Minor impact areas. Tables 5-23 to 5-25 in the subsections below display the single-event damages and EAD results for each area.

It should be pointed out that the terms "major" and "minor" are relative and were used mainly to associate the geographic areas tied to the two sets of index points. When performing the HEC-FDA analysis to compute initial EAD results for the separate impact areas (different economic inventories) at each index point, the "Major" area was tied to index points NAT A through NAT E, NAT H, and NAT I and the "Minor" area was tied to index points NAT F and NAT G. In terms of geographic extent, the "major" area is much larger than the "minor" area; in terms of single-event damages, the "major" area also shows much greater damages than the "minor" area. However, on an absolute basis, the "minor" area still shows significant damages. Tables 5-23 through 5-33 display the single-event damages for each index point after splitting the Basin inventory into two separate areas.

[13] The terms "Major" and "Minor" used to describe the impact areas are used as relative terms as well as to distinguish that one area was treated as the main area and the other as a secondary area (or "residual" area) in order to facilitate the with-project analysis described in Chapter 6 of this Appendix. On a relative basis and in terms of geographic area, the "Major" area is larger than the "Minor" area; as will be seen in the last section of this chapter, the without-project EAD value ($886 million) computed as the baseline without-project damages for the "Major" area is greater than the EAD value ($477 million) computed as the baseline without-project damages for the "Minor" area. However, on an absolute basis, without-project EAD used as the baseline for each respective area can actually be considered "major."

Figure 5-1 Minor impact area (shaded); major impact area (non-shaded)



5.10.2 Single-Event Damages: Two Impact Areas

Table 5-23
Single-Event Without-Project Damages
Index Points Tied to Inventory of Major Impact Area

ECONOMIC REACH/INDEX POINT	MAJOR IMPACT AREA SINGLE-EVENT WITHOUT-PROJECT DAMAGES (VALUES IN $MILLIONS, OCTOBER 2010 PRICE LEVELS)						
	2-yr	10-yr	25-yr	50-yr	100-yr	200-yr	500-yr
NAT A	3,280	3,549	3,667	4,200	4,626	4,920	5,156
NAT B	2,466	3,718	3,738	4,139	4,550	4,827	5,192
NAT C	4,032	4,807	4,958	5,177	5,252	5,470	5,427
NAT D	4,724	5,148	5,242	5,359	5,402	5,431	5,451
NAT E	1,788	3,619	4,198	4,595	4,828	5,028	5,242
NAT H	0	709	1,585	2,110	2,684	3,087	3,517
NAT I	2,525	3,704	3,893	4,446	4,847	5,089	5,230

Table 5-24
Single-Event Without-Project Damages
Index Points Tied to Inventory of Minor Impact Area

ECONOMIC REACH/INDEX POINT	MINOR IMPACT AREA SINGLE-EVENT WITHOUT-PROJECT DAMAGES (VALUES IN $MILLIONS, OCTOBER 2010 PRICE LEVELS)						
	2-yr	10-yr	25-yr	50-yr	100-yr	200-yr	500-yr
NAT F	0	43	77	134	191	259	1,024
NAT G	81	81	635	735	892	893	1,171

Table 5-25
Single-Event Without-Project Damages
NAT A (Tied to Inventory of Major Impact Area)

DAMAGE CATEGORY	NAT A SINGLE-EVENT WITHOUT-PROJECT DAMAGES (VALUES IN $ MILLIONS, OCTOBER 2010 PRICE LEVEL)						
	2-yr	10-yr	25-yr	50-yr	100-yr	200-yr	500-yr
Residential	1,868	2,495	2,578	2,921	3,217	3,394	3,534
Commercial	195	268	278	326	378	412	443
Industrial	906	191	204	257	289	327	354
Public	131	364	370	438	466	505	539
Farm	1	3	3	5	8	9	10
Auto Losses	179	228	234	254	269	273	276
TOTAL	3,280	3,549	3,667	4,200	4,626	4,920	5,156

Table 5-26
Single-Event Without-Project Damages
NAT B (Tied to Inventory of Major Impact Area)

DAMAGE CATEGORY	NAT B SINGLE-EVENT WITHOUT-PROJECT DAMAGES (VALUES IN $ MILLIONS, OCTOBER 2010 PRICE LEVEL)						
	2-yr	10-yr	25-yr	50-yr	100-yr	200-yr	500-yr
Residential	1,718	2,588	2,599	2,874	3,164	3,345	3,556
Commercial	170	276	281	315	358	392	442
Industrial	85	204	205	250	283	315	355
Public	323	411	412	442	469	494	552
Farm	2	4	5	6	7	9	10
Auto Losses	168	235	235	252	268	272	276
TOTAL	**2,466**	**3,718**	**3,738**	**4,139**	**4,550**	**4,827**	**5,192**

Table 5-27
Single-Event Without-Project Damages
NAT C (Tied to Inventory of Major Impact Area)

DAMAGE CATEGORY	NAT C SINGLE-EVENT WITHOUT-PROJECT DAMAGES (VALUES IN $ MILLIONS, OCTOBER 2010 PRICE LEVEL)						
	2-yr	10-yr	25-yr	50-yr	100-yr	200-yr	500-yr
Residential	2,804	3,332	3,424	3,548	3,597	3,645	3,664
Commercial	302	388	406	438	451	569	484
Industrial	236	312	329	352	361	375	390
Public	436	493	516	552	556	594	600
Farm	5	9	10	10	10	11	11
Auto Losses	249	272	274	276	277	277	277
TOTAL	**4,032**	**4,807**	**4,958**	**5,177**	**5,252**	**5,470**	**5,427**

Table 5-28
Single-Event Without-Project Damages
NAT D (Tied to Inventory of Major Impact Area)

DAMAGE CATEGORY	NAT D SINGLE-EVENT WITHOUT-PROJECT DAMAGES (VALUES IN $ MILLIONS, OCTOBER 2010 PRICE LEVEL)						
	2-yr	10-yr	25-yr	50-yr	100-yr	200-yr	500-yr
Residential	3,283	3,532	3,590	3,641	3,658	3,665	3,666
Commercial	378	432	450	467	475	486	493
Industrial	295	349	360	373	383	391	401
Public	489	548	555	590	598	601	603
Farm	9	10	10	11	11	11	12
Auto Losses	271	276	277	277	277	277	277
TOTAL	**4,724**	**5,148**	**5,242**	**5,359**	**5,402**	**5,431**	**5,451**

Table 5-29
Single-Event Without-Project Damages
NAT E (Tied to Inventory of Major Impact Area)

DAMAGE CATEGORY	NAT E SINGLE-EVENT WITHOUT-PROJECT DAMAGES (VALUES IN $ MILLIONS, OCTOBER 2010 PRICE LEVEL)						
	2-yr	10-yr	25-yr	50-yr	100-yr	200-yr	500-yr
Residential	1,296	2,541	2,926	3,195	3,346	3,461	3,590
Commercial	135	270	316	361	393	415	450
Industrial	123	194	251	286	315	338	360
Public	102	379	443	475	494	531	555
Farm	0	3	6	9	9	10	10
Auto Losses	131	233	257	269	272	274	277
TOTAL	**1,788**	**3,619**	**4,198**	**4,595**	**4,828**	**5,028**	**5,242**

Table 5-30
Single-Event Without-Project Damages
NAT F (Tied to Inventory of Minor Impact Area)

DAMAGE CATEGORY	NAT F SINGLE-EVENT WITHOUT-PROJECT DAMAGES (VALUES IN $ MILLIONS, OCTOBER 2010 PRICE LEVEL)						
	2-yr	10-yr	25-yr	50-yr	100-yr	200-yr	500-yr
Residential	0	41	68	118	164	225	592
Commercial	0	0	0	0	0	0	153
Industrial	0	0	0	0	0	0	183
Public	0	0	4	4	10	10	37
Farm	0	0	0	0	0	0	0
Auto Losses	0	3	6	11	17	24	58
TOTAL	**0**	**43**	**77**	**134**	**191**	**259**	**1,024**

Table 5-31
Single-Event Without-Project Damages
NAT G (Tied to Inventory of Minor Impact Area)

DAMAGE CATEGORY	NAT G SINGLE-EVENT WITHOUT-PROJECT DAMAGES (VALUES IN $ MILLIONS, OCTOBER 2010 PRICE LEVEL)						
	2-yr	10-yr	25-yr	50-yr	100-yr	200-yr	500-yr
Residential	71	71	317	368	437	437	611
Commercial	0	0	143	165	225	225	281
Industrial	0	0	118	133	152	152	183
Public	4	4	24	30	32	32	38
Farm	0	0	0	0	0	0	0
Auto Losses	6	6	33	40	47	47	59
TOTAL	**81**	**81**	**635**	**735**	**892**	**893**	**1,171**

Table 5-32
Single-Event Without-Project Damages
NAT H (Tied to Inventory of Major Impact Area)

DAMAGE CATEGORY	NATOMAS REACH H SINGLE-EVENT WITHOUT-PROJECT DAMAGES (VALUES IN $ MILLIONS, OCTOBER 2010 PRICE LEVEL)						
	2-yr	**10-yr**	**25-yr**	**50-yr**	**100-yr**	**200-yr**	**500-yr**
Residential	0	530	1,105	1,539	1,983	2,271	2,451
Commercial	0	63	135	174	212	250	270
Industrial	0	15	124	136	159	185	203
Public	0	43	103	108	140	166	364
Farm	0	0	0	1	1	2	3
Auto Losses	0	58	117	152	189	212	227
TOTAL	**0**	**709**	**1,585**	**2,110**	**2,684**	**3,087**	**3,517**

Table 5-33
Single-Event Without-Project Damages
NAT I (Tied to Inventory of Major Impact Area)

DAMAGE CATEGORY	NAT I SINGLE-EVENT WITHOUT-PROJECT DAMAGES (VALUES IN $ MILLIONS, OCTOBER 2010 PRICE LEVEL)						
	2-yr	**10-yr**	**25-yr**	**50-yr**	**100-yr**	**200-yr**	**500-yr**
Residential	1,860	2,605	2,735	3,091	3,349	3,493	3,576
Commercial	205	282	300	358	405	433	454
Industrial	143	206	220	277	321	348	362
Public	131	371	390	449	491	529	552
Farm	1	3	3	6	9	10	10
Auto Losses	185	237	245	265	272	276	276
TOTAL	**2,525**	**3,704**	**3,893**	**4,446**	**4,847**	**5,089**	**5,230**

5.10.3 Expected Annual Damages: Two Impact Areas, Post Basin Split

Tables 5-34 and 5-35 show the EAD results after the Basin was split into two impact areas – Major and Minor. These HEC-FDA results reflect the use of 1) reach-specific suite of floodplains 2) reach-specific HEC-FDA engineering input data (frequency-discharge-stage curves and GRU curves) and 3) a split Basin inventory where NAT A through E, NAT H, and NAT I damage results account for flooding to those structures in the non-shaded area of Figure 5-1; and NAT F and NAT G damage results account for flooding to those structures in the shaded area of Figure 5-1.

By comparing the EAD results in Tables 5-34 and 5-35 (two inventories, split Basin) to the EAD results in Table 5-20 (one inventory, whole Basin), it can be seen that, as expected, EAD results across all reaches decrease. For example, EAD for NAT D prior to splitting the Basin (i.e., damages based on inventory of whole Basin) is approximately $1.2 billion; EAD for NAT D decreases to approximately $900 million after splitting the Basin (i.e., damages based on a smaller inventory). Similarly, EAD for NAT F decreases from approximately $26 million to approximately $18 million, reflecting the reduced inventory tied to the NAT F index point after splitting up the Basin into two areas.

Table 5-34
Expected Annual Damages by Reach/Index Point (Oct 2010 Price Level)
Split Inventory: Index Points Tied to Inventory of Major Impact Area

PLAN	EXPECTED ANNUAL DAMAGES (EAD) IN $MILLIONS						
	Natomas Basin Reach/Index Point						
	SR			NCC	PGCC/NEMDC		AR
	A	B	C	D	E	H	I
Without-Project	552	593	215	894	563	76	68

Notes: SR = Sacramento River, NCC = Natomas Cross Canal; PGCC = Pleasant Grove Creek Canal; NEMDC = Natomas East Main Drainage Canal; AR = American River

Table 5-35
Expected Annual Damages by Reach/Index Point (Oct 2010 Price Level)
Split Inventory: Index Points Tied to Inventory of Minor Impact Area

PLAN	EXPECTED ANNUAL DAMAGES (EAD) IN $MILLIONS	
	Natomas Basin Reach/Index Point	
	NEMDC	
	F	G
Without-Project	18	60

Notes: NEMDC = Natomas East Main Drainage Canal

5.11 PURPOSE OF CHAPTER 5 RESULTS & ESTABLISHING THE BASIS FOR THE WITH-PROJECT ANALYSIS DOCUMENTED IN CHAPTER 6

As noted in previous sections of this report, this chapter is intended to show the steps that were taken and the analyses that were completed in order to obtain the data/information necessary to inform and guide the with-project, net benefit, and benefit-to-cost analyses, which are presented in Chapters 6, 7A, and 7B of this Appendix. In summary, the data/information presented in this chapter was used to:

- Determine that a re-delineation of the Basin was necessary in order to facilitate the with-project analysis; thus, two impact areas (Major and Minor) were created. (This decision was based on the EAD and AEP results pre-split.)
- Determine that NAT D on the Natomas Cross Canal (NCC) is the weakest link in terms of overall flood risk: the probability of flooding and the consequences of flooding. (This determination was based on the EAD and AEP results of the pre-split and post-split.)
- Determine that NAT D, all of its associated HEC-FDA engineering input data, and event floodplains would serve as the starting point (baseline) for the with-project benefit analysis for the Major impact area. (This determination was based on the reach-specific HEC-FDA EAD and AEP results post-split.)
- Determine that NAT F, all of its associated HEC-FDA engineering input data, and NAT D floodplains would serve as the starting point (baseline) for the with-project benefit analysis for the Minor impact area. (This determination was based on the reach-specific HEC-FDA and AEP results post-split.)
- Determine the order of fixes by reach for the with-project analysis for the Major and Minor impact areas. (This determination was based on the EAD and AEP results, post-split.)
- Determine the "floodplain assignments" for each levee reach improvement in the Major and Minor impact areas. (This determination was based on the reach-specific AEP results and single-event damages, post-split.)

A summary of the EAD results (and inputs these results are based on) thus far in the analytical process is provided in Table 5-36 below. The without-project EAD for each impact area used as the baseline for the with-project analysis presented in Chapter 6 is also displayed in Table 5-36. The information provided in the table is described in more detail in the bulleted points below:

- As displayed in the first section of the table, initial HEC-FDA base modeling runs (first step of the analysis) were completed for all reaches/index points around the Basin independent of each other; AEP and EAD results were obtained for each reach from these base model runs, which helped inform the next step on the way to performing the with-project analysis, which is documented in Chapter 6.
- The AEP and EAD information gained in the first step guided the next step of the analytical process. While the initial results indicated that, generally, a reach with a high AEP also had a high EAD, reaches NAT F and NAT G had relatively high AEPs and low EADs. From this information, it was determined that the Basin should be split into two areas with two separate economic inventories, each area tied to specific reaches/index points – one area tied to reaches NAT A, B, C, D, E, H, and I and the other area tied to

reaches NAT F and G; this decision was made in order to facilitate the with-project analysis. As in the initial modeling runs, the HEC-FDA modeling runs in this second step were completed for each reach around the Basin to obtain EAD results for each reach independent of each other (AEP for each reach, as expected, did not change from the initial model runs); the only difference between the modeling runs in this step and those in the first step is the economic inventory tied to each reach. This difference is reflected in the lower EAD values seen in section two of Table 5-36, as each reach is now tied to a smaller inventory (i.e., split-Basin inventory rather than a full-Basin inventory). This second step was necessary in order to split the economic inventory into two areas for with-project analysis purposes; the EAD results were not used as input into the with-project analysis.

- Finally, the third section of Table 5-36 displays the inputs and results used in the final step of the analytical process. This section shows the baseline without-project EAD (per impact area) used as the starting point in the with-project analysis (Chapter 6). As displayed in the table, NAT D was determined to be the without-project controlling index point (CIP) for the Major area since overall risk (probability and consequences) at this index point is the greatest; the without-project EAD for the Major impact area is the same as those EAD values for NAT D obtained in step two in the process since none of the HEC-FDA inputs (engineering data used in the AEP calculations, economic inventory, and flood depth data) has changed. In the Minor impact area, NAT F was determined to be the without-project CIP since NAT F's AEP is greater than NAT G's. Unlike in the Major impact area, the EAD value for the Minor impact area differs from the previous step (step two) – the without-project EAD value for the Minor area is not the same as the EAD for NAT F as shown in step two. This difference is purely the result of using different floodplain depth data ("floodplain assignments") for the Minor area: whereas in step two Nat F floodplain depth data were used to compute EAD at NAT F, in this step NAT D floodplain depth data were used. The flood depth data from the NAT D floodplains were used because, even though the structures in the Minor impact area are being tied to the NAT F index point, these structures are still at great risk of being flooded by a breakout at NAT D, which result in larger and deeper floodplains (compared to floodplains from breaches in any of the other reaches, including NAT F). Not using the depth data from NAT D would understate the possible consequences (damages) to those structures in the Minor impact area. The process of "floodplain assignments," which are really flood depth data taken from a respective floodplain (e.g., NAT D 500-year floodplain) assigned to structures in either the Major or Minor impact area, is explained further in Chapter 6, Section 6.7. In this section the with-project analysis and "floodplain assignments" used for each levee reach improvement and for each impact area is explained in more detail. At this point of the analysis, the without-project EAD values for each impact area have been established (last row of Table 5-36 below) for the with-project analysis presented in Chapter 6: without-project EAD for the Major impact area is $886 million and without-project EAD for the Minor impact area is $477 million.

Table 5-36
Summary of Steps Leading Up to the Establishment of Without-Project EAD for Purposes of the With-Project Analysis

ANALYTICAL STEP	ECONOMIC ANALYSIS INPUT/OUTPUT	INDEX POINTS TIED TO MAJOR AREA							INDEX POINTS TIED TO MINOR AREA	
1	Index Point	A	B	C	D	E	H	I	F	G
	Inventory	Entire Basin							Entire Basin	
	Floodplain Suite Used	A	B	C	D	E	H	I	F	G
	EAD ($Millions)	747	351	265	1,167	789	122	95	26	67
2	Index Point	A	B	C	D	E	H	I	F	G
	Inventory	Split Basin							Split Basin	
	Floodplain Suite Used	A	B	C	D	E	H	I	F	G
	EAD ($Millions)	552	228	215	886	563	76	68	18	60
3	Index Point	D							F	
	Inventory	Spit Basin							Split Basin	
	Floodplain Suite Used	D							D	
	Without-Project EAD ($Millions)	**886**							**477**	

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CHAPTER 6
WITH-PROJECT ANALYSIS

At the end of Chapter 5, the baseline without-project EADs for the Major ($886 million) and Minor ($477 million) impact areas were presented. These without-project EAD values are carried forward to this chapter and are used as the baseline without-project damages (per impact area) for the with-project benefit analysis.

It is important to note that the without-project EAD values and the with-project benefit analysis presented in this chapter, as it turns out, were only preliminary and are NOT used as the basis for plan formulation. Based on agency technical review, these EAD and benefit values were adjusted in order to account for aspects of human behavior that significantly reduce the EAD and benefit values. The revised with-project and net benefit analyses are presented in Chapter 7B.

This chapter is important in that it describes in detail the approach used to perform the with-project analysis; the exact same approach is also used in the analysis presented in Chapter 7B, where the adjustment to EAD and benefit values (as well as the net benefit analysis) are presented. So, while the numbers presented here are not the "final" numbers used to formulate plans, understanding the process used to derive these numbers will aid in understanding the analysis presented in Chapter 7B.

6.1 PURPOSE OF WITH-PROJECT REACH-BY-REACH ANALYSIS

This chapter, along with Chapters 7a and 7b, describe the economic analysis from a purely NED perspective, resulting in 1) a net benefit curve which shows the benefits associated with each successive levee reach improvement and 2) a project performance curve which shows the associated reduction in flood risk to the Basin with each successive levee reach improvement. These curves were developed by analyzing each of the nine levee reaches within the context that each reach has different problems or different combination of problems; that each reach has differing probability of failure and associated set of damage consequences; and that each reach has its own unique set of potential engineering solutions. A reach-by-reach analysis was necessary primarily to 1) show the residual risk remaining after each successive reach improvement and to 2) layout the potential order of fixes based on a comparative analysis of the overall risk associated with each of the nine reaches.

6.2 A LOOK AHEAD TO THE FINAL ARRAY OF ALTERNATIVES

The final array of alternatives was narrowed down to two action alternatives: strengthening the levees along the entire perimeter (all nine reaches) of the Natomas Basin through construction of adjacent levees, where practical, and fixing levees in place where that was most practical. The final array is the result of an iterative plan formulation/re-formulation process, which ultimately considered more than just the NED account as presented in Chapters 6, 7a, and 7b. Additional discussion of the Interim NED Plan can be found in the Main Report.

6.3 OVERVIEW OF REACH-BY-REACH ANALYSIS

Flood risk management benefits are measured by comparing the without-project expected annual damages (EAD) to the with-project residual damages (with-project EAD) for various alternatives or in the case of this NPACR, various levee reach improvements based on ordered fixes by geotechnical reach (A through I) around the Natomas Basin. With-project conditions for various project measures/levee reach improvement were modeled in HEC-FDA; benefits of each measure/levee reach improvement equate to the difference between the without-project and with-project EAD. The following chapter explains the process of measuring the economic outputs of each project levee reach improvement. General steps include:

- Modeling in HEC-FDA specific with-project improvements and without-project conditions (explained in Chapter 5) on a reach-by-reach basis
- Evaluating the without-project and/or the with-project EAD and AEP results on a reach-by-reach basis.
- Using these reach-specific results to inform and guide the order of fixes (by reach) for the with-project analysis.
- Using the nine suites (one for each index point) of floodplains provided by the Hydraulic Design Section to compile a unique suite of floodplains for each levee reach; individual event floodplains are selected by taking into account any previous levee reach improvements and by determining the residual floodplains, or the ones still remaining in the “mix,” that would likely remain once a fix is implemented[14].
- Modeling each levee reach improvement in HEC-FDA to compute AEP and EAD results on a basin-wide basis.

6.4 HYDROLOGIC, HYDRAULIC, AND GEOTECHNICAL DATA

The with-project hydrology and hydraulics (exceedance probability-discharge and stage-discharge functions for NAT B and NAT C; exceedance probability-stage functions for all other reaches/index points) differed slightly from the without-project hydrology and hydraulics. In the initial HEC-FDA base models for each reach/index point, two sets of curves were entered into HEC-FDA - one set to represent the without-project condition and another set to represent the with-project condition (fixes). Additionally, the GRU curves also differed between the without-project and with-project conditions. In the without-project condition one GRU curve for each reach/index point was entered into HEC-FDA; in the with-project condition, at least one GRU curve was entered into HEC-FDA, depending on the number of geotechnical fixes (as represented by a GRU curve) evaluated. The complete set of without-project and with-project

[14] Throughout the remainder of this chapter, the “unique suite of floodplains for each levee reach improvement” as explained in this bullet point will be referred to as the “floodplain assignment” for each respective levee reach improvement and impact area (Major or Minor). It should be noted that the term “floodplain assignment” as used to describe the suite of floodplains for each levee reach improvement actually means that the flood depth data from a respective event floodplain (e.g., the NAT D 500-year) were assigned to the structures in the respective impact area (Major or Minor).

hydrologic, hydraulic, and geotechnical engineering data used in HEC-FDA is presented in Enclosure 2 of this Appendix.

6.5 RE-DELINEATION OF IMPACT AREAS FOR WITH-PROJECT ANALYSIS PURPOSES

The without-project HEC-FDA base modeling results for each index point were presented in Chapter 5. For ease of comparison and discussion purposes, these results are also presented in subsection 6.2.1. The initial HEC-FDA modeling and results were used as "building blocks" to define a way forward to perform the with-project benefit analysis, which is the focus of this chapter.

6.5.1 AEP and EAD Results

As explained in Chapter 5, the NAT F and NAT G without-project AEP and EAD results seemed counterintuitive, as HEC-FDA results for these reaches/index points were showing a relatively high probability of flooding but relatively low expected damages as compared to the other reaches. A closer look at the underlying floodplain data revealed that although AEP (.30 for NAT F and .20 for NAT G) in these reaches were relatively high, levee breaches in these reaches from more frequent events (below 100-yr to 200-yr) did not cause significant damages, in expected annual terms. This can be explained by the relatively shallow depths of flooding and/or the non-existence of any significant amount of damageable property (i.e., higher frequency event floodplains consists of a large amount of vacant/agricultural land instead of structures) that result from potential levee breaches in these reaches.
Table 6-1 below displays the without-project EAD results for each reach/index point; Table 6-2 below displays the AEP results for each reach/index point. Both of these tables are reproduced from Chapter 5. Please refer to Chapter 5 to see the single-event without-project damages tables by reach/index point.

Table 6-1
Expected Annual Damages (EAD) by Reach/Index Point
October 2010 Price Level

PLAN	EXPECTED ANNUAL DAMAGES (EAD) IN $MILLIONS								
	Natomas Basin Reach/Index Point								
	SR			NCC	PGCC/NEMDC				AR
	A	B	C	D	E	F	G	H	I
Without-Project	747	351	265	1,167	789	26	67	122	95

Notes: SR = Sacramento River, NCC = Natomas Cross Canal; PGCC = Pleasant Grove Creek Canal; NEMDC = Natomas East Main Drainage Canal; AR = American River

Table 6-2
Annual Exceedance Probability (AEP) by Reach/Index Point

PLAN	ANNUAL EXCEEDANCE PROBABILITY (AEP) Natomas Basin Reach/Index Point								
	SR			NCC	PGCC/NEMDC				AR
	A	B	C	D	E	F	G	H	I
Without-Project	0.20	0.12	0.04	0.21	0.18	0.30	0.20	0.04	0.015

Notes: SR = Sacramento River, NCC = Natomas Cross Canal; PGCC = Pleasant Grove Creek Canal; NEMDC = Natomas East Main Drainage Canal; AR = American River

6.5.2 Major and Minor Impact Areas

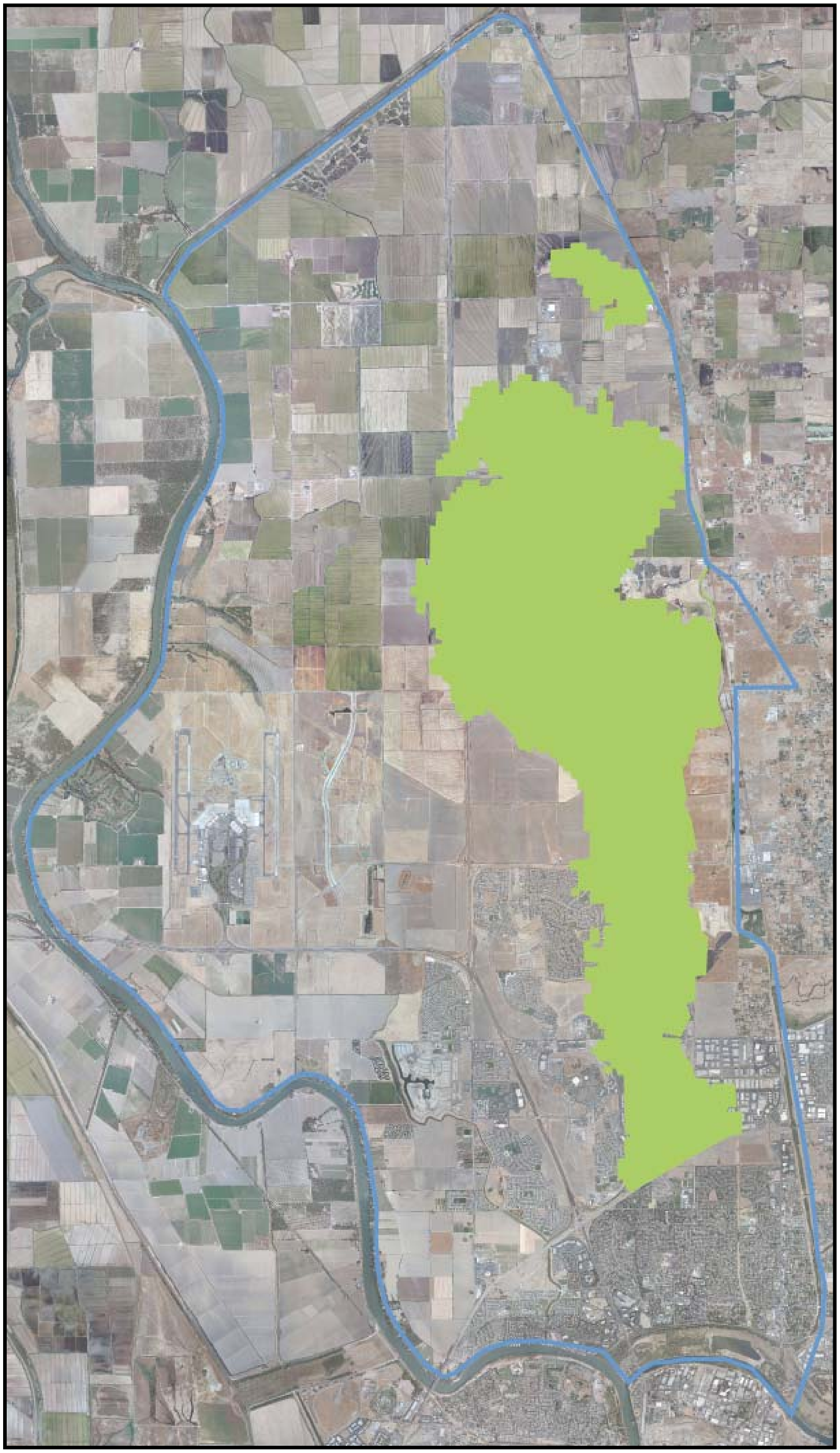
Upon further evaluation of the without-project HEC-FDA results, it was determined that in order to accurately reflect within the with-project analysis the order of fixes by reach, NAT F and NAT G were analyzed on their own by creating two structure inventories and two impact areas – a Major impact area and a Minor impact area. The structure inventory for the Major impact area is tied to index points/reaches NAT A, NAT B, NAT C, NAT D, NAT E, NAT H, and NAT I; the inventory for the Minor area, delineated as those structures that lay within the 100-yr floodplains of NAT F and NAT G, is tied to index points/reaches NAT F and G. This approach relies on two with-project analyses (one each for the Major and Minor impact areas) occurring concurrently.[15]

For each levee reach improvement, total damages (residual damages) would be computed by adding the results of the with-project analysis of each impact area[16]. Section 6.4.2 explains this process in more detail and in a step-by-step fashion. Figure 6-1 below displays the Minor impact area in color, whose structures are tied to the NAT F and NAT G index points. The non-shaded area is the Major impact area, whose structures are tied to the NAT A, NAT B, NAT C, NAT D, NAT E, NAT H, and NAT I index points.

[15] The primary reason for separating the Basin into two impact areas was to be able to perform a Basin-wide with-project analysis by balancing the factors of risk (probability and consequences of flooding), which drive the analysis; this proved to be a challenge when using only one impact area, since NAT F and NAT G were producing relatively high AEPs but relatively low EADs. Having only one impact area would result in NAT F and NAT G being fixed early on in the with-project analysis, even though the consequences (damages) of flooding from these reaches were the lowest. In reality, NAT F and NAT G should probably be fixed only after other reaches are fixed, where the risk is greater (in terms of damages).

[16] It is important to note that using this approach does not result in double counting of damages/benefits because the two impact areas have unique economic structure inventories.

Figure 6-1 Minor impact area (shaded green)



6.5.3 AEP, EAD, and Single-Event Damages by Major and Minor Areas

The following tables show the HEC-FDA-computed AEP, EAD, and single-event damages results for the major and minor impact areas. The tables include results for each reach/index point under the without-project, which repeats what was reported in Chapter 5. The tables also include the HEC-FDA results for each reach/index point under the with-project (geotechnical fixes) levee reach improvements. All of the numbers reflect the impact area/economic inventory split corresponding to the Major and Minor impact areas.

The tables show that for each reach/index point, without-project AEPs do not change after the inventory/impact area split; for each reach/index point, without-project EAD and single-event damage results do change, and now reflect flooding consequences based on the two separate inventories. The tables also show the residual EAD and AEP results for each reach/index point under the with-project fixes. It should be noted that not all measures listed in Table 6-3 through 6-6 were evaluated for each reach/index point since these are reach/location-specific fixes; therefore, not all cells in the tables are populated with results.

Table 6-3
Expected Annual Damages (EAD) by Reach/Index Point (Oct 2010 Price Level)
Without-Project and With-Project (Fixes)
Reaches/Index Points Tied to Inventory of Major Impact Area

PLAN	EAD IN $MILLIONS						
	NATOMAS REACH/INDEX POINT						
	SR			NCC	PGCC/NEMDC		AR
	A	B	C	D	E	H	I
Without-Project	552	230	215	894	563	76	68
SCB Cutoff Wall	29	25				13	38
CB Cutoff Wall	29						
Adjacent Levee w/SB Cutoff Wall		25	39				
Drained Seepage Berm		78					
Drained Seepage Berm + Cutoff Wall			91				
SB Cutoff Wall			53		37	13	38
SB Cutoff Wall (ditch filled)				81			
SCB Cutoff Wall (ditch filled)				81			
Drained Stability Berm							
Flattened Landside Levee Slope							
First Raise	15	24	24	28	31	2	8
Second Raise					9		

Notes: SR = Sacramento River, NCC = Natomas Cross Canal; PGCC = Pleasant Grove Creek Canal; NEMDC = Natomas East Main Drainage Canal; AR = American River

Table 6-4
Expected Annual Damages (EAD) by Reach/Index Point (Oct 2010 Price Level)
Without-Project and With-Project (Fixes)
Reaches/Index Points Tied to Inventory of Minor Impact Area

PLAN	EAD IN $MILLIONS	
	NATOMAS REACH/INDEX POINT	
	NEMDC	
	F	G
Without-Project	18	60
SCB Cutoff Wall		
CB Cutoff Wall		
Adjacent Levee w/SB Cutoff Wall		
Drained Seepage Berm		
Drained Seepage Berm + Cutoff Wall		
SB Cutoff Wall		6
SB Cutoff Wall (ditch filled)		
SCB Cutoff Wall (ditch filled)		
Drained Stability Berm	5	
Flattened Landside Levee Slope	9	
First Raise	2	5
Second Raise		

Notes: NEMDC = Natomas East Main Drainage Canal

Table 6-5
Annual Exceedance Probability by Reach/Index Point
Without-Project and With-Project (Fixes)
Reaches/Index Points Tied to Major Impact Area

PLAN	**ANNUAL EXCEEDANCE PROBABILITY (AEP)**						
	NATOMAS REACH/INDEX POINT						
	SR			**NCC**	**PGCC/NEMDC**		**AR**
	A	**B**	**C**	**D**	**E**	**H**	**I**
Without-Project	0.20	0.12	0.04	0.21	0.18	0.04	0.015
SCB Cutoff Wall	0.007	0.017					0.008
CB Cutoff Wall	0.007						
Adjacent Levee w/SB Cutoff Wall		0.017	0.007				
Drained Seepage Berm		0.036					
Drained Seepage Berm + Cutoff Wall			0.017				
SB Cutoff Wall			0.010		0.019	0.004	0.008
SB Cutoff Wall (ditch filled)				0.016			
SCB Cutoff Wall (ditch filled)				0.016			
Drained Stability Berm							
Flattened Landside Levee Slope							
First Raise	0.003	0.006	0.005	0.005	0.007	.001	0.002
Second Raise					0.002		

Notes: SR = Sacramento River, NCC = Natomas Cross Canal; PGCC = Pleasant Grove Creek Canal; NEMDC = Natomas East Main Drainage Canal; AR = American River

Table 6-6
Annual Exceedance Probability by Reach/Index Point
Without-Project and With-Project (Fixes)
Reaches/Index Points Tied to Minor Impact Area

PLAN	AEP	
	NATOMAS REACH/INDEX POINT	
	NEMDC	
	F	G
Without-Project	0.30	0.20
SCB Cutoff Wall		
CB Cutoff Wall		
Adjacent Levee w/SB Cutoff Wall		
Drained Seepage Berm		
Drained Seepage Berm + Cutoff Wall		
SB Cutoff Wall		0.006
SB Cutoff Wall (ditch filled)		
SCB Cutoff Wall (ditch filled)		
Drained Stability Berm	0.023	
Flattened Landside Levee Slope	0.045	
First Raise	0.002	0.004
Second Raise		

Notes: NEMDC = Natomas East Main Drainage Canal

The tables above show the geotechnical methods of fixes (measures) evaluated for each reach; a GRU curve was provided by the SPK Geotechnical Section to represent each method of fix. (Enclosure 2 includes the GRU curves for each fix and reach/index point.) The HEC-FDA results listed in Tables 6-3 to 6-6 above were used primarily to guide the with-project analysis. In other words, the "building block" AEP and EAD results shown above were used to select the order of fixes. As will be seen later on in subsection 6.4.2, *Mechanics of with-project Analysis*, the first nine levee reach improvements resulted in fixing individual reaches without any levee raises. For these improvements, an individual fix in a particular reach assumes that the method of fix is the one that provides the most protection/benefits – in most cases methods of fixes within a particular reach provide the same level of protection and benefits (refer to tables above). This assumption is not explicitly apparent in the mechanics of the with-project analysis, which shows that the reduction in damages (benefits) are realized mainly through the removal of vulnerable reaches and then moving to the next weakest point in the Basin; a method of fix is not explicitly stated and really does not come into play until the last three levee reach improvements when levee raises take place (i.e., which reaches' levees should be raised first based on with-project AEP/EAD results) and where there are differences between the performance of the methods of fixes within a particular reach.

It is also important to note that the following sections will refer to two general types of alternatives – "fix-in-place"-type alternatives and "adjacent levee"-type alternatives. These two types of alternatives are basically differentiated by the location of the improvement, not the method of fix. So, for example, an alternative could be comprised of a Soil Bentonite (SB) Cutoff Wall in each reach, but this could be considered a "fix-in-place" alternative or an "adjacent levee" alternative, depending on the location of the fix. This clarification is important for two main reasons and will become more apparent in Chapter 7, *Net Benefit and Benefit-to-Cost Analyses*:

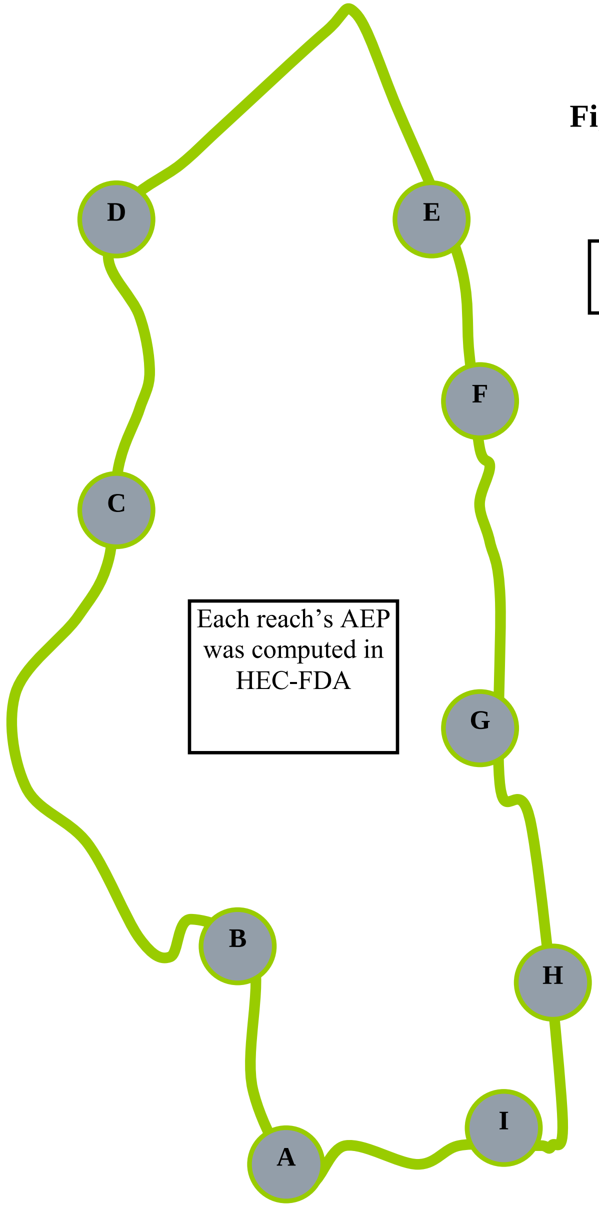
- From a geotechnical performance point of view, the performance of a specific method of fix (as represented by a GRU curve) is the same whether it's considered a "fix-in-place" or "adjacent levee" alternative; therefore with-project (with a fix) AEP and EAD computations were determined using the GRU curves representing specific methods of fixes.
- The differentiation between the two types of alternatives comes in the form of costs and not benefits.

6.6 GENERAL DESCRIPTION OF WITH-PROJECTAL ANALYSIS

A with-project benefit analysis was performed using the nine geotechnical reaches/index points to reasonably show, on a Basin-wide basis, the residual damages, expected benefits, and AEP after performing each levee reach improvement around the Natomas Basin. Based on the results of the with-project analysis, levee reach improvements were grouped together in order to develop alternatives that made logical sense from the perspective of reducing the probability of flooding and consequences around the Basin and from the perspective of capturing synergies between individual fixes (e.g., NAT A and NAT E should be fixed as one levee improvement because fixing only one does not provide significant benefits). The general approach taken to perform the with-project analysis is described conceptually in Figure 6-2 below.

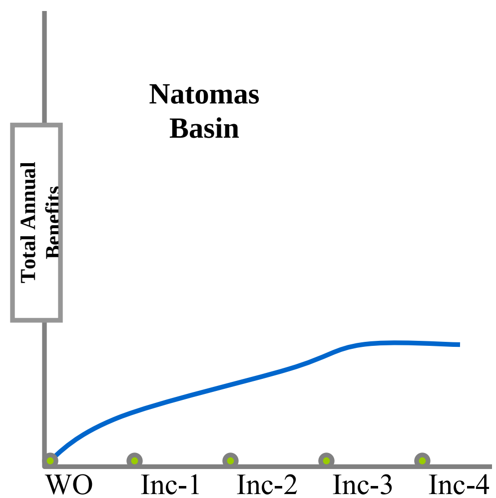
With each levee reach improvement, it is assumed that the method of fix for a particular reach is the one that is the most cost-effective – that is, that the benefits of the protection it provides (as shown in Tables 6-3 and 6-4 above) are greater than the costs (as shown in Enclosure 6).

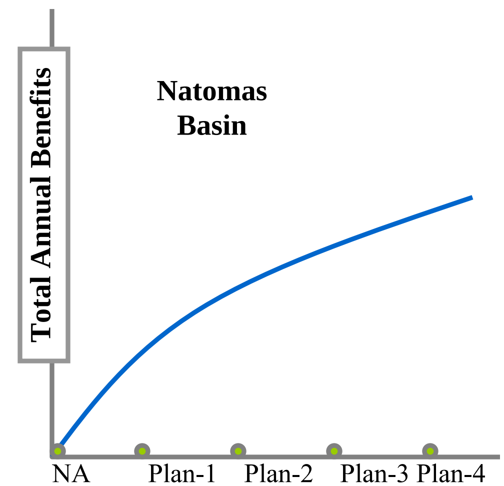
Figure 6-2



Fixes around basin

Reach	Without-Project	Fix-1	Fix-2	Fix-3	Levee Raise
A					
B					
C					
D					
E					
F					
G					
H					
I					





Total Annual Benefits are based on fixes for each representative reach around the basin. A with-project benefit analysis entails fixing the weakest reach first.

Total annual benefits were first computed for each levee reach; improvements were then grouped together to create plans. Benefits increase with each successive improvement.

6.7 NPACR WITH-PROJECT ANALYSIS – DETAILS

The following subsections will describe the details of the NPACR with-project benefit analysis by explaining how the HEC-FDA base modeling results were used to order levee reach improvements, how floodplains were selected for each levee reach improvement, and the mechanics of modeling each levee reach improvement in the HEC-FDA model.

6.7.1 Summary of Ordered Fixes Based on HEC-FDA Base Modeling Results

Levee reach improvements, or the order of fixes on a reach-by-reach basis, were selected using the information provided by the initial HEC-FDA base modeling results. Separate HEC-FDA models (one for the Major impact area and one for the Minor impact area) were created in order to evaluate each levee reach improvement for each area concurrently; these models serve as the final HEC-FDA models used to document the with-project benefit analysis results. Tables 6-7 and 6-8 below summarize the final order of levee reach improvements and show the controlling index point (CIP)[17] and floodplain assignments used for each improvement. Two tables are shown in order to properly display the CIP and floodplain assignments used for each impact area (Major and Minor) and which were used for the HEC-FDA modeling.

The order of improvement described in the following sections and used to perform the with-project analysis was based primarily on the EAD and AEP results reported in Chapter 5; these results informed/guided the order of improvements outlined in Tables 6-7 and 6-8. The order was based on a combination of AEP and EAD values for each reach. Generally, a reach with a high AEP also had high expected damages (e.g., NAT D); in the analysis, the reach with the highest AEP was fixed first. After this fix, the reach with the next highest AEP was considered the "weakest link" in the Basin and so was fixed next. The "floodplain assignments" (i.e., flood depths taken from the floodplain of the reach listed in the tables) displayed in Tables 6-7 and 6-8 show the progression (i.e., reduction in the number of floodplains from the total mix of floodplains) as each reach was fixed. Based on base modeling AEP and EAD results, the reaches in the Major area would be ordered as follows: D (AEP = .21), A (AEP = .20), E (AEP = .18), B (AEP = .12), C (AEP = .04), H (AEP = .04), and I (AEP = .015). In the case of reaches C and H, where AEP is the same, EAD was used to determine which reach would be fixed first. Here, reach C had a much greater EAD value than reach H ($215 million for C versus $76 million for H), so C was selected to be fixed before H. Based on base modeling AEP and EAD results and by comparing potential benefits between fixing these reaches and other reaches tied to the Major area, NAT F and NAT G (Minor area) was determined to be fixed after NAT H but before NAT I; fixing NAT F and G before fixing NAT H produced smaller with-project benefits than fixing NAT H before NAT F and NAT G, and fixing NAT I before NAT F and NAT G did not produce any additional with-project benefits (not only is AEP at NAT I significantly lower than the AEPs at NAT F and NAT G, but in order to gain any additional with-project benefit from fixing NAT I, levee raises in other reaches would have to occur.)

[17] The controlling index point (CIP) for a respective levee reach improvement is the index point/reach that will be fixed in the following improvement – this is the next "weakest link" of the Basin. In the Major area and for improvements 6-9, NAT I was selected as the index point, since this would be the next fix in the with-project analysis.

Table 6-7
Summary of Floodplain and Controlling Index Point Assignments by Levee Reach Improvement
Major Impact Area

LEVEE REACH IMPROVEMENT	CIP	FLOODPLAIN ASSIGNMENTS BY EVENT						
		2-yr	10-yr	25-yr	50-yr	100-yr	200-yr	500-yr
No fixes	D	D	D	D	D	D	D	D
D	A	B	B	C	C	D	D	D
D+A	E	B	B	C	C	D	D	D
D+A+E	B	B	B	C	C	D	D	D
D+A+E+B	C	--	--	C	C	D	D	D
D+A+E+B+C	H	--	--	H	E	D	D	D
D+A+E+B+C+H	I	--	--	--	E	D	D	D
D+A+E+B+C+H+G	I	--	--	--	E	D	D	D
D+A+E+B+C+H+G+F	I	--	--	--	E	D	D	D
D+A+E+B+C+H+F+G+I	I	--	--	--	E	D	D	D
Fix all and raise D, B, E, F	I	--	--	--	--	--	D	D
Fix all and raise D, B, E, F, A, C, I, G	I	--	--	--	--	--	--	D
Fix all and raise all to 500-yr WSEL	I	--	--	--	--	--	--	D

Table 6-8
Summary of Floodplain and Controlling Index Point Assignments by Levee Reach Improvement
Minor Impact Area

LEVEE REACH IMPROVEMENT	CIP	FLOODPLAIN ASSIGNMENTS BY EVENT						
		2-yr	10-yr	25-yr	50-yr	100-yr	200-yr	500-yr
No fixes	F	D	D	D	D	D	D	D
D	F	B	B	C	C	D	D	D
D+A	F	B	B	C	C	D	D	D
D+A+E	F	B	B	C	C	D	D	D
D+A+E+B	F	G	G	C	C	D	D	D
D+A+E+B+C	F	G	G	H	E	D	D	D
D+A+E+B+C+H	F	G	G	G	E	D	D	D
D+A+E+B+C+H+G	F	F	F	F	E	D	D	D
D+A+E+B+C+H+G+F	F	--	--	--	E	D	D	D
D+A+E+B+C+H+F+G+I	F	--	--	--	E	D	D	D
Fix all and raise D, B, E, F	F	--	--	--	--	--	D	D
Fix all and raise D, B, E, F, A, C, I, G	F	--	--	--	--	--	--	D
Fix all and raise all to 500-yr WSEL	F	--	--	--	--	--	--	D

The steps taken to perform each levee reach improvement (per Major and Minor impact areas) were:

- Selecting the controlling index point (CIP) for each levee reach improvement was based on several factors, including reach-specific AEP, reach-specific EAD, and the comparison of potential benefits of fixing one reach instead of another would provide.
- Once a levee reach/fix was determined, floodplain assignments for that levee reach were identified by evaluating the floodplains that were ultimately removed from the "mix" of floodplains (suites from each index point) due to previous fixes and the floodplains that still remain[18].

[18] For example, in the second levee reach improvement (fix D and A, with NAT E as the CIP), flood depths taken from NAT B (2-yr, 10yr), NAT C (25-yr, 50-yr), and NAT D (100-yr to 500-yr) floodplains were used. For the 2-year and 10-year events, the floodplains associated with NAT D and NAT A produce the most consequences (single-event damages); however these floodplains have, theoretically, been removed from the "mix" of floodplains since NAT D has already been fixed (first levee reach improvement) and NAT A is being fixed in this second levee reach improvement. While NAT E is the CIP for this second levee reach improvement and will be fixed in the third improvement, flood depths from NAT B (which also has not been fixed yet but will be in the fourth levee reach improvement) were used for the 2-year and 10-year events as the consequences (single-event damages, see Tables 5-26 and 5-27) from NAT B are slightly higher than from NAT E. This same rationale was used for selecting NAT C flood depths for the 25-yr and 50-year events for this levee reach improvement and for assigning flood depth data for all of the other levee reaches and areas.

- Once floodplains for a levee reach were assigned, the suite was compiled (individual event floodplains taken from the nine suites of floodplains) and imported into HEC-FDA as a WSP.
- A row of stage data associated with the CIP was then inserted into the WSP.
- Stage-damage curves were computed in HEC-FDA using the newly-compiled suite of floodplains for that levee reach and the economic inventory (already imported into HEC-FDA).
- The HEC-FDA input data (exceedance probability-discharge-stage curves and GRU curves) associated with the CIP was entered into HEC-FDA.
- AEP and EAD computations were completed in HEC-FDA.

An important point to note, and which may be more clear once the results of the with-project analysis is explained using graphs (section 6.5), is that with each levee reach improvement a reduction in risk (either the probability of flooding using AEP as a measure, the consequences of flooding via smaller floodplains, or both) takes place. In Chapter 7, *Net Benefit and Benefit-to-Cost Analyses*, benefits will be compared to costs to determine the feasibility of each alternative and the optimal plan (i.e., the one with the most net benefits) amongst all of those evaluated.

More detailed explanations of each levee reach improvement are explained in Section 6.4.2 below.

6.7.2 Mechanics of Reach-by-Reach With-Project Analysis

For better understanding, the following discussion may require the reader to refer back to the tables in subsection 6.2.3 (AEP, EAD, single-event damages), the suites of floodplain plates located in Enclosure 1 of this Appendix, and Tables 6-7 and 6-8 above that show the floodplain assignments.

6.7.2.1 Establishing the Without-Project Condition for the Basis of the With-Project Analysis

An important first step was to identify the basis/starting point of the with-project analysis – or establishing the without-project condition for which all other levee reaches would be compared to. Evaluation of the reach/index point-specific without-project HEC-FDA results indicated that a levee breach at NAT D, from both a probability of flooding (measured using AEP) point of view and consequences of flooding (measured using EAD and single-event damages) point of view, could be considered the weakest link of the entire Natomas Basin. This determination is borne out by the AEP, EAD, and single-event damages results:

- AEP of .21
- EAD of over a billion dollars
- Single-event damages range from $6.3 billion (2-yr) to $7.0 billion (500yr)

NAT D was selected as the controlling index point (CIP) to represent the baseline without-project condition for the Major impact area; NAT F was selected as the CIP to represent the baseline without-project condition for the Minor impact area. The baseline without-project EAD values used in the with-project analysis and taken from the results of the initial modeling documented in Chapter 5, are $886 million (Major area) and $477 million (Minor area). These values are also displayed in Tables 6-9, 6-10, and 6-11 below.

Individual event (2-yr to 500-yr) floodplains for the without-project (both Major and Minor impact areas) were selected exclusively from the suite of floodplains developed for NAT D, as the NAT D floodplains produced the greatest amount of damages than any other floodplains associated with the other reaches/index points. This suite of floodplains (shown in Tables 6-7 and 6-8 for both areas) was then imported into HEC-FDA and stage-damage curves were computed within HEC-FDA. (The economic structure inventory was also imported into HEC-FDA.) All of the engineering data (exceedance probability-stage, equivalent record length, and GRU curve) associated with the NAT D index point was entered into HEC-FDA, and EAD was computed.

Tables 6-9 and 6-10 below show the results by Major and Minor impact areas. Table 6-11 combines the results to show total EAD for the without-project. Considering both impact areas, baseline without-project EAD is $1.363 billion.

Table 6-9
Without-Project
Major Impact Area
AEP, EAD, and Annual Benefits, in $Millions and Oct 2010 Price Level

MEASURE	EAD	AEP	ANNUAL BENEFITS	% DAMAGE REDUCED
Without	886	.21	--	--

Table 6-10
Without-Project
Minor Impact Area
AEP, EAD, and Annual Benefits, in $Millions and Oct 2010 Price Level

MEASURE	EAD	AEP	ANNUAL BENEFITS	% DAMAGE REDUCED
Without	477	.30	--	--

Table 6-11
Without-Project
Major and Minor Impact Areas
AEP, EAD, and Annual Benefits, in $Millions and Oct 2010 Price Level

MEASURE	EAD			AEP		ANN BEN	% DAM REDUCED
	Major	Minor	Total	Major	Minor		
Without	886	477	1,363	.21	.30	--	--

Notes: ANN BEN = Annual Benefits; % Dam Reduced = Percent Damages Reduced

The remaining levee reach improvements will be explained in a similar way to this one, however only one combined table showing the results for both the Major and Minor impact areas will be displayed. The rationale for selecting the CIP and floodplains (both impact areas) will be explained for each levee reach.

6.7.2.2 Levee Reach Improvement– Fix NAT D

The first levee reach improvement selected was to fix NAT D. NAT A was selected as the CIP, which had the next highest AEP/damages (Major impact area); the CIP for the Minor impact area remained NAT F, and remained the CIP for all levee reach improvements. Holding the CIP constant at NAT F for all levee reach improvements enabled residual damages in the Minor impact area to be computed for each levee reach based solely on the removal of floodplains from the "mix" due to fixes that occurred in the Major impact area, until NAT F and NAT G were fixed. Once NAT F and NAT G were fixed, residual damages for the Minor impact area resulted from the removal of floodplains from the "mix" as well as a reduction in the probability of flooding.

For this levee reach improvement, the floodplains selected are shown in Tables 6-7 and 6-8 (2-yr = B, 10-yr = B, 25-yr = C, 50-yr = C, and 100-yr to 500-yr = D); they are the same for both impact areas. By fixing NAT D, the 2-, 10-, 25-, and 50-yr floodplains for NAT D were removed from the "mix" and were replaced by NAT B (2-yr and 10-yr) and NAT C (25-yr and 50-yr) floodplains. These were chosen because they represented the floodplains having the greatest consequences (damages) for a specific event and which were still in the "mix" of floodplains to choose from.

Table 6-12
First Levee Reach Improvement: Fix NAT D
Major and Minor Impact Areas
AEP, EAD, and Annual Benefits, in $Millions and Oct 2010 Price Level

MEASURE	EAD			AEP		ANN BEN	% DAM REDUCED
	Major	Minor	Total	Major	Minor		
Without	886	477	1,363	.21	.30	--	--
Fix D	582	449	1,031	.21	.30	332	24%

Notes: ANN BEN = Annual Benefits; % Dam Reduced = Percent Damages Reduced

The results in Table 6-12 show that fixing NAT D reduces damages significantly in the Major impact area. This can be explained by the substantial reduction in both the extent and depths of flooding when switching from NAT D floodplains (without; 2-yr and 10-yr) to NAT B floodplains (first levee reach improvement; 2-yr and 10-yr) and NAT C floodplains (25-yr and 50-year). On the other hand, damages are reduced only relatively minimally in the Minor impact area. This can be explained by the relatively minimal reduction in the extent and depths of flooding within this impact area when going from NAT D to NAT B/NAT C floodplains.

6.7.2.3 Levee Reach Improvement – Fix NAT A

The second levee reach improvement selected was to fix NAT A (and the previous fix, NAT D). NAT E was selected as the CIP, which had the next highest AEP/damages (Major impact area) once NAT A is fixed; the CIP for the Minor impact area remained NAT F.

For this levee reach improvement, the floodplains selected are shown in Tables 6-7 and 6-8 (2-yr = B, 10-yr = B, 25-yr = C, 50-yr = C, and 100-yr to 500-yr = D); the assignments are the same for both impact areas and do not change from the first levee reach improvement. This is because fixing NAT A does not remove any floodplains from the "mix" that effectively changes the assignments.[19]

Table 6-13
Second Levee Reach Improvement: Fix NAT A
Major and Minor Impact Areas
AEP, EAD, and Annual Benefits, in $Millions and Oct 2010 Price Level

MEASURE	EAD			AEP		ANN BEN	% DAM REDUCED
	Major	Minor	Total	Major	Minor		
Without	886	477	1,363	.21	.30	--	--
Fix D	582	449	1,031	.21	.30	332	24%
Fix D+A	576	449	1,025	.18	.30	338	25%

Notes: ANN BEN = Annual Benefits; % Dam Reduced = Percent Damages Reduced

[19] NAT A floodplains (2-yr through 100-yr) are removed, but other floodplains still exist that produce as much or more damages for these frequency events; in this case, NAT B (2-yr and 10-yr) and NAT C (25-yr and 50-yr) and NAT D (100-yr to 500yr) floodplains still exist.

The results in Table 6-13 show that fixing NAT A reduces damages minimally (about $6 million) in the Major impact area. The reduction in damages for this levee reach improvement can be attributed to a slight reduction in the probability of flooding (as measured by a lower AEP -- from .21 to .18) but cannot be attributed to a reduction in flooding consequences (as represented by event floodplains) because these were unchanged.

Fixing NAT A does not reduce damages in the Minor impact area. Here, both the probability of flooding (as measured by AEP) and consequences of flooding are unchanged from the previous levee reach improvement.

On first glance this levee reach improvement suggests that fixing NAT A as a second improvement does not result in a significant amount of additional benefits. However, it is not until the next levee reach improvement (3^{rd}) is completed does it become apparent that fixing NAT A without fixing NAT E (or vice versa) would not make sense since full benefits are realized only when both are fixed; no benefits are realized when neither is fixed. It can be argued that NAT A and NAT E have a synergistic relationship.

6.7.2.4 Levee Reach Improvement – Fix NAT E

The third levee reach improvement selected was to fix NAT E (along with NAT D and NAT A). NAT B was selected as the CIP, which had the next highest AEP/damages (Major impact area) once NAT E is fixed; the CIP for the Minor impact area remained NAT F.

For this levee reach improvement, the floodplains selected are shown in Tables 6-7 and 6-8 (2-yr = B, 10-yr = B, 25-yr = C, 50-yr = C, and 100-yr to 500-yr = D); the assignments are the same for both impact areas and do not change from the first and second levee reach improvements. As in the second improvement, fixing NAT E does not remove any floodplains from the "mix" that effectively changes the assignments.[20]

Table 6-14
Third Levee Reach Improvement: Fix NAT E
Major and Minor Impact Areas
AEP, EAD, and Annual Benefits, in $Millions and Oct 2010 Price Level

MEASURE	EAD			AEP		ANN BEN	% DAM REDUCED
	Major	Minor	Total	Major	Minor		
Without	886	477	1,363	.21	.30	--	--
Fix D	582	449	1,031	.21	.30	332	24%
Fix D+A	576	449	1,025	.18	.30	338	25%
Fix D+A+E	261	449	710	.12	.30	653	48%

Notes: ANN BEN = Annual Benefits; % Dam Reduced = Percent Damages Reduced

[20] NAT A floodplains (2-yr through 100-yr) are removed, but other floodplains still exist that produce as much or more damages for these frequency events; in this case, NAT B (2-yr and 10-yr) and NAT C (25-yr and 50-yr) and NAT D (100-yr to 500yr) floodplains still exist.

The results in Table 6-14 show that fixing NAT E reduces damages significantly ($315 million for this levee reach improvement) in the Major impact area. The reduction in damages for this levee reach improvement can be attributed to a relatively significant reduction in the probability of flooding (as measured by a lower AEP -- from .18 to .12) but cannot be attributed to a reduction in flooding consequences (as represented by event floodplains) because these were unchanged.

Fixing NAT E does not reduce damages in the Minor impact area. Here, both the probability of flooding (as measured by AEP) and consequences of flooding are unchanged from the previous levee reach improvement.

6.7.2.5 Levee Reach Improvement – Fix NAT B

The fourth levee reach improvement selected was to fix NAT B (along with NAT D, NAT A, and NAT E). NAT C was selected as the CIP, which had the next highest AEP/damages (Major impact area) once NAT B is fixed; the CIP for the Minor impact area remained NAT F.

For this levee reach improvement, the floodplains selected are shown in Table 6-7 (25-yr = C, 50-yr = C, and 100-yr to 500-yr = D) for the Major impact area; this levee reach improvement finally removes several event floodplains from the “mix.” Fixing NAT D, NAT A, NAT E, and NAT B reduces the probability of flooding (and levee breaches) from these reaches and effectively removes the 2-yr and 10-yr floodplains in the Major impact area. For the Minor impact area, the floodplain assignments change from the previous levee reach improvement (2-yr = G, 10-yr = G, 25-yr = C, 50-yr = C, 100-yr to 500-yr = D). There are still 2-yr and 10-yr floodplains in the Minor impact area because there is still a possibility of flooding from the smaller events (AEP = .30) in this area.

Table 6-15
Fourth Levee Reach Improvement: Fix NAT B
Major and Minor Impact Areas
AEP, EAD, and Annual Benefits, in $Millions and Oct 2010 Price Level

MEASURE	EAD			AEP		ANN BEN	% DAM REDUCED
	Major	Minor	Total	Major	Minor		
Without	886	477	1,363	.21	.30	--	--
Fix D	582	449	1,031	.21	.30	332	24%
Fix D+A	576	449	1,025	.18	.30	338	25%
Fix D+A+E	261	449	710	.12	.30	653	48%
Fix D+A+E+B	129	97	226	.04	.30	1,137	83%

Notes: ANN BEN = Annual Benefits; % Dam Reduced = Percent Damages Reduced

The results in Table 6-15 show that fixing NAT B again reduces damages significantly in both the Major impact area ($132 million) and Minor impact area ($352 million) for combined reduction in damages of $484 million. The reduction in damages for this levee reach improvement can be attributed to a relatively significant reduction in the probability of flooding (as measured by a lower AEP -- from .12 to .04) and to the reduction in flooding consequences (removal of event floodplains in the Major impact area) and a significant reduction in the extent and depths of flooding for the 2-yr and 10-yr events in the Minor impact area (refer to NAT G 2-yr and 10-yr floodplains in Enclosure 1).

6.7.2.6 Levee Reach Improvement– Fix NAT C

The fifth levee reach improvement selected was to fix NAT C (along with NAT D, NAT A, NAT E, and NAT B). NAT H was selected as the CIP, which had the highest AEP/damages (Major impact area) once NAT C is fixed; the CIP for the Minor impact area remained NAT F.

For this improvement, the floodplains selected are shown in Table 6-7 (25-yr = H, 50-yr = E, and 100-yr to 500-yr = D) for the Major impact area; this levee reach improvement removes additional event floodplains from the "mix." Fixing NAT D, NAT A, NAT E, NAT B and NAT C reduces the probability of flooding (and levee breaches) from these reaches and effectively removes the 2-yr and 10-yr floodplains (as in the fourth improvement). What also happens is that the 25-yr and 50-yr event floodplains change in the Major impact area, with the bigger NAT C floodplains being replaced by the smaller NAT H (25-yr) and slightly smaller NAT E (50-yr) floodplains. For the Minor impact area, the floodplain assignments change from the previous levee reach improvement (2-yr = G, 10-yr = G, 25-yr = H, 50-yr = E, 100-yr to 500-yr = D), with NAT H (25-yr) and NAT E (50-yr) floodplains replacing the bigger NAT C floodplains, as in the Major impact area.

Table 6-16
Fifth Levee Reach Improvement: Fix NAT C
Major and Minor Impact Areas
AEP, EAD, and Annual Benefits, in $Millions and Oct 2010 Price Level

MEASURE	EAD			AEP		ANN BEN	% DAM REDUCED
	Major	Minor	Total	Major	Minor		
Without	886	477	1,363	.21	.30	--	--
Fix D	582	449	1,031	.21	.30	332	24%
Fix D+A	576	449	1,025	.18	.30	338	25%
Fix D+A+E	261	449	710	.12	.30	653	48%
Fix D+A+E+B	129	97	226	.04	.30	1,137	83%
Fix D+A+E+B+C	101	95	196	.04	.30	1,167	86%

Notes: ANN BEN = Annual Benefits; % Dam Reduced = Percent Damages Reduced

The results in Table 6-16 show that fixing NAT C reduces damages relatively slightly in both the Major impact area ($28 million) and Minor impact area ($2 million) for combined reduction in damages of $30 million. The reduction in damages for this improvement can be attributed solely to reduction in flooding consequences (replacement of event floodplains with slightly larger floodplains in both impact areas).

6.7.2.7 Levee Reach Improvement– Fix NAT H

The sixth levee reach improvement selected was to fix NAT H (along with NAT D, NAT A, NAT E, NAT B, and NAT C). NAT I was selected as the CIP, which had one of the highest remaining AEP/damages (Major impact area) once NAT H is fixed. Although HEC-FDA AEP results showed that post-fix NAT D (.016), post-fix NAT B (.017), post-fix NAT E (.019), and pre-fix NAT I (.015) all had very similar AEPs, NAT I was selected as the CIP not only because of its AEP, but also because of its relatively high EAD value; furthermore, NAT I was selected as the CIP because, in terms of engineering data, it had what could be considered the most reliable data (compared to NAT D, E, B) based on the period of record (NAT I = 87 years; NAT B = 71 years; NAT D and E = 25 years). The CIP for the Minor impact area remained NAT F.

For this improvement, the floodplains selected are shown in Table 6-7 (50-yr = E, and 100-yr to 500-yr = D) for the Major impact area; this levee reach improvement removes the 25-year event floodplain from the "mix." Fixing NAT D, NAT A, NAT E, NAT B, NAT C, and NAT H reduces the probability of flooding (and levee breaches) from these reaches and effectively removes the 25-yr floodplain. For the Minor impact area, the floodplain assignments change from the previous levee reach improvement (2-yr = G, 10-yr = G, 25-yr = G, 50-yr = E, 100-yr to 500-yr = D), with the slightly smaller NAT G (25-yr) floodplain replacing the NAT H (25-yr) floodplain. Again, in the Minor impact area no event floodplains have been removed yet (i.e., full suite of floodplains were used to compute EAD) as the probability of flooding in this area still remains high (NAT F AEP = .30).

Table 6-17
Sixth Levee Reach Improvement: Fix NAT H
Major and Minor Impact Areas
AEP, EAD, and Annual Benefits, in $Millions and Oct 2010 Price Level

MEASURE	EAD			AEP		ANN BEN	% DAM REDUCED
	Major	Minor	Total	Major	Minor		
Without	886	477	1,363	.21	.30	--	--
Fix D	582	449	1,031	.21	.30	332	24%
Fix D+A	576	449	1,025	.18	.30	338	25%
Fix D+A+E	261	449	710	.12	.30	653	48%
Fix D+A+E+B	129	97	226	.04	.30	1,137	83%
Fix D+A+E+B+C	101	95	196	.04	.30	1,167	86%
Fix D+A+E+B+C+H	28	94	122	.015	.30	1,241	91%

Notes ANN BEN = Annual Benefits; % Dam Reduced = Percent Damages Reduced

The results in Table 6-17 show that fixing NAT H reduces damages by $73 million in the Major impact area and only minimally ($1 million) in the Minor impact area for a combined reduction in damages of $74 million. The reduction in damages for this improvement can be attributed mostly to the reduction in the probability of flooding (AEP reduced from .04 to .015) and flooding consequences (removal of 25-yr event floodplain) in the Major impact area.

6.7.2.8 Levee Reach Improvement– Fix NAT G

The seventh levee reach improvement selected was to fix NAT G (along with NAT D, NAT A, NAT E, NAT B, NAT C, and NAT H). This is the improvement where the probability of flooding in the Minor impact area (breaches from NAT F and NAT G) is finally addressed – where the consequences of flooding warrants fixes to NAT F and NAT G. NAT I remained the CIP in the Major impact area (since this levee reach improvement only affects the Minor impact area). The CIP for the Minor impact area remained NAT F.

For this improvement, the floodplains selected are shown in Table 6-7 (50-yr = E, and 100-yr to 500-yr = D) for the Major impact area; they are exactly the same as the previous improvement. For the Minor impact area, the floodplain assignments changed from the previous improvement (2-yr =F, 10-yr = F, 25-yr = F, 50-yr = E, 100-yr to 500-yr = D), with the slightly smaller NAT F (2-yr to 25-yr) floodplains replacing the NAT G floodplains. Again, in the Minor impact area no event floodplains have been removed yet (i.e., full suite of floodplains were used to compute EAD) as the probability of flooding in this area still remains high (NAT F AEP = .30) until Fixes to both NAT F and NAT G are completed.

Table 6-18
Seventh Levee Reach Improvement: Fix NAT G
Major and Minor Impact Areas
AEP, EAD, and Annual Benefits, in $Millions and Oct 2010 Price Level

MEASURE	EAD			AEP		ANN BEN	% DAM REDUCED
	Major	Minor	Total	Major	Minor		
Without	886	477	1,363	.21	.30	--	--
Fix D	582	449	1,031	.21	.30	332	24%
Fix D+A	576	449	1,025	.18	.30	338	25%
Fix D+A+E	261	449	710	.12	.30	653	48%
Fix D+A+E+B	129	97	226	.04	.30	1,137	83%
Fix D+A+E+B+C	101	95	196	.04	.30	1,167	86%
Fix D+A+E+B+C+H	28	94	122	.015	.30	1,241	91%
Fix D+A+E+B+C+H+G	28	81	109	.015	.30	1,254	92%

Notes: ANN BEN = Annual Benefits; % Dam Reduced = Percent Damages Reduced

The results in Table 6-18 show that fixing NAT G reduces damages by $13 million in the Minor impact area; damages in the Major impact area remain the same as none of the contributing factors (probability of flooding or floodplain assignments) have changed from the previous levee reach improvement. The reduction in damages for this improvementcan be attributed solely to the reduction in flooding consequences (smaller 2-yr, 10-yr, 25-yr floodplains) in the Minor impact area.

6.7.2.9 Levee Reach Improvement– Fix NAT F

The eighth levee reach improvement was to fix NAT F (along with NAT D, NAT A, NAT E, NAT B, NAT C, NAT H, and NAT G). As with the previous improvement, in this levee reach improvement the probability of flooding in the Minor impact area (breaches from NAT F and NAT G) is addressed. NAT I again remained the CIP in the Major impact area (since this improvement only affects the Minor impact area). The CIP for the Minor impact area remained NAT F.

For this levee reach improvement, the floodplains selected are shown in Tables 6-7 (50-yr = E, and 100-yr to 500-yr = D) for the Major impact area; they are exactly the same as the previous improvement. For the Minor impact area, the floodplain assignments changed from the previous improvement (50-yr = E, 100-yr to 500-yr = D), and floodplains (2-yr, 10-yr, 25-yr) are finally removed from this area as fixing both NAT G and NAT F reduced the probability of flooding from .30 to .023.

Table 6-19
Eighth Levee Reach Improvement: Fix NAT F
Major and Minor Impact Areas
AEP, EAD, and Annual Benefits, in $Millions and Oct 2010 Price Level

MEASURE	EAD			AEP		ANN BEN	% DAM REDUCED
	Major	Minor	Total	Major	Minor		
Without	886	477	1,363	.21	.30	--	--
Fix D	582	449	1,031	.21	.30	332	24%
Fix D+A	576	449	1,025	.18	.30	338	25%
Fix D+A+E	261	449	710	.12	.30	653	48%
Fix D+A+E+B	129	97	226	.04	.30	1,137	83%
Fix D+A+E+B+C	101	95	196	.04	.30	1,167	86%
Fix D+A+E+B+C+H	28	94	122	.015	.30	1,241	91%
Fix D+A+E+B+C+H+G	28	81	109	.015	.30	1,254	92%
Fix D+A+E+B+C+H+G+F	28	37	65	.015	.023	1,298	95%

Notes: ANN BEN = Annual Benefits; % Dam Reduced = Percent Damages Reduced

The results in Table 6-19 show that fixing NAT F reduces damages by an added levee reach improvement of $44 million in the Minor impact area; damages in the Major impact area remain the same as none of the contributing factors (probability of flooding or floodplain assignments) have changed from the previous improvement. The reduction in damages for this levee reach improvement can be attributed to both the reduction in the probability of flooding (AEP improved from .30 to .023) and in flooding consequences (removal of 2-yr, 10-yr, and 25-yr floodplains) in the Minor impact area.

6.7.2.10 Levee Reach Improvement– Fix NAT I

The ninth levee reach improvement was to fix NAT I (along with NAT D, NAT A, NAT E, NAT B, NAT C, NAT H, NAT G, and NAT F). For this improvement, the CIP for the Major impact area remained NAT I. The CIP for the Minor impact area remained NAT F.

For this levee reach improvement, the floodplains selected are shown in Table 6-7 (50-yr = E, and 100-yr to 500-yr = D) for the Major impact area; they are exactly the same as the previous improvement. For the Minor impact area, the floodplain assignments also remained the same from the previous improvement.

Table 6-20
Ninth Levee Reach Improvement: Fix NAT I
Major and Minor Impact Areas
AEP, EAD, and Annual Benefits, in $Millions and Oct 2010 Price Level

MEASURE	EAD			AEP		ANN BEN	% DAM REDUCED
	Major	Minor	Total	Major	Minor		
Without	886	477	1,363	.21	.30	--	--
Fix D	582	449	1,031	.21	.30	332	24%
Fix D+A	576	449	1,025	.18	.30	338	25%
Fix D+A+E	261	449	710	.12	.30	653	48%
Fix D+A+E+B	129	97	226	.04	.30	1,137	83%
Fix D+A+E+B+C	101	95	196	.04	.30	1,167	86%
Fix D+A+E+B+C+H	28	94	122	.015	.30	1,241	91%
Fix D+A+E+B+C+H+G	28	81	109	.015	.30	1,254	92%
Fix D+A+E+B+C+H+G+F	28	37	65	.015	.023	1,298	95%
Fix D+A+E+B+C+H+G+F+I	28	37	65	.015	.023	1,298	95%

Notes: ANN BEN = Annual Benefits% Dam Reduced = Percent Damages Reduced

The results in Table 6-20 show that fixing NAT I does not reduce damages in either the Major or Minor impact areas. This is because that although NAT I is fixed, there are other reaches (NAT D, NAT B, NAT E) where the probability of flooding (with-project AEP; refer to Table__) is still around .015 (which is the without-project AEP of NAT); in other words, the benefits of fixing NAT I are not realized until *additional* improvements (i.e, levee raises) are made to other reaches since there is still an equivalent chance of flooding from these other reaches as there was from NAT I prior to NAT I being fixed.

6.7.2.11 Levee Reach Improvements– Fix All and Raise NAT D, B, E, and F

The tenth levee reach improvement was to fix all reaches and to raise those reaches where AEP still remains relatively high compared to the other reaches. These improvements included raising reaches NAT D, NAT B, and NAT E. For these improvement, the CIP for the Major impact area remained NAT I. NAT I was selected for two reasons: there is more complete data (exceedance probability-discharge and stage-discharge curves) and more reliable data (equivalent record length of 87 years versus 71 years or 25 years for other reaches) for input into the HEC-FDA model. The CIP for the Minor impact area remained NAT F.

For these levee reach improvements, the floodplains selected are shown in Tables 6-7 and 6-8 (200-yr = D, 500-yr = D) for both areas. Here, the 50-yr and 100-yr floodplains are removed from both impact areas. In effect, raising certain reaches in conjunction with fixing NAT I removes floodplains from the "mix" (improves the flooding consequences) as well as reduces the probability of flooding (AEP is reduced from .016 to .008 in the Major impact area and from .023 to .006 in the Minor impact area).

Table 6-21
Tenth Levee Reach Improvements: Fix All and Raise NAT D, NAT B, NAT E, and NAT F
Major and Minor Impact Areas
AEP, EAD, and Annual Benefits, in $Millions and Oct 2010 Price Level

MEASURE	EAD			AEP		ANN BEN	% DAM REDUCED
	Major	Minor	Total	Major	Minor		
Without	886	477	1,363	.21	.30	--	--
Fix D	582	449	1,031	.21	.30	332	24%
Fix D+A	576	449	1,025	.18	.30	338	25%
Fix D+A+E	261	449	710	.12	.30	653	48%
Fix D+A+E+B	129	97	226	.04	.30	1,137	83%
Fix D+A+E+B+C	101	95	196	.04	.30	1,167	86%
Fix D+A+E+B+C+H	28	94	122	.015	.30	1,241	91%
Fix D+A+E+B+C+H+G	28	81	109	.015	.30	1,254	92%
Fix D+A+E+B+C+H+G+F	28	37	65	.015	.023	1,298	95%
Fix D+A+E+B+C+H+G+F+I	28	37	65	.015	.023	1,298	95%
Fix all and raise D, B, E, and F	21	9	30	.008	.006	1,333	98%

Notes: ANN BEN = Annual Benefits; % Dam Reduced = Percent Damages Reduced

The results in Table 6-21 show that fixing all of the reaches and raising NAT D, NAT B, NAT E, and NAT F reduces damages in the Major impact area ($7 million) and the Minor impact area ($28 million) for a combined reduction of $35 million.

6.7.2.12 Levee Reach Improvements– Fix All and Raise NAT D, B, E, F, A, C, I, G

The eleventh levee reach improvements were to fix all reaches and to raise all reaches (except for NAT H). For these improvements, the CIP for the Major impact area remained NAT I. The CIP for the Minor impact area remained NAT F.

For these improvements, the floodplains selected are shown in Tables 6-7 and 6-8 (500-yr = D) for both areas; the 200-yr floodplain is removed from both impact areas. Fixing and raising levees improves the flooding consequences (removes 200-yr floodplain in both areas) as well as reduces the probability of flooding (AEP is reduced from .008 to .006 in the Major impact area; AEP is reduced from .006 to .004 in the Minor impact area).

Table 6-22
Eleventh Levee Reach Improvements: Fix All and Raise NAT D, NAT B, NAT E, NAT F, NAT A, NAT C, NAT I, NAT G
Major and Minor Impact Areas
AEP, EAD, and Annual Benefits, in $Millions and Oct 2010 Price Level

MEASURE	EAD			AEP		ANN BEN	% DAM REDUCED
	Major	Minor	Total	Major	Minor		
Without	886	477	1,363	.21	.30	--	--
Fix D	582	449	1,031	.21	.30	332	24%
Fix D+A	576	449	1,025	.18	.30	338	25%
Fix D+A+E	261	449	710	.12	.30	653	48%
Fix D+A+E+B	129	97	226	.04	.30	1,137	83%
Fix D+A+E+B+C	101	95	196	.04	.30	1,167	86%
Fix D+A+E+B+C+H	28	94	122	.015	.30	1,241	91%
Fix D+A+E+B+C+H+G	28	81	109	.015	.30	1,254	92%
Fix D+A+E+B+C+H+G+F	28	37	65	.015	.023	1,298	95%
Fix D+A+E+B+C+H+G+F+I	28	37	65	.015	.023	1,298	95%
Fix all and raise D, B, E, F	21	9	30	.008	.006	1,333	98%
Fix all and raise D, B, E, F, A, C, I, G	4	7	11	.006	.004	1,352	99%

Notes: ANN BEN = Annual Benefits; % Dam Reduced = Percent Damages Reduced

The results in Table 6-22 show that fixing all of the reaches and raising all reaches except NAT H reduces damages in the Major impact area ($17 million) and the Minor impact area ($2 million) for a combined reduction of $19 million.

6.7.2.13 Levee Reach Improvements– Fix All and Raise All

The final levee reach improvements were to fix all reaches and to raise all reaches. For these improvements, the CIP for the Major impact area remained NAT I. The CIP for the Minor impact area remained NAT F.

For these improvements, the floodplain assignment remained the same as in the previous levee reach improvements. Fixing and raising levees improves the flooding consequences (removes 200-yr floodplain in both areas) as well as reduces the probability of flooding (AEP is reduced from .006 to .001 in the Major impact area; AEP is reduced from .004 to .002 in the Minor impact area).

Table 6-23
Twelfth Levee Reach Improvements: Fix All and Raise NAT D, NAT B, NAT E, NAT F, NAT A, NAT C, NAT I
Major and Minor Impact Areas
AEP, EAD, and Annual Benefits, in $Millions and Oct 2010 Price Level

MEASURE	EAD			AEP		ANN BEN	% DAM REDUCED
	Major	Minor	Total	Major	Minor		
Without	886	477	1,363	.21	.30	--	--
Fix D	582	449	1,031	.21	.30	332	24%
Fix D+A	576	449	1,025	.18	.30	338	25%
Fix D+A+E	261	449	710	.12	.30	653	48%
Fix D+A+E+B	129	97	226	.04	.30	1,137	83%
Fix D+A+E+B+C	101	95	196	.04	.30	1,167	86%
Fix D+A+E+B+C+H	28	94	122	.015	.30	1,241	91%
Fix D+A+E+B+C+H+G	28	81	109	.015	.30	1,254	92%
Fix D+A+E+B+C+H+G+F	28	37	65	.015	.023	1,298	95%
Fix D+A+E+B+C+H+G+F+I	28	37	65	.015	.023	1,298	95%
Fix all and raise D, B, E, and F	21	9	30	.008	.006	1,333	98%
Fix all and raise D, B, E, F, A, C, I, G	4	7	11	.006	.004	1,352	99%
Fix all and raise all	4	2	6	.001	.002	1,357	99%

Notes: ANN BEN = Annual Benefits;% Dam Reduced = Percent Damages Reduced

The results in Table 6-23 show that fixing all of the reaches and raising all reaches except NAT H reduces damages in the Major impact area ($17 million) and the Minor impact area ($2 million) for a combined reduction of $19 million.

6.8 SUMMARY & EVALUATION OF RESULTS OF WITH-PROJECT ANALYSIS

The following subsections summarize the results of the with-project benefit analysis through tables and graphs. The graphs visually show how benefits increase with each levee reach improvement, either through the reduction in the probability of flooding (measured by AEP), the reduction in the consequences of flooding (i.e., removing floodplains from the "mix" as improvements to the Basin are made), or both.

6.8.1 EAD and Damages Reduced by Levee Reach Improvement

Table 6-24 summarizes the with-project analysis and shows EAD, damages reduced, and damages reduced as a percent of the total for each levee reach improvement and for each type of alternative ("fix-in-place" or "adjacent levee"); Figure 6-3 graphs the total annual benefits by levee reach improvement. As explained in previous sections, a specific method of fix (e.g., cutoff wall) can be considered a "fix-in-place" or an "adjacent levee" alternative depending on the physical location of the fix. From a geotechnical performance standpoint, a specific method of fix provides the same level of performance whether it's considered a "fix-in-place" or an "adjacent levee" alternative; from an economic benefits point of view, a specific method of fix provides the same amount of benefits whether it is considered a "fix-in-place" or an "adjacent levee" alternative.

Table 6-24
Summary of EAD and Damages Reduced by Reach Improvement and Alternative Type
In $Millions and October 2010 Price Level

MEASURES	ALTERNATIVE	EXPECTED ANNUAL DAMAGES	DAMAGES REDUCED (BENEFITS)	% DAMAGES REDUCED
Without	Adjacent Levee	1,363	--	--
	Fix-in-Place			
Fix D	Adjacent Levee	1,031	332	24%
	Fix-in-Place			
Fix D+A	Adjacent Levee	1,025	338	25%
	Fix-in-Place			
Fix D+A+E	Adjacent Levee	710	653	48%
	Fix-in-Place			
Fix D+A+E+B	Adjacent Levee	226	1,137	83%
	Fix-in-Place			
Fix D+A+E+B+C	Adjacent Levee	196	1,167	86%
	Fix-in-Place			
Fix D+A+E+B+C+H	Adjacent Levee	122	1,241	91%
	Fix-in-Place			
Fix D+A+E+B+C+H+G	Adjacent Levee	109	1,254	92%
	Fix-in-Place			
Fix D+A+E+B+C+H+G+F	Adjacent Levee	65	1,298	95%
	Fix-in-Place			
Fix D+A+E+B+C+H+G+F+I	Adjacent Levee	65	1,298	95%
	Fix-in-Place			
Fix all and raise D, B, E, and F	Adjacent Levee	30	1,333	98%
	Fix-in-Place			
Fix all and raise D, B, E, F, A, C, I, G	Adjacent Levee	11	1,352	99%
	Fix-in-Place			
Fix all and raise all	Adjacent Levee	6	1,357	100%
	Fix-in-Place			

One main point that can be made from the data in Table 6-24 is that fixing all reaches except NAT I reduces 95% of the total damages.

Figure 6-3 Total Annual Benefits by Levee Reach Improvement (in $Millions and Oct 2010 Price Level). (Yellow = Adjacent Levee; Blue = Fix-in-Place)

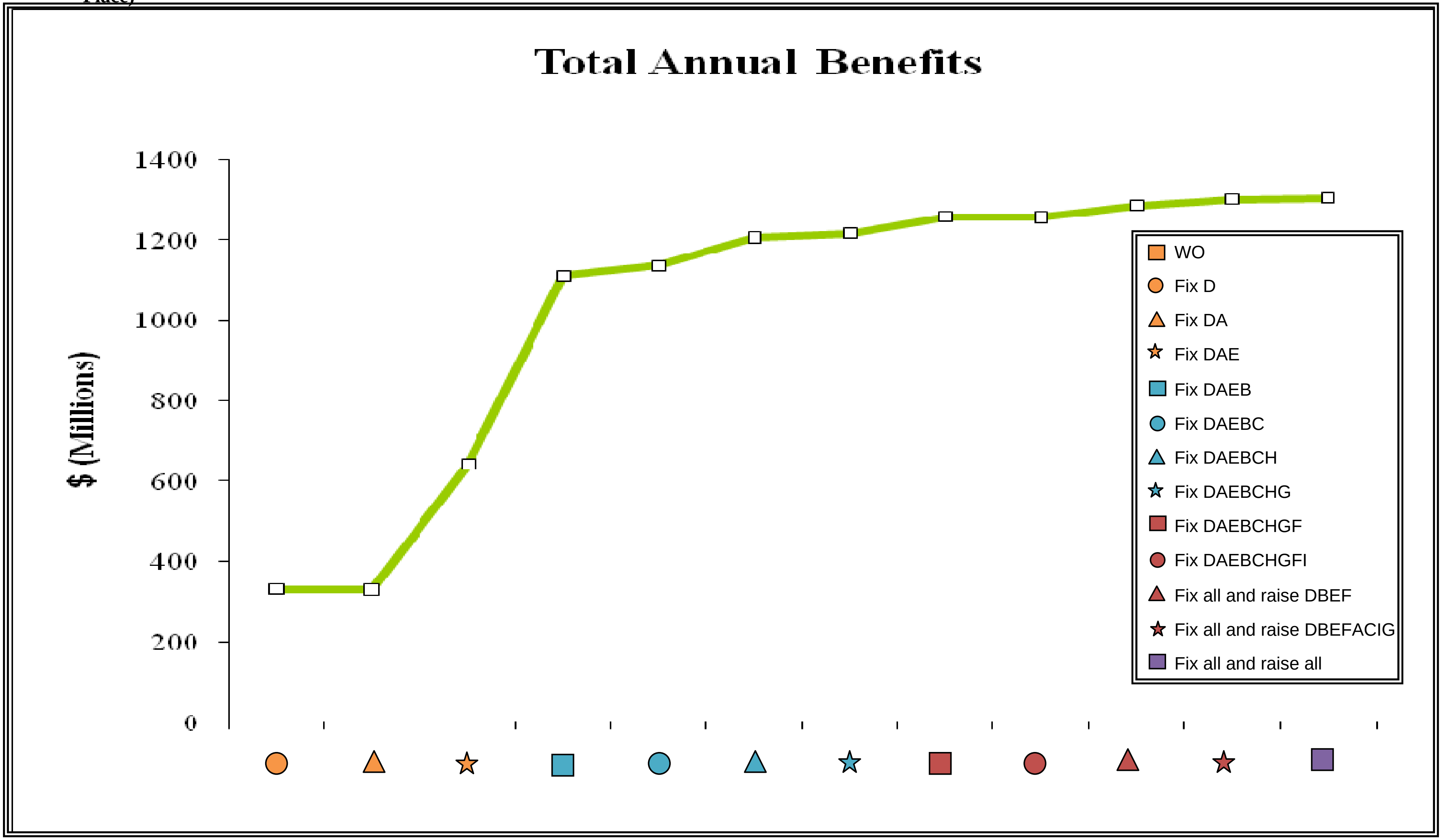


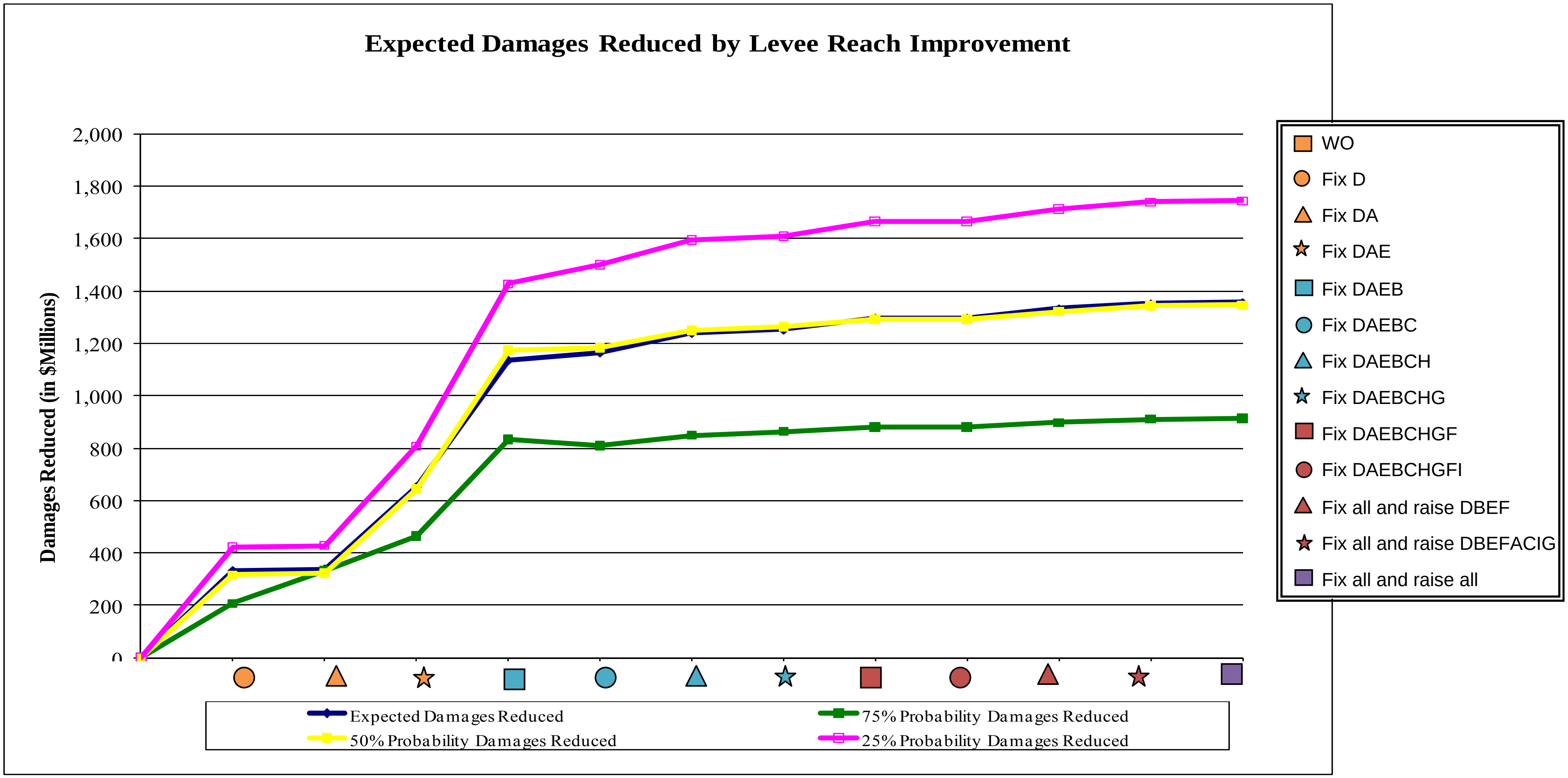
Table 6-25 and Figure 6-4 show the EAD and damages reduced (benefits) for each levee reach improvement, as well as the 25%, 50%, and 75% probabilities that benefits would exceed a specific value. The table and graph describe the magnitude of uncertainty surrounding the benefits.

Table 6-25
Damages Reduced and Probability Damages Reduced Exceeds Indicated Value
In $Millions and October 2010 Price Level

MEASURES	ALTERNATIVE	EXPECTED ANNUAL DAMAGES (EAD)			PROBABILITY DAMAGE REDUCED EXCEEDS INDICATED VALUE		
		Without	With Fix	Damages Reduced	75%	50%	25%
Without	AL or FIP	1,363	--	--	--	--	--
Fix D	AL or FIP	1,363	1,031	332	207	316	422
Fix D + A	AL or FIP	1,363	1,025	338	332	324	429
Fix D + A +E	AL or FIP	1,363	710	653	465	645	808
Fix D + A + E + B	AL or FIP	1,363	226	1,137	835	1,175	1,428
Fix D + A+ E + B + C	AL or FIP	1,363	196	1,167	809	1,185	1,500
Fix D + A + E + B + C + H	AL or FIP	1,363	122	1,241	850	1,249	1,594
Fix D + A + E + B + C + H + G	AL or FIP	1,363	109	1,254	864	1,263	1,610
Fix D + A + E + B + C + H + G + F	AL or FIP	1,363	65	1,298	881	1,293	1,665
Fix D + A + E + B + C + H + G + F + I	AL or FIP	1,363	65	1,298	881	1,293	1,665
Fix All and Raise D, B, E, F	AL or FIP	1,363	30	1,333	898	1,323	1,713
Fix All and Raise D, B, E, F, A, C, I, G	AL or FIP	1,363	11	1,352	911	1,344	1,740
Fix All and Raise All	AL or FIP	1,363	6	1,357	913	1,347	1,745

Notes: AL= Adjacent Levee; FIP = Fix-in-Place

Figure 6-4


Expected Damages Reduced by Levee Reach Improvement
Damages Reduced (in $Millions)
2,000
1,800
1,600
1,400
1,200
1,000
800
600
400
200
0
WO
Fix D
Fix DA
Fix DAE
Fix DAEB
Fix DAEBC
Fix DAEBCH
Fix DAEBCHG
Fix DAEBCHGF
Fix DAEBCHGFI
Fix all and raise DBEF
Fix all and raise DBEFACIG
Fix all and raise all
Expected Damages Reduced
50% Probability Damages Reduced
75% Probability Damages Reduced
25% Probability Damages Reduced

6.8.2 Performance Statistics by Levee Reach Improvement

Tables 6-25 and 6-26 below show the AEP, long-term risk, and conditional non-exceedance probability by event results by levee reach improvement for both the Major and Minor impact areas.

Table 6-26
Performance Statistics by Levee Reach Improvement
Major Impact Area

MEASURE	AEP	LONG-TERM RISK (YEARS)			CONDITIONAL NON-EXCEEDANCE PROBABILITY BY EVENTS					
		10	30	50	10%	4%	2%	1%	.4%	.2%
Without	0.21	.90	.99	1.00	.43	.27	.21	.15	.08	.06
Fix D	0.20	.90	.99	1.00	.36	.23	.19	.14	.06	.03
Fix D+A	0.18	.87	.99	1.00	.37	.23	.19	.15	.08	.06
Fix D+A+E	0.12	.72	.96	.99	.70	.59	.56	.49	.35	.29
Fix D+A+E+B	.04	.33	.63	.86	.85	.74	.71	.64	.43	.30
Fix D+A+E+B+C	.04	.35	.66	.88	.85	.73	.67	.58	.40	.13
Fix D+A+E+B+C+H*	.015	.14	.32	.54	.96	.92	.88	.81	.60	.50
Fix D+A+E+B+C+H+G*	.015	.14	.32	.54	.96	.92	.88	.81	.60	.50
Fix D+A+E+B+C+H+G+F*	.015	.14	.32	.54	.96	.92	.88	.81	.60	.50
Fix D+A+E+B+C+H+G+F+I*	.015	.14	.32	.54	.96	.92	.88	.81	.60	.50
Fix all and raise D, B, E, and F	.008	.08	.18	.33	.98	.97	.96	.96	.91	.14
Fix all and raise D, B, E, F, A, C, I, G	.006	.06	.14	.27	.98	.97	.96	.96	.94	.56
Fix all and raise all	.001	.01	.02	.05	.99	.98	.98	.97	.94	.56

*For these improvements, the performance statistics are associated with NAT D (with-project), since after fixing these reaches (H, G, F, I) NAT D (post-fix) becomes the "weakest link" associated with the Major impact area.

Table 6-27
Performance Statistics by Levee Reach Improvement
Minor Impact Area

MEASURE	AEP	LONG-TERM RISK (YEARS)			CONDITIONAL NON-EXCEEDANCE PROBABILITY BY EVENTS					
		10	30	50	10%	4%	2%	1%	.4%	.2%
Without	0.30	.97	.99	1.00	.42	.25	.17	.12	.06	.02
Fix D	0.30	.97	.99	1.00	.42	.25	.17	.12	.06	.02
Fix D+A	0.30	.97	.99	1.00	.42	.25	.17	.12	.06	.02
Fix D+A+E	0.30	.97	.99	1.00	.42	.25	.17	.12	.06	.02
Fix D+A+E+B	0.30	.97	.99	1.00	.42	.25	.17	.12	.06	.02
Fix D+A+E+B+C	0.30	.97	.99	1.00	.42	.25	.17	.12	.06	.02
Fix D+A+E+B+C+H	0.30	.97	.99	1.00	.42	.25	.17	.12	.06	.02
Fix D+A+E+B+C+H+G	0.30	.97	.99	1.00	.42	.25	.17	.12	.06	.02
Fix D+A+E+B+C+H+G+F	.023	.21	.44	.69	.96	.96	.96	.95	.94	.52
Fix D+A+E+B+C+H+G+F+I	.023	.21	.44	.69	.96	.96	.96	.95	.94	.52
Fix all and raise D, B, E, and F	.006	.01	.01	.03	1.00	1.00	1.00	1.00	.99	.68
Fix all and raise D, B, E, F, A, C, I, G	.006	.01	.01	.03	1.00	1.00	1.00	1.00	.99	.68
Fix all and raise all	.006	.01	.01	.03	1.00	1.00	1.00	1.00	.99	.68

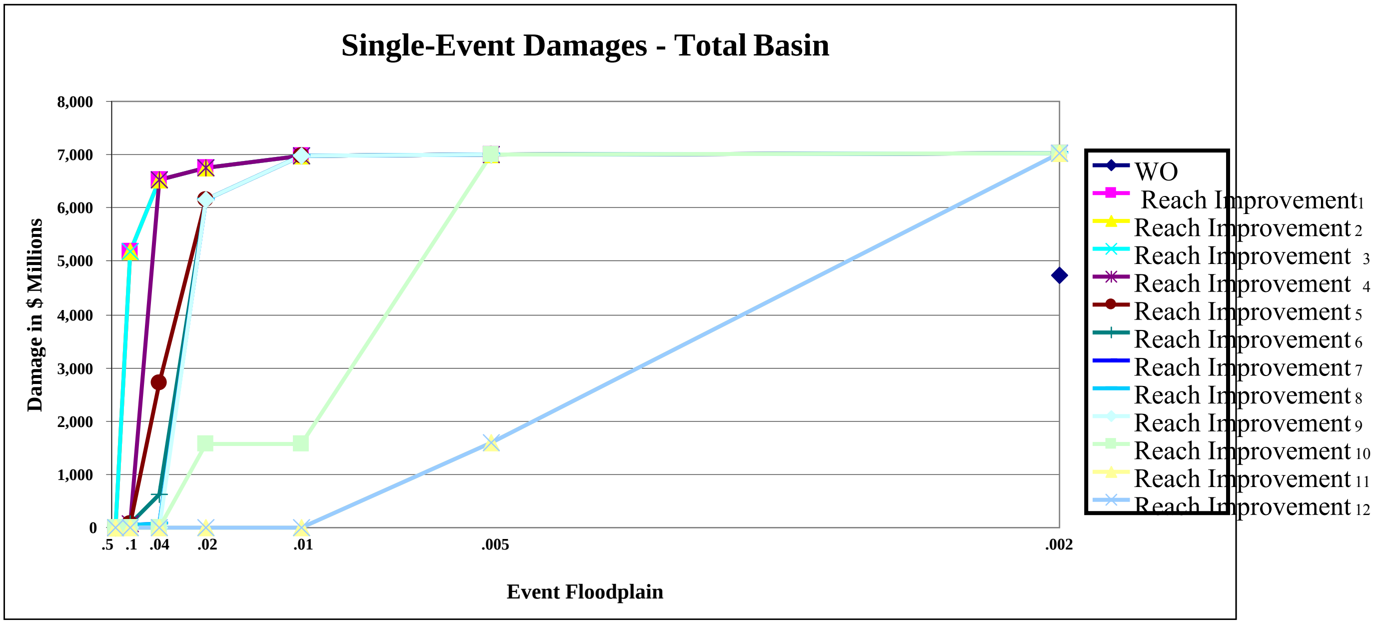
6.8.3 Single-Event Damages by Levee Reach Improvement

Table 6-28 shows the single-event damages (without uncertainty) for both the combined Major and Minor impact areas and for each levee reach improvement. Figure 6-4 shows the graphical representation of Table 6-28.

Table 6-28
Total Single-Event Damages by Levee Reach Improvement (without uncertainty)

MEASURE	(VALUES IN $ MILLIONS, OCTOBER 2010 PRICE LEVEL)						
	2-yr	10-yr	25-yr	50-yr	100-yr	200-yr	500-yr
Without	4,724	6,731	6,825	6,942	6,986	7,015	7,034
Fix D	2,466	5,176	6,540	6,760	6,986	7,015	7,034
Fix D+A	2,466	5,176	6,540	6,760	6,986	7,015	7,034
Fix D+A+E	2,466	5,176	6,540	6,760	6,986	7,015	7,034
Fix D+A+E+B	0	81	6,540	6,760	6,986	7,015	7,034
Fix D+A+E+B+C	0	81	2,727	6,162	6,986	7,015	7,034
Fix D+A+E+B+C+H	0	81	635	6,162	6,986	7,015	7,034
Fix D+A+E+B+C+H+G	0	43	77	6,162	6,986	7,015	7,034
Fix D+A+E+B+C+H+G+F	0	43	77	6,162	6,986	7,015	7,034
Fix D+A+E+B+C+H+G+F+I	0	0	0	6,162	6,986	7,015	7,034
Fix all and raise D, B, E, and F	0	0	0	1,567	1,581	7,015	7,034
Fix all and raise D, B, E, F, A, C, I, G	0	0	0	0	0	1,584	7,034
Fix all and raise all	0	0	0	0	0	1,584	7,034

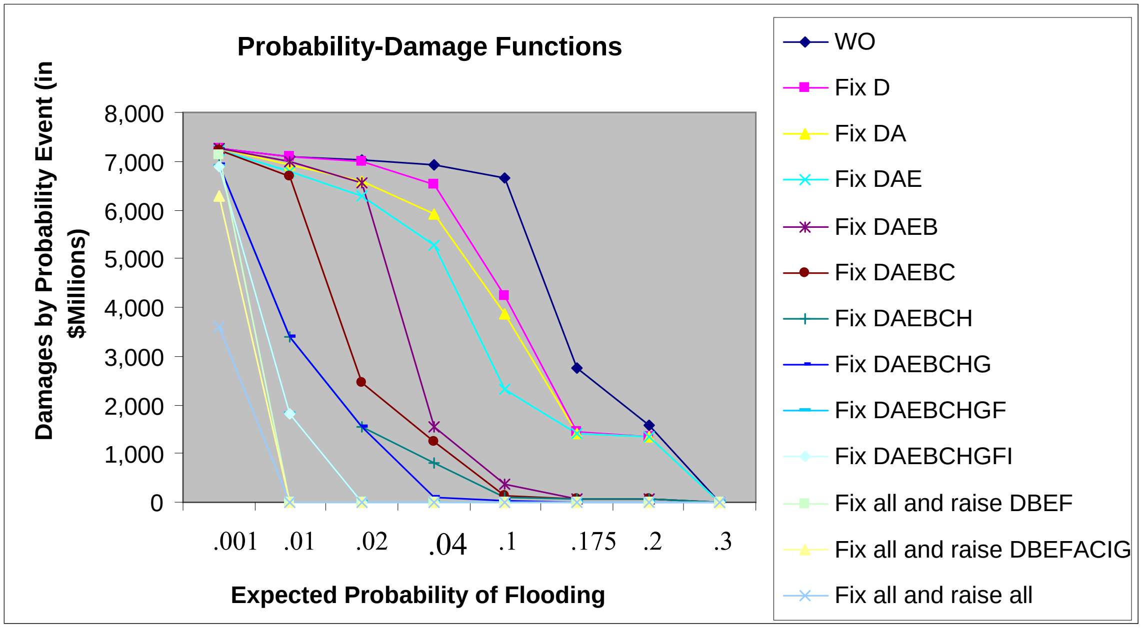
Figure 6-5 Total Single-Event Damages by Levee Reach Improvement (without uncertainty)



6.8.4 Exceedance-Probability Damage Functions

Figure 6-5 displays the exceedance-probability damage functions for each of the twelve levee reach improvements. The expected probabilities of flooding were plotted against damages by probability event using the HEC-FDA results. Since expected annual damages are computed by integrating under an individual exceedance-probability damage function, it can be seen from the graph that with each successive levee reach improvement the area under the respective curve becomes smaller, indicating a reduction in damages from one improvement to the next.

Figure 6-6 Exceedance-Probability Damage Functions (with uncertainty)



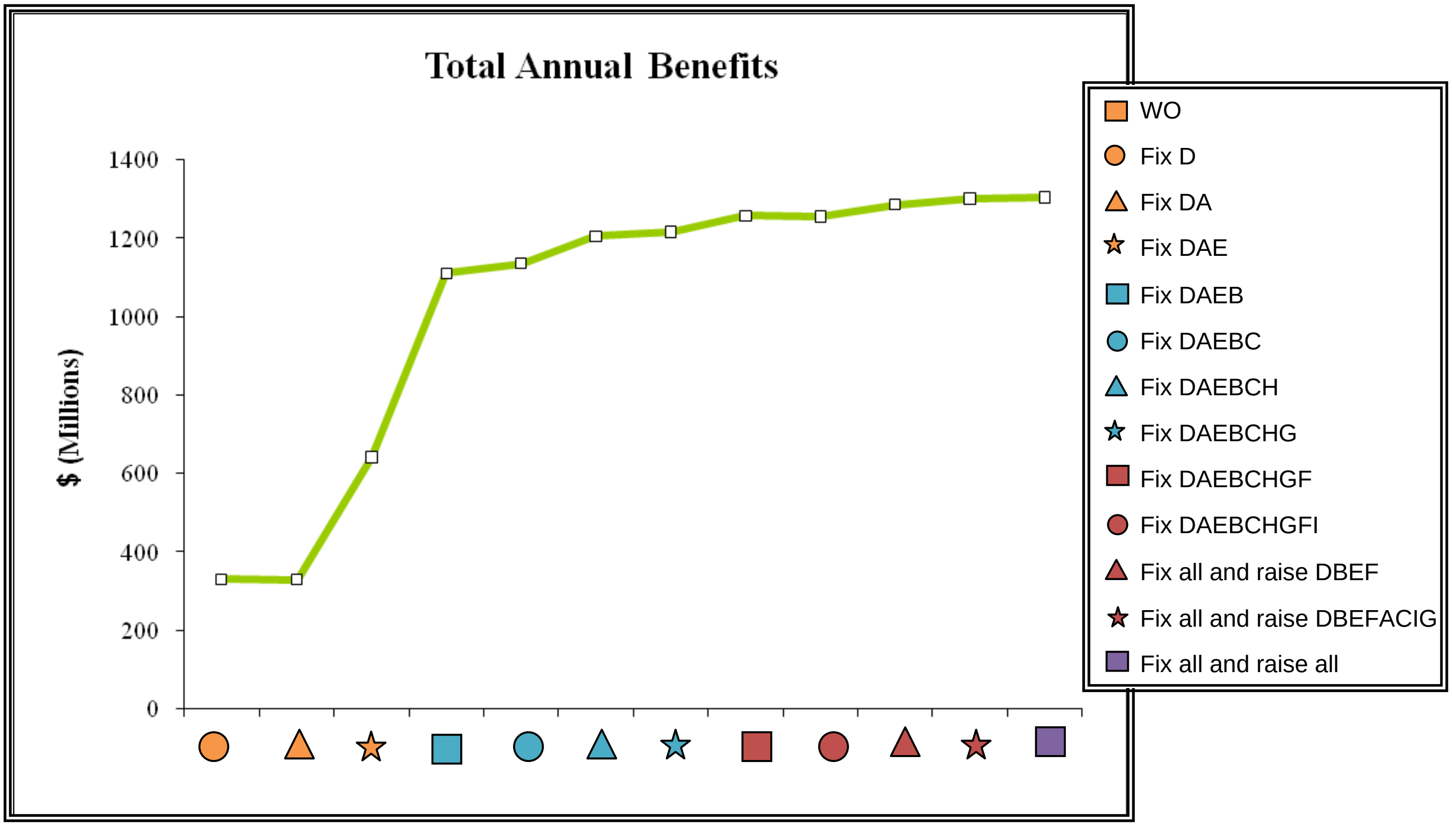
6.9 LEVEE REACH IMPROVEMENTS

Table 6-28 below shows the residual damages and benefits of each levee reach improvement. Figure 6-6 shows the graphical representation of Table 6-28. Total benefits increase with each improvement.

Table 6-259
With-Project Residual Damages and Benefits by Levee Reach Improvement
Damages/Benefits in $Millions and October 2010 Price Level

MEASURES	ALTERNATIVE TYPE	EXPECTED ANNUAL DAMAGES	RESIDUAL DAMAGES	DAMAGES REDUCED (BENEFITS)
Without-Project	Adjacent Levee	462	--	--
	Fix-in-Place			
Fix D	Adjacent Levee	--	341	121
	Fix-in-Place			
Fix D+A	Adjacent Levee	--	330	132
	Fix-in-Place			
Fix D+A+E	Adjacent Levee	--	299	163
	Fix-in-Place			
Fix D+A+E+B	Adjacent Levee	--	101	361
	Fix-in-Place			
Fix D+A+E+B+C	Adjacent Levee	--	60	402
	Fix-in-Place			
Fix D+A+E+B+C+H	Adjacent Levee	--	32	430
	Fix-in-Place			
Fix D+A+E+B+C+H+G	Adjacent Levee	--	24	438
	Fix-in-Place			
Fix D+A+E+B+C+H+G+F	Adjacent Levee	--	19	443
	Fix-in-Place			
Fix D+A+E+B+C+H+G+F+I	Adjacent Levee	--	19	443
	Fix-in-Place			
Fix All + Raise D,B,E,& F	Adjacent Levee	--	10	452
	Fix-in-Place			
Fix All + Raise D,B,E,F, A,C,I,& G	Adjacent Levee	--	8	454
	Fix-in-Place			
Fix All + Raise All	Adjacent Levee	--	2	460
	Fix-in-Place			

Figure 6-7 Total Annual Benefits by Levee Reach Improvement (in $Millions)



These levee reach improvements will be discussed further in Chapter 7, *Net Benefit and Benefit-to-Cost Analyses*. Preliminary costs for each method of fix and alternative type used in economic analysis will be presented. For each improvement and alternative type, average annual benefits will be compared to average annual costs.

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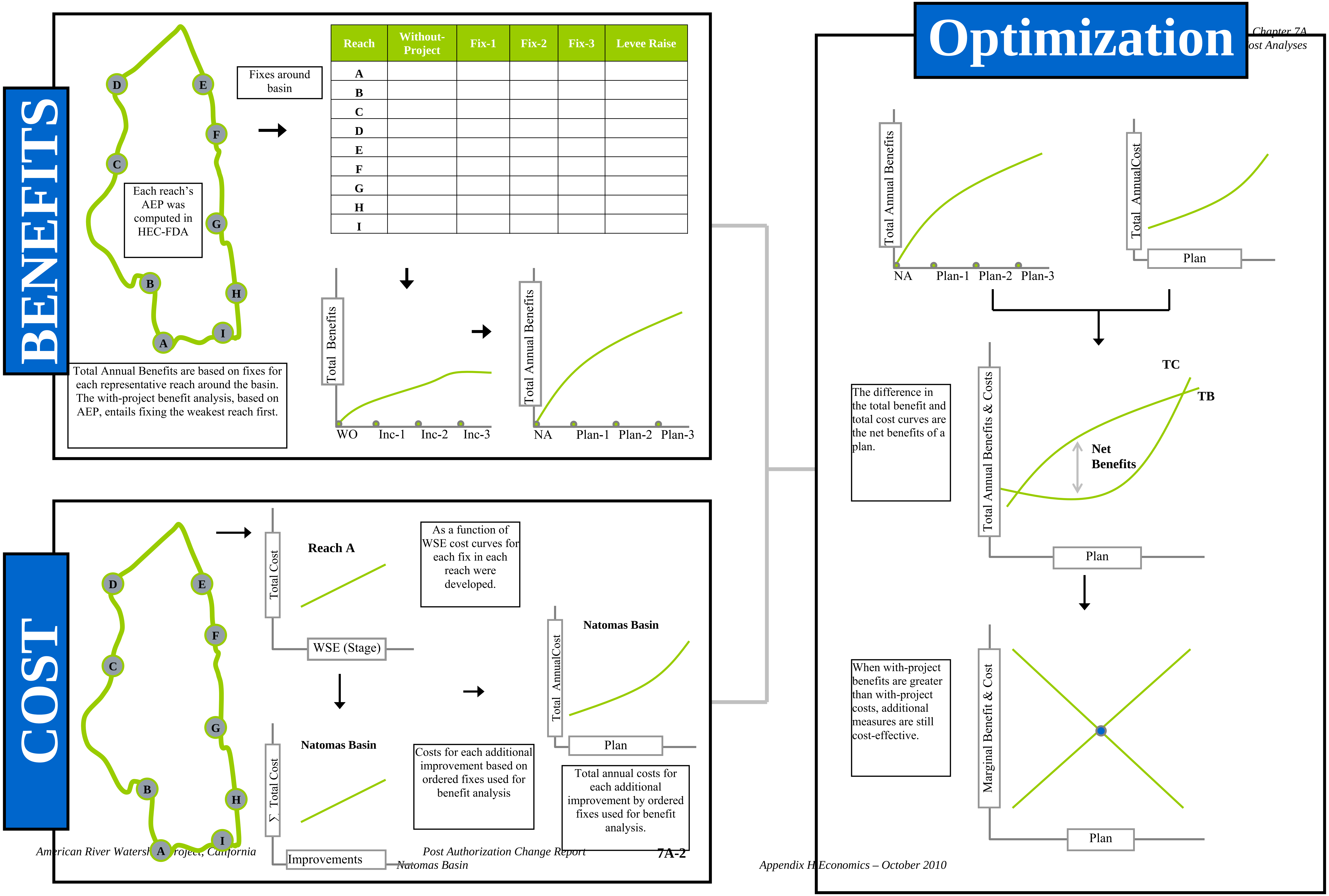
CHAPTER 7A
NET BENEFIT AND BENEFIT-TO-COST ANALYSES

This chapter presents the net benefit and benefit-to-cost analyses using the HEC-FDA results presented in Chapters 5 and 6 and screening-level cost estimates provided by the USACE SPK Cost Engineering Section. Again, it is important to note that the results presented here are NOT the results used as the basis for plan formulation. As was previously noted, an adjustment to without-project EAD and benefits was made and this adjustment process/analysis is presented in Chapter 7B. Accordingly, the net benefit and benefit-to-cost analyses have been revised to reflect the adjusted EAD and benefit values; cost estimates have not changed and so the estimates presented in this chapter are the same as those presented in Chapter 7B.

7.1 GENERAL DESCRIPTION OF NET BENEFIT AND BENEFIT-TO-COST ANALYSES

The benefits of each group (1 through 5) and alternative type (“fix-in-place” or “adjacent levee”) were compared to the costs of each group and alternative type. A conceptual diagram which shows the benefit and costs curves and graphically describes in general terms the with-project analysis approach is provided below in Figure 7-1.

Optimization



Reach	Without-Project	Fix-1	Fix-2	Fix-3	Levee Raise
A					
B					
C					
D					
E					
F					
G					
H					
I					

7.2 PROJECT COSTS

Tables 7-1 to 7-5 display the costs by reach, method of fix, and alternative type for each of the five groups. For each reach, the method of fix used in the with-project analysis is identified and its associated first costs, interest during construction (IDC), total investment costs, annualized costs, annual operation and maintenance costs (OMRR&R), and total average annual costs are displayed. Total average annual costs (shaded in green) of each alternative type/group were compared to the total average annual benefits of each alternative type/group. This comparison can be seen in both table and graphical formats in section 7.3.

Table 7A-1
Project Cost Summary (in $Millions, Oct 2010 Prices, 4.375% Interest Rate, 50-yr Period of Analysis)
Levee Reach Improvement: Fix NAT D

ALTERNATIVE	REACH	METHOD OF FIX	TOTAL FIRST COST	IDC	TOTAL INV COSTS	ANNUALIZED COST	ANNUAL OMRR&R	TOTAL AAC
Fix-in-Place	D	Cutoff Wall	36.68	1.56	38.24	1.90	0.06	1.96
	Total		**36.68**	**1.56**	**38.24**	**1.90**	**0.06**	**1.96**
Adjacent Levee	D	Cutoff Wall	36.68	1.56	38.24	1.90	0.06	1.96
	Total		**36.68**	**1.56**	**38.24**	**1.90**	**0.06**	**1.96**

Table 7A-2
Project Cost Summary (in $Millions, Oct 2010 Prices, 4.375% Interest Rate, 50-yr Period of Analysis)
Levee Reach Improvement: Fix NAT D, NAT A,

ALTERNATIVE	REACH	METHOD OF FIX	TOTAL FIRST COST	IDC	TOTAL INV COSTS	ANNUALIZED COST	ANNUAL OMRR&R	TOTAL AAC
Fix-in-Place	D	Cutoff Wall	36.68	1.56	38.24	1.90	0.06	1.96
	A	Cutoff Wall/Slope Flat.	107.30	20.05	127.35	6.31	0.32	6.63
	Total		**143.98**	**21.61**	**165.59**	**8.21**	**0.38**	**8.59**
Adjacent Levee	D	Cutoff Wall	36.68	1.56	38.24	1.90	0.06	1.96
	A	Cutoff Wall/Slope Flat.	102.87	19.22	122.09	6.05	0.30	6.35
	Total		**139.55**	**20.78**	**160.33**	**7.95**	**0.36**	**8.31**

Table 7A-3
Project Cost Summary (in $Millions, Oct 2010 Prices, 4.375% Interest Rate, 50-yr Period of Analysis)
Levee Reach Improvement: Fix NAT D, NAT A, NAT E

ALTERNATIVE	REACH	METHOD OF FIX	TOTAL FIRST COST	IDC	TOTAL INV COSTS	ANNUALIZED COST	ANNUAL OMRR&R	TOTAL AAC
Fix-in-Place	D	Cutoff Wall	36.68	1.56	38.24	1.90	0.06	1.96
	A	Cutoff Wall/Slope Flat.	107.30	20.05	127.35	6.31	0.32	6.63
	E	Cutoff Wall	50.79	14.88	65.67	3.26	0.10	3.36
	Total		**194.77**	**36.49**	**231.26**	**11.47**	**0.48**	**11.95**
Adjacent Levee	D	Cutoff Wall	36.68	1.56	38.24	1.90	0.06	1.96
	A	Cutoff Wall/Slope Flat.	102.87	19.22	122.09	6.05	0.30	6.35
	E	Cutoff Wall	44.87	15.68	60.55	3.00	0.15	3.15
	Total		**184.42**	**36.46**	**220.88**	**10.95**	**0.51**	**11.46**

Table 7A-4
Project Cost Summary (in $Millions, Oct 2010 Prices, 4.375% Interest Rate, 50-yr Period of Analysis)
Levee Reach Improvement: Fix NAT D, NAT A, NAT E, NAT B

ALTERNATIVE	REACH	METHOD OF FIX	TOTAL FIRST COST	IDC	TOTAL INV COSTS	ANNUALIZED COST	ANNUAL OMRR&R	TOTAL AAC
Fix-in-Place	D	Cutoff Wall	36.68	1.56	38.24	1.90	0.06	1.96
	A	Cutoff Wall/Slope Flat.	107.30	20.05	127.35	6.31	0.32	6.63
	E	Cutoff Wall	50.79	14.88	65.67	3.26	0.10	3.36
	B	Cutoff Wall	307.34	23.66	331.00	16.41	0.83	17.24
	Total		**502.11**	**60.15**	**562.26**	**27.88**	**1.31**	**29.19**
Adjacent Levee	D	Cutoff Wall	36.68	1.56	38.24	1.90	0.06	1.96
	A	Cutoff Wall/Slope Flat.	102.87	19.22	122.09	6.05	0.30	6.35
	E	Cutoff Wall	44.87	15.68	60.55	3.00	0.15	3.15
	B	Cutoff Wall	272.58	20.89	293.47	14.55	0.73	15.28
	Total		**457.00**	**57.35**	**514.35**	**25.50**	**1.24**	**26.74**

Table 7A-5
Project Cost Summary (in $Millions, Oct 2010 Prices, 4.375% Interest Rate, 50-yr Period of Analysis)
Levee Reach Improvement: Fix NAT D, NAT A, NAT E, NAT B, NAT C

ALTERNATIVE	REACH	METHOD OF FIX	TOTAL FIRST COST	IDC	TOTAL INV COSTS	ANNUALIZED COST	ANNUAL OMRR&R	TOTAL AAC
Fix-in-Place	D	Cutoff Wall	36.68	1.56	38.24	1.90	0.06	1.96
	A	Cutoff Wall/Slope Flat.	107.30	20.05	127.35	6.31	0.32	6.63
	E	Cutoff Wall	50.79	14.88	65.67	3.26	0.10	3.36
	B	Cutoff Wall	307.34	23.66	331.00	16.41	0.83	17.24
	C	Cutoff Wall	127.19	3.06	130.25	6.46	0.33	6.79
	Total		**629.30**	**63.21**	**692.51**	**34.33**	**1.64**	**35.97**
Adjacent Levee	D	Cutoff Wall	36.68	1.56	38.24	1.90	0.06	1.96
	A	Cutoff Wall/Slope Flat.	102.87	19.22	122.09	6.05	0.30	6.35
	E	Cutoff Wall	44.87	15.68	60.55	3.00	0.15	3.15
	B	Cutoff Wall	272.58	20.89	293.47	14.55	0.73	15.28
	C	Cutoff Wall	91.86	2.59	94.45	4.68	0.24	4.92
	Total		**548.86**	**59.94**	**608.80**	**30.18**	**1.48**	**31.66**

Table 7A-6
Project Cost Summary (in $Millions, Oct 2010 Prices, 4.375% Interest Rate, 50-yr Period of Analysis)
Levee Reach Improvement: Fix NAT D, NAT A, NAT E, NAT B, NAT C, NAT H

ALTERNATIVE	REACH	METHOD OF FIX	TOTAL FIRST COST	IDC	TOTAL INV COSTS	ANNUALIZED COST	ANNUAL OMRR&R	TOTAL AAC
Fix-in-Place	D	Cutoff Wall	36.68	1.56	38.24	1.90	0.06	1.96
	A	Cutoff Wall/Slope Flat.	107.30	20.05	127.35	6.31	0.32	6.63
	E	Cutoff Wall	50.79	14.88	65.67	3.26	0.10	3.36
	B	Cutoff Wall	307.34	23.66	331.00	16.41	0.83	17.24
	C	Cutoff Wall	127.19	3.06	130.25	6.46	0.33	6.79
	H	Cutoff Wall	64.94	12.13	77.07	3.82	0.11	3.93
	Total		**694.24**	**75.34**	**769.58**	**38.15**	**1.75**	**39.90**
Adjacent Levee	D	Cutoff Wall	36.68	1.56	38.24	1.90	0.06	1.96
	A	Cutoff Wall/Slope Flat.	102.87	19.22	122.09	6.05	0.30	6.35
	E	Cutoff Wall	44.87	15.68	60.55	3.00	0.15	3.15
	B	Cutoff Wall	272.58	20.89	293.47	14.55	0.73	15.28
	C	Cutoff Wall	91.86	2.59	94.45	4.68	0.24	4.92
	H	Cutoff Wall	64.94	12.13	77.07	3.82	0.11	3.93
	Total		**613.80**	**72.07**	**685.87**	**34.00**	**1.59**	**35.59**

Table 7A-7
Project Cost Summary (in $Millions, Oct 2010 Prices, 4.375% Interest Rate, 50-yr Period of Analysis)
Levee Reach Improvement: Fix NAT D, NAT A, NAT E, NAT B, NAT C, NAT H, NAT G

ALTERNATIVE	REACH	METHOD OF FIX	TOTAL FIRST COST	IDC	TOTAL INV COSTS	ANNUALIZED COST	ANNUAL OMRR&R	TOTAL AAC
Fix-in-Place	D	Cutoff Wall	36.68	1.56	38.24	1.90	0.06	1.96
	A	Cutoff Wall/Slope Flat.	107.30	20.05	127.35	6.31	0.32	6.63
	E	Cutoff Wall	50.79	14.88	65.67	3.26	0.10	3.36
	B	Cutoff Wall	307.34	23.66	331.00	16.41	0.83	17.24
	C	Cutoff Wall	127.19	3.06	130.25	6.46	0.33	6.79
	H	Cutoff Wall	64.94	12.13	77.07	3.82	0.11	3.93
	G	Cutoff Wall	39.72	9.48	49.20	2.44	0.07	2.51
	Total		**733.96**	**84.82**	**818.78**	**40.59**	**1.82**	**42.41**
Adjacent Levee	D	Cutoff Wall	36.68	1.56	38.24	1.90	0.06	1.96
	A	Cutoff Wall/Slope Flat.	102.87	19.22	122.09	6.05	0.30	6.35
	E	Cutoff Wall	44.87	15.68	60.55	3.00	0.15	3.15
	B	Cutoff Wall	272.58	20.89	293.47	14.55	0.73	15.28
	C	Cutoff Wall	91.86	2.59	94.45	4.68	0.24	4.92
	H	Cutoff Wall	64.94	12.13	77.07	3.82	0.11	3.93
	G	Cutoff Wall	32.93	9.65	42.58	2.11	0.11	2.22
	Total		**646.73**	**81.72**	**728.45**	**36.11**	**1.70**	**37.81**

Table 7A-8
Project Cost Summary (in $Millions, Oct 2010 Prices, 4.375% Interest Rate, 50-yr Period of Analysis)
Levee Reach Improvement: Fix NAT D, NAT A, NAT E, NAT B, NAT C, NAT H, NAT G, NAT F

ALTERNATIVE	REACH	METHOD OF FIX	TOTAL FIRST COST	IDC	TOTAL INV COSTS	ANNUALIZED COST	ANNUAL OMRR&R	TOTAL AAC
Fix-in-Place	D	Cutoff Wall	36.68	1.56	38.24	1.90	0.06	1.96
	A	Cutoff Wall/Slope Flat.	107.30	20.05	127.35	6.31	0.32	6.63
	E	Cutoff Wall	50.79	14.88	65.67	3.26	0.10	3.36
	B	Cutoff Wall	307.34	23.66	331.00	16.41	0.83	17.24
	C	Cutoff Wall	127.19	3.06	130.25	6.46	0.33	6.79
	H	Cutoff Wall	64.94	12.13	77.07	3.82	0.11	3.93
	G	Cutoff Wall	39.72	9.48	49.20	2.44	0.07	2.51
	F	Drained Seepage Berm	56.19	16.46	72.65	3.60	0.11	3.71
	Total		**790.15**	**101.28**	**891.43**	**44.19**	**1.93**	**46.12**
Adjacent Levee	D	Cutoff Wall	36.68	1.56	38.24	1.90	0.06	1.96
	A	Cutoff Wall/Slope Flat.	102.87	19.22	122.09	6.05	0.30	6.35
	E	Cutoff Wall	44.87	15.68	60.55	3.00	0.15	3.15
	B	Cutoff Wall	272.58	20.89	293.47	14.55	0.73	15.28
	C	Cutoff Wall	91.86	2.59	94.45	4.68	0.24	4.92
	H	Cutoff Wall	64.94	12.13	77.07	3.82	0.11	3.93
	G	Cutoff Wall	32.93	9.65	42.58	2.11	0.11	2.22
	F	Drained Seepage Berm	48.91	17.09	66.00	3.27	0.16	3.43
	Total		**695.64**	**98.81**	**794.45**	**39.39**	**1.86**	**41.25**

Table 7A-9
Project Cost Summary (in $Millions, Oct 2010 Prices, 4.375% Interest Rate, 50-yr Period of Analysis)
Levee Reach Improvement: Fix NAT D, NAT A, NAT E, NAT B, NAT C, NAT H, NAT G, NAT F, NAT I

ALTERNATIVE	REACH	METHOD OF FIX	TOTAL FIRST COST	IDC	TOTAL INV COSTS	ANNUALIZED COST	ANNUAL OMRR&R	TOTAL AAC
Fix-in-Place	D	Cutoff Wall	36.68	1.56	38.24	1.90	0.06	1.96
	A	Cutoff Wall/Slope Flat.	107.30	20.05	127.35	6.31	0.32	6.63
	E	Cutoff Wall	50.79	14.88	65.67	3.26	0.10	3.36
	B	Cutoff Wall	307.34	23.66	331.00	16.41	0.83	17.24
	C	Cutoff Wall	127.19	3.06	130.25	6.46	0.33	6.79
	H	Cutoff Wall	64.94	12.13	77.07	3.82	0.11	3.93
	G	Cutoff Wall	39.72	9.48	49.20	2.44	0.07	2.51
	F	Drained Seepage Berm	56.19	16.46	72.65	3.60	0.11	3.71
	I	Cutoff Wall	25.02	3.43	28.45	1.41	0.07	1.48
	Total		**815.17**	**104.71**	**919.88**	**45.61**	**2.00**	**47.61**
Adjacent Levee	D	Cutoff Wall	36.68	1.56	38.24	1.90	0.06	1.96
	A	Cutoff Wall/Slope Flat.	102.87	19.22	122.09	6.05	0.30	6.35
	E	Cutoff Wall	44.87	15.68	60.55	3.00	0.15	3.15
	B	Cutoff Wall	272.58	20.89	293.47	14.55	0.73	15.28
	C	Cutoff Wall	91.86	2.59	94.45	4.68	0.24	4.92
	H	Cutoff Wall	64.94	12.13	77.07	3.82	0.11	3.93
	G	Cutoff Wall	32.93	9.65	42.58	2.11	0.11	2.22
	F	Drained Seepage Berm	48.91	17.09	66.00	3.27	0.16	3.43
	I	Cutoff Wall	24.89	3.41	28.30	1.40	0.07	1.47
	Total		**720.53**	**102.22**	**822.75**	**40.79**	**1.93**	**42.72**

Table 7A-10
Project Cost Summary (in $Millions, Oct 2010 Prices, 4.375% Interest Rate, 50-yr Period of Analysis)
Levee Reach Improvement: Fix NAT D, NAT A, NAT E, NAT B, NAT C, NAT H, NAT G, NAT F, NAT I; raise NAT D, B, E, F

ALTERNATIVE	REACH	METHOD OF FIX	TOTAL FIRST COST	IDC	TOTAL INV COSTS	ANNUALIZED COST	ANNUAL OMRR&R	TOTAL AAC
Fix-in-Place	D	Cutoff Wall/raise	75.90	3.08	78.98	3.92	0.12	4.04
	A	Cutoff Wall/Slope Flat.	113.00	21.00	134.00	6.64	0.29	6.93
	E	Cutoff Wall/raise	55.81	16.35	72.16	3.58	0.11	3.69
	B	Cutoff Wall/raise	317.42	24.61	342.03	16.96	0.85	17.81
	C	Cutoff Wall	144.97	4.19	149.16	7.39	0.32	7.71
	H	Cutoff Wall	73.00	13.64	86.64	4.30	0.19	4.49
	G	Cutoff Wall	39.72	9.48	49.20	2.44	0.11	2.55
	F	Drained Seepage Berm/raise	59.11	17.32	76.43	3.79	0.11	3.90
	I	Cutoff Wall	26.44	3.62	30.06	1.49	0.07	1.56
	Total		**905.37**	**113.29**	**1018.66**	**50.50**	**2.17**	**52.67**
Adjacent Levee	D	Cutoff Wall/raise	75.90	3.08	78.98	3.92	0.12	4.04
	A	Cutoff Wall/Slope Flat.	107.33	20.05	127.38	6.32	0.28	6.60
	E	Cutoff Wall/raise	51.10	17.86	68.96	3.42	0.17	3.59
	B	Cutoff Wall/raise	295.25	22.67	317.92	15.76	0.78	16.54
	C	Cutoff Wall	99.28	3.08	102.36	5.07	0.23	5.30
	H	Cutoff Wall	73.00	13.64	86.64	4.30	0.19	4.49
	G	Cutoff Wall	32.93	7.86	40.79	2.02	0.09	2.11
	F	Drained Seepage Berm/raise	55.13	19.27	74.40	3.69	0.18	3.87
	I	Cutoff Wall	25.84	3.54	29.38	1.46	0.06	1.52
	Total		**815.76**	**111.05**	**926.81**	**45.95**	**2.10**	**48.05**

Table 7A-11
Project Cost Summary (in $Millions, Oct 2010 Prices, 4.375% Interest Rate, 50-yr Period of Analysis)
Levee Reach Improvement: Fix NAT D, NAT A, NAT E, NAT B, NAT C, NAT H, NAT G, NAT F, NAT I; raise NAT D, B, E, F, G, I, A, C

ALTERNATIVE	REACH	METHOD OF FIX	TOTAL FIRST COST	IDC	TOTAL INV COSTS	ANNUALIZED COST	ANNUAL OMRR&R	TOTAL AAC
Fix-in-Place	D	Cutoff Wall/raise	75.90	3.08	78.98	3.92	0.12	4.04
	A	Cutoff Wall/Slope Flat.	145.97	26.40	172.37	8.55	0.43	8.98
	E	Cutoff Wall/raise	61.99	18.16	80.15	3.97	0.12	4.09
	B	Cutoff Wall/raise	317.42	24.61	342.03	16.96	0.85	17.81
	C	Cutoff Wall	130.87	3.16	134.03	6.64	0.33	6.97
	H	Cutoff Wall	73.00	13.64	86.64	4.30	0.19	4.49
	G	Cutoff Wall	43.18	10.31	53.49	2.65	0.08	2.73
	F	Drained Seepage Berm/raise	59.11	17.32	76.43	3.79	0.11	3.90
	I	Cutoff Wall	27.14	3.72	30.86	1.53	0.08	1.61
	Total		**934.58**	**120.40**	**1054.98**	**52.30**	**2.31**	**54.61**
Adjacent Levee	D	Cutoff Wall/raise	75.90	3.08	78.98	3.92	0.12	4.04
	A	Cutoff Wall/Slope Flat.	135.41	24.43	159.84	7.92	0.40	8.32
	E	Cutoff Wall/raise	56.35	19.69	76.04	3.77	0.19	3.96
	B	Cutoff Wall/raise	295.25	22.67	317.92	15.76	0.78	16.54
	C	Cutoff Wall	97.99	2.78	100.77	5.00	0.25	5.25
	H	Cutoff Wall	73.00	13.64	86.64	4.30	0.19	4.49
	G	Cutoff Wall	38.20	11.19	49.39	2.45	0.12	2.57
	F	Drained Seepage Berm/raise	55.13	19.27	74.40	3.69	0.18	3.87
	I	Cutoff Wall	34.98	4.79	39.77	1.97	0.10	2.07
	Total		**862.21**	**121.54**	**983.75**	**48.77**	**2.33**	**51.10**

Table 7A-12
Project Cost Summary (in $Millions, Oct 2010 Prices, 4.375% Interest Rate, 50-yr Period of Analysis)
Levee Reach Improvement: Fix NAT D, NAT A, NAT E, NAT B, NAT C, NAT H, NAT G, NAT F, NAT I; raise all

ALTERNATIVE	REACH	METHOD OF FIX	TOTAL FIRST COST	IDC	TOTAL INV COSTS	ANNUALIZED COST	ANNUAL OMRR&R	TOTAL AAC
Fix-in-Place	D	Cutoff Wall/raise	75.90	3.08	78.98	3.92	0.12	4.04
	A	Cutoff Wall/Slope Flat.	113.00	21.00	134.00	6.64	0.29	6.93
	E	Cutoff Wall/raise	55.81	16.35	72.16	3.58	0.11	3.69
	B	Cutoff Wall/raise	317.42	24.61	342.03	16.96	0.85	17.81
	C	Cutoff Wall	144.97	4.19	149.16	7.39	0.32	7.71
	H	Cutoff Wall	165.68	30.95	196.63	9.75	0.15	9.90
	G	Cutoff Wall	39.72	9.48	49.20	2.44	0.11	2.55
	F	Drained Seepage Berm/raise	59.11	17.32	76.43	3.79	0.11	3.90
	I	Cutoff Wall	26.44	3.62	30.06	1.49	0.07	1.56
	Total		**998.05**	**130.60**	**1128.65**	**55.96**	**2.13**	**58.09**
Adjacent Levee	D	Cutoff Wall/raise	75.90	3.08	78.98	3.92	0.12	4.04
	A	Cutoff Wall/Slope Flat.	107.33	20.05	127.38	6.32	0.28	6.60
	E	Cutoff Wall/raise	51.10	17.86	68.96	3.42	0.17	3.59
	B	Cutoff Wall/raise	295.25	22.67	317.92	15.76	0.78	16.54
	C	Cutoff Wall	99.28	3.08	102.36	5.07	0.23	5.30
	H	Cutoff Wall	165.68	30.95	196.63	9.75	0.15	9.90
	G	Cutoff Wall	32.93	7.86	40.79	2.02	0.09	2.11
	F	Drained Seepage Berm/raise	55.13	19.27	74.40	3.69	0.18	3.87
	I	Cutoff Wall	25.84	3.54	29.38	1.46	0.06	1.52
	Total		**908.44**	**128.36**	**1036.80**	**51.40**	**2.06**	**53.46**

7.3 NET BENEFIT AND BENEFIT-TO-COST ANALYSES -- DETAILS

Net benefits determine the efficiency of a plan and are determined by subtracting annual costs from annual benefits. The group that maximizes net benefits is considered the most efficient from an NED perspective. The first costs for each Group displayed in the tables in section 7.2 are the summation of costs by individual reach improvements presented in Enclosure 6, *Project Costs Used for Preliminary Screening of Alternatives.*

Table 7-6[21] shows the comparison of costs and benefits by group and alternative type. As mentioned in previous sections, the benefits for each alternative type ("fix-in-place" and "adjacent levee") are the same as both types perform equally from a geotechnical point of view and so were represented by the same fragility curve (per method of fix); the costs of each alternative type differ, however. Benefits by group are differentiated primarily through scale, as each successive plan incorporates additional reach improvements, levee raises, or both.

[21] For the complete table of with-project "Net Benefit and Benefit-to-Cost Analysis" see Enclosure 2.

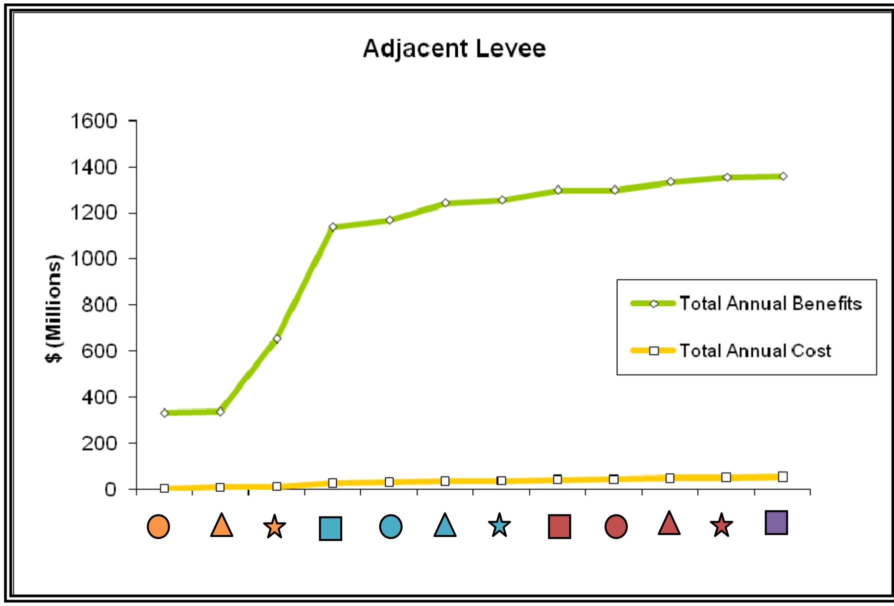
Table 7A-13
Net Benefit and Benefit-to-Cost Analysis
In $Millions, October 2010 Prices, 4.375% Interest Rate, 50-yr Period of Analysis

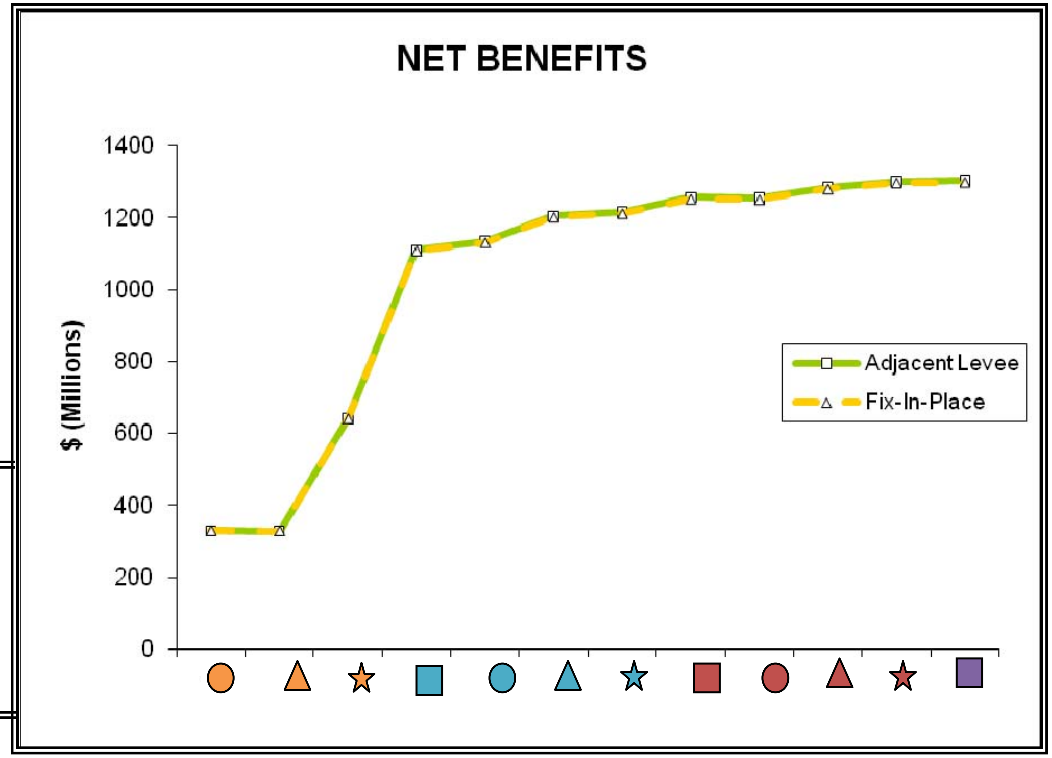
MEASURES	ALTERNATIVE TYPE	EXPECTED ANNUAL DAMAGES	ANNUAL BENEFITS	ANNUAL COST	NET BENEFITS	B/C RATIO
WITHOUT-PROJECT	-	1363	-	-	-	-
FIX D	Adjacent Levee	1031	332	2.0	330.0	169.4
	Fix-in-Place			2.0	330.0	169.4
FIX D, A	Adjacent Levee	1025	338	8.3	329.7	40.7
	Fix-in-Place			8.6	329.4	39.3
FIX D, A, E	Adjacent Levee	710	653	11.5	641.5	57.0
	Fix-in-Place			12.0	641.1	54.6
FIX D, A, E, B	Adjacent Levee	226	1137	26.7	1110.3	42.5
	Fix-in-Place			29.2	1107.8	39.0
FIX D, A, E, B, C	Adjacent Levee	196	1167	31.7	1135.3	36.9
	Fix-in-Place			36.0	1131.0	32.4
FIX D, A, E, B, C, H	Adjacent Levee	122	1241	35.6	1205.4	34.9
	Fix-in-Place			39.9	1201.1	31.1
FIX D, A, E, B, C, H, G	Adjacent Levee	109	1254	37.8	1216.2	33.2
	Fix-in-Place			42.4	1211.6	29.6
FIX D, A, E, B, C, H, G, F	Adjacent Levee	65	1298	41.3	1256.8	31.5
	Fix-in-Place			46.1	1251.9	28.1
FIX D, A, E, B, C, H, G, F, I	Adjacent Levee	65	1298	42.7	1255.3	30.4
	Fix-in-Place			47.6	1250.4	27.3
FIX ALL + RAISE D, B, E, F	Adjacent Levee	30	1333	48.1	1285.0	27.7
	Fix-in-Place			52.7	1280.3	25.3
FIX ALL + RAISE D, B, E-2, F, G, I, A, C	Adjacent Levee	11	1352	51.1	1300.9	26.5
	Fix-in-Place			54.6	1297.4	24.8
FIX ALL + RAISE ALL	Adjacent Levee	6	1357	53.5	1303.5	25.4
	Fix-in-Place			58.1	1298.9	23.4

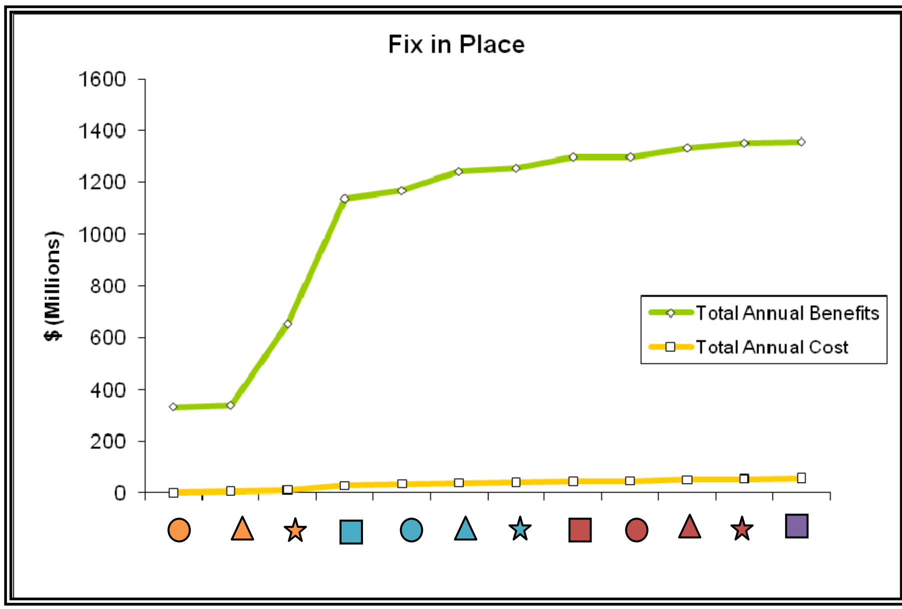
Figure 7-2 shows graphically the annual benefit, annual cost, and net benefit curves by group for the "adjacent levee" alternative type; Figure 7-3 shows graphically the annual benefit, annual cost, and net benefit curves by group for the "fix-in-place" alternative type; Figure 7-4 overlays the net benefit curves of each alternative type. It can be seen from Figure 7-4 that for all groups, the net benefits of the "adjacent levee" alternative are greater than the net benefits of the "fix-on-place" alternative. Figure 7-4 also shows that Groups 1 to 4 are on the 'rising limb' of the net benefit curve, while Group 5 is not.[22]

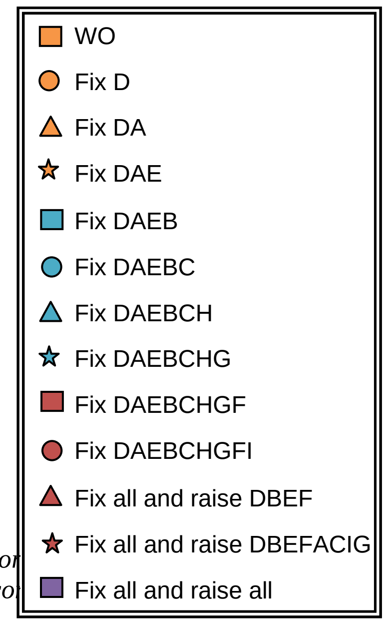
[22] The net benefit curves are comprised of five discrete points, which represent the five plans and their respective net benefits; the points were connected to visually show that net benefits increase with each successive plan up until Plan 5. The net benefit "curve" is not truly a continuous function.

Figure 7A-2, 7A-3, Figure 7A-4









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CHAPTER 7B
EAD AND BENEFITS ADJUSTMENTS CONSIDERING REBUILD PERIOD AND DECREASING INVENTORY STOCK

The adjusted EAD, benefits, and net benefit results documented in this chapter were computed using supporting information/data already presented in Chapters 5, 6 and 7A as well as by using an @Risk/MS Excel spreadsheet model. These results are considered the "final" results and override any other EAD/benefit/net benefit results presented previously in Chapters 5, 6, and 7A. The results presented in this chapter are the ones used as the basis for plan formulation, and are also what were presented in the Executive Summary of this Appendix.

7.1 BACKGROUND

This chapter documents the EAD and benefits adjustments that were performed using the without-project AEP and single-event damages results reported in Chapters 5 and 6 of this Economic Appendix. These adjustments are based on the acknowledgement that the without-project damages and with-project benefits as currently reported may be overstated for the Natomas Basin. This acknowledgement, in turn, is based on several factors:

- The current HEC-FDA modeling results, which are based on frequency analysis and not life cycle analysis over the 50-year period of analysis, show a high annual exceedance probability (AEP of .21) and high expected annual damages (EAD of approximately $1.4 billion)
- The Natomas Basin floodplain characteristics, including the population and structure inventory
- The basic economic methodological premise that individuals will behave rationally

Taken together, the salient points above indicate that given the extremely high risk in the Natomas Basin area in terms of frequency of flooding (1 in 5 chance of flooding in any given year)[23] and consequences of flooding ($7.0 billion in damages from a 100-year event from NAT

[23] Although not addressed here, one cause of the high calculations of EAD/AEP in HEC-FDA may be the conservative assumptions in regard to the geotechnical risk and uncertainty (GRU) curves. Following the March 2009 F3 Conference (milestone conference which establishes the without-project condition), Sacramento District's Engineering Division attempted to address Planning Division's concerns about the GRU curves; Engineering Division held an expert elicitation as well as provided input (adjusted GRU curve at NAT C) to account for flood fighting. A sensitivity analysis, which is documented in Enclosure 3, was performed by the Economics Section using the adjusted curves. For NAT C, AEP (and EAD) were reduced significantly using the adjusted GRU curve from the expert elicitation; there was only minimal change to AEP (and EAD) using the revised GRU curves adjusted to account for flood fighting. Since the F3 Conference, additional index points were evaluated in order to better facilitate the with-project analysis; many of these points (e.g., NAT D) are producing high AEP/EAD values.

D) coupled with the fact that the Natomas Basin contains close to 23,000 structures and nearly 80,000 residents, it is highly unlikely that people would continue to occupy the area after multiple floods, assuming they behave rationally. In order to fully consider that individuals act rationally, the damages and benefits adjustments took into account:

- A rebuild period following a flood event
- Rebuild scenarios in terms of how quickly the area would be redeveloped
- A decrease in structure inventory stock following a flood event
- A limit on the number of flood events allowed to occur; once this limit was reached, the assumption was made that floodplain occupants would choose to not live in the Natomas Basin

It is important to note that this analysis was performed using the information documented in Chapters 5 and 6 of this Appendix. Specifically, AEP data and single-event damage data reported in Chapter 5 and the order of fixes used in the with-project analysis as outlined in Chapter 6 were taken and incorporated into this analysis using a newly-developed @Risk spreadsheet model; costs reported in Chapter 7A and used for the net benefit and BCR analyses are the same ones used for the Chapter 7B adjustment analysis.

The @Risk model developed specifically for this study was created to account for rational human behavior, which is the basic economic methodological premise in most economic studies. Rational human behavior, in the case of flooding in the Natomas Basin, was captured within the model in the form of a rebuild period, rebuild scenarios, loss of inventory stock, and a limit to the number of flood events that would occur before the Natomas Basin would be abandoned and people would decide not to live there. One drawback of HEC-FDA is that it is frequency-based, and its computational framework is not set-up to account for these factors related to human behavior; the Natomas @Risk model was set-up to be able to account for human behavior through the use of Monte Carlo simulation and life-cycle analysis.

7.2 PURPOSE OF EAD AND BENEFITS ADJUSTMENTS

The main purpose of this analysis is to adjust the EAD and benefit numbers obtained from the HEC-FDA modeling to account for human behavior by making assumptions about post-flood event rebuild periods, rebuild scenarios, floodplain inventory stock, and a reasonable assumption of the number of floods allowed to occur over the 50-year period of analysis before the Basin would be abandoned. Initially, these adjustments were not intended to replace the results obtained from the HEC-FDA modeling as presented in Chapters 5, 6, and 7a of this Economic Appendix. However, comments received during the Agency Technical Review (ATR) from the technical reviewer (USACE Los Angeles District, SPL) as well as from policy reviewers (USACE Headquarters and USACE SPD) , it was determined that these adjustments should actually be the basis for plan formulation and not just serve as a supplement to the HEC-FDA results. In addition, the PDT believes that the approach to use the @Risk model to make EAD

At this time, it is believed that Engineering Division has followed their process in terms of developing GRU curves and has at least considered Planning Division's concerns about the curves. The issue of high AEP/EAD values, then, has been addressed by the SPK Planning Division through this EAD/benefit adjustment.

and benefits adjustments described in this chapter was a necessary step in light of the fact that there is currently no other Corps-approved economic model that can do this type of analysis and also because there is no approved way to account for this EAD and benefits overestimation.

7.3 ASSUMPTIONS

Several assumptions were made in order to perform the analysis. These assumptions are also indicated in Figure 7B-1, which shows a graphical snapshot of the @Risk model. Figure 7B-1 will be referred to in this section as well as in sections 7.4, 7.5, and 7.6 to explain the EAD and benefits adjustment calculation process and to point out significant details related to the model. For example, the major assumptions used in the model are:

- After a flood event, the floodplain inventory stock would only be replaced by not more than 80% of the damaged property; this assumption captures the idea that not all floodplain occupants would choose to rebuild and live in the Natomas Basin after a flood event – some occupants would choose to leave the area.
- A rebuild period of three (3) years (Figure 7B-1, point 1). Rebuilding would take place over a 3-year period immediately following the flood event. The process of reducing the inventory stock to 80% of damaged property and rebuilding over a 3-year period would start all over with the next flood event
- Four (4) rebuild scenarios were delineated (Figure 7B-1, point 2), and range from a "slow" rebuild to an "aggressive" rebuild. For example, in the "slow" rebuild scenario (see Figure 7B-1), it was assumed that 20% of those properties damaged would be rebuilt in each of the 3 years of rebuilding.
- There is a limit of three (3) flood events that would be allowed to occur in the Basin at which point people would decide not to rebuild and live in the Basin; once this limit was reached, the model assumes that the Natomas community would abandon the region.

7.4 DESRIPTION OF @RISK MODEL: INPUT DATA AND APPLICATION WITHIN MODEL

The @Risk/MS Excel spreadsheet simulation model uses Monte Carlo techniques to derive outputs (e.g., in this case the outputs are EAD and benefits) based on key input variables that have uncertainty parameters attached to them; the uncertainty of key variables are described in the @Risk model through the assignment of probability distributions.

The Natomas @Risk model was developed to address the unique flooding situation in the Natomas Basin – high probability of flooding as well as high consequences (damages) if flooding were to occur – in order to account for rational human behavior. The model is set-up to calculate event damages over a 50-year period of analysis by:

- randomly selecting whether or not a flood event occurs in each year of the 50-year period of analysis; AEP information obtained from the initial HEC-FDA modeling is used as a basis to determine the likelihood of a flood event occurring in any given year
- incorporating a 3-year rebuild period following a flood event and sampling from four different rebuild scenarios to determine how much of the floodplain is rebuilt

- calculating event damages for up to 3 flood events over the 50-year period of analysis for each iteration of the @Risk simulation
- calculating EAD/benefits

The sections below describe the @Risk model developed specifically for the adjustment of Natomas EAD and benefits. The data used in the model and the application of this data within the model are explained in more detail in the subsections below[24]. The discussion below references Figure 7B-1.

7.4.1 HEC-FDA Computed Stage-Damage Curves

The damages from the stage-damage curves computed by HEC-FDA (Chapter 5, initial modeling) were used to populate the frequency-damage table (point A) in Figure 7B-1. For each impact area (Major and Minor) and for each levee reach improvement, the stages associated with each frequency event (2-year to 500-year) were pulled from the engineering frequency-stage curves also taken from the HEC-FDA analysis; the corresponding damages and uncertainty in damages (standard deviation of damages) at each frequency event stage were then pulled from the stage-damage curves computed by HEC-FDA.

For each frequency event, the damage and standard deviation of damage data pulled from the stage-damage curves in HEC-FDA were then used to calculate in @Risk minimum and maximum damage values; a normal probability distribution was used to describe the uncertainty in damages for this @Risk run. The minimum and maximum values obtained from this run were then used as input into the cumulative probability distribution function used to compute event damages (section 7.4.3). Additionally, damage and standard deviation of damage data pulled from the stage-damage curves in HEC-FDA were used to calculate coefficient of variation (COV) information; COVs were also used as input into the cumulative probability distribution functions (section 7.4.3).

7.4.2 Annual Exceedance Probability (AEP) and Randomly Generated Flood Events

Annual Exceedance Probability (AEP) data reported in Chapters 5 as well as in the with-project analysis documented in Chapter 6 were also used as input into the Natomas @Risk model. The AEP was applied within the @Risk model as the basis for determining whether a flood event resulting in levee failure would occur in any given year over the 50-year period of analysis. For example, in Figure 7B-1 (without-project for the Major area), an AEP of .21 was entered. This AEP corresponds to the AEP obtained at NAT D, which was used as the without-project baseline for the Major impact area in the with-project analysis documented in Chapter 6. The @Risk model is set-up to randomly generate numbers between zero and 1 for each year of the period of analysis; a randomly generated number that was lower than .21 triggered a levee failure and a number greater than or equal to .21 did not trigger a levee failure. In other words, for the without-project and for this impact area, there was 21% chance that a flood event resulting in levee failure would occur in any given year throughout the 50-year period of analysis.

[24] Additional information regarding the Natomas @Risk model can also be found in Enclosure 7 (@Risk Model Approval Documentation) to this Appendix.

7.4.3 @Risk-Computed Event Damages & Cumulative Probability Distribution

In the @Risk model, when a flood event occurs event damages for that specific event are calculated. Event damages are calculated with uncertainty using a cumulative probability distribution function. As is displayed in Figure 7B-1 (point B), event damages for the first flood event in this example and for this iteration of the simulation is $4,217 billion. The formula used to calculate event damages is also shown at point B. In this example, minimum and maximum values were set at $4.211 billion and $5.53 billion, respectively. The cumulative probability distribution function was formed by setting the damage value at each respective frequency event shown in the frequency-damage table (point A) to a corresponding probability based on the actual event frequencies. For example, the first damage point on the cumulative probability distribution function is $4.357 billion, which is taken directly from the frequency-damage table; the corresponding probability for this damage is .5, which says that, should a flood event occur, a damage value of $4.357 billion or lower will occur 50% of the time. The last damage point on the curve is $5.33 billion, which says that, should a flood event occur, a damage value of $5.33 billion or lower will occur 100% of the time[25].

Finally, a COV was entered as part of the formula used to calculate event damages. This COV was based on the HEC-FDA computed stage-damage curves with uncertainty (as described in section 7.4.1). Within the @Risk model, once event damages were calculated for the first flood event (and through using a cumulative probability distribution function as described previously), the uncertainty associated with these event damages were described by setting it to a normal distribution having a standard deviation equal to plus/minus the previously-computed COV. Incorporating the COV into the event damages specifically addresses the requirement of incorporating uncertainty in the first floor elevation of structures, uncertainty in structure and content values, and uncertainty in structure and content depth-damage percentages since the damage values and COVs used here were based on the HEC-FDA computed stage-damage curves with uncertainty, which already have these uncertainties factored in.

7.4.4 @Risk-Computed Expected Annual Damages (EAD)

The @Risk model computes EAD by discounting event damages of each flood event to the present year, summing the discounted values, and then amortizing this value over the 50-year period of analysis. In each @Risk simulation, thousands of iterations are completed, each resulting in a different EAD value; the final EAD value reported in the @Risk output results table is the average of all EAD values across all iterations.

In the example shown in Figure 7B-1, the first flood event occurs in year 3 of the period of analysis and produces damages of $4.217 billion. As can be seen in the table marked by point D, after the first year of rebuild the inventory stock is only restored to the remaining value after the flood event ($6.918 billion minus $4.217 billion = $2.701 billion) plus the amount of rebuilding (15% of damaged property, or $4.217 billion multiplied by .15 = $634 billion) assumed to occur for that year, in this case it’s $3.334 billion ($2.701 billion + $633 billion). In the second year, an additional 30% of the damaged property is rebuilt to get a value of $4.599 billion; in the third

[25] In actuality, the probability associated with the last damage point would be .998; however, 1.0 was used in order to be able to satisfy the @Risk software requirement of having a probability of 1.0 (100%) designated as the last point on the cumulative probability distribution function.

year an additional 15% of the damaged property is rebuilt to get a value of $5.231 billion. This value is then carried forward as the baseline total value of damageable property for the next flood event.

Point D also shows that after the third flood event (in this example this flood event occurs in year 25), no other flood event is allowed to occur within the 50-year period of analysis. This effectively prevents any other damages to be incurred and caps the calculation of EAD to three flood events. After this third event, it is assumed that people would abandon the Natomas Basin.

Expected Annual Damages	Net Present Value	Total Value of Damageable Property	Event Damage	Percent Loss	Annual Exceedance Probability	Discount Rate	Reconstruction Scenarios
$277.08	$5,588.85	$6,918	$4,217	61%	0.21	4.375%	2

B

=(RiskCumul(4211,5530,{4357,5026,5129,5227,5281,5312,5330},{0.5,0.9,0.96,0.98,0.99,0.995,1}))*RiskNormal(1,N7)

D

Year	Event Occurrence	Beginning Prop. Damage	Damages	Post Event Value	EOY Value
0	0	6,918	$ -	6,918	6,918
1	0	6,918	$ -	6,918	6,918
2	0	6,918	$ -	6,918	6,918
3	1	6,918	$ 4,217	2,701	3,334
4	0	3,334	$ -	3,334	4,599
5	0	4,599	$ -	4,599	5,231
6	0	5,231	$ -	5,231	5,231
7	0	5,231	$ -	5,231	5,231
8	0	5,231	$ -	5,231	5,231
9	0	5,231	$ -	5,231	5,231
10	0	5,231	$ -	5,231	5,231
11	0	5,231	$ -	5,231	5,231
12	0	5,231	$ -	5,231	5,231
13	0	5,231	$ -	5,231	5,231
14	0	5,231	$ -	5,231	5,231
15	0	5,231	$ -	5,231	5,231
16	0	5,231	$ -	5,231	5,231
17	0	5,231	$ -	5,231	5,231
18	0	5,231	$ -	5,231	5,231
19	0	5,231	$ -	5,231	5,231
20	0	5,231	$ -	5,231	5,231
21	1	5,231	$ 3,189	2,042	2,521
22	0	2,521	$ -	2,521	3,477
23	0	3,477	$ -	3,477	3,956
24	0	3,956	$ -	3,956	3,956
25	1	3,956	$ 2,411	1,544	1,906
26	0	1,906	$ -	1,906	2,630
27	0	2,630	$ -	2,630	2,991
28	0	2,991	$ -	2,991	2,991
29	0	2,991	$ -	2,991	2,991
30	0	2,991	$ -	2,991	2,991
31	0	2,991	$ -	2,991	2,991
32	0	2,991	$ -	2,991	2,991
33	0	2,991	$ -	2,991	2,991
34	0	2,991	$ -	2,991	2,991
35	0	2,991	$ -	2,991	2,991
36	0	2,991	$ -	2,991	2,991
37	0	2,991	$ -	2,991	2,991

COV
1.40%

2

R.Scenario	Year I	Year II	Year III
1	20%	20%	20%
2	15%	30%	15%
3	30%	20%	10%
4	45%	10%	5%

1

1st-Year	15%
2nd-Year	30%
3rd-Year	15%

A

Inc.	Stage-Damage Relationship @ Frequency						
	2-yr	10-yr	25-yr	50-yr	100-yr	200-yr	500-yr
0	4357	5026	5129	5227			
1							
2	2381	3590	4814	5061			
3							
4							
5			1184		5281	5312	
6							5330
7				4086			
8							
9							
10							
11							
12							

C

Inc.	Cumulative Probability Distribution						
	2-yr	10-yr	25-yr	50-yr	100-yr	200-yr	500-yr
	0.5	0.1	0.04	0.02	0.01	0.005	0.002
0	0.500	0.900	0.960	0.980			
1							
2	0.500	0.900	0.960	0.980			
3							
4					0.990		
5			0.960			0.995	
6							1.000
7				0.980			
8							
9							
10							
11							
12							

Index Point	
D	
B	E
C	H

FIGURE 7B-1
Diagram of Natomas EAD Adjustment Model

Damage values are in millions of dollars.

7.5 WITH-PROJECT ANALYSIS & RESULTS USING THE @RISK MODEL

It is important to note that the process described in Section 6.4 above applies to each levee reach improvementof the analysis (from the without-project condition to the final levee reach improvement). A separate worksheet within the @Risk model was created in order to compute without-project EAD (without-project) and with-project residual EAD (Levee Reach Improvements 1 to 12). Additionally, the process also applies to each impact area (Major and Minor) – a separate @Risk model was run for each area.

Table 7B-1 below shows the results of each levee reach improvement analyzed for the Major and Minor impact areas. This is similar to Table 6-23 in Chapter 6 – the levee reach improvements replicate those outlined in Chapter 6, but the adjusted EAD and benefit values derived from the @Risk model are displayed in Table 7B-1. Cost estimates displayed in Tables 7B-2 and 7B-3 are those previously presented in Chapter 7A; a more detailed breakdown of screening-level cost estimates for each of the twelve levee reach improvements can be found in Tables 7A-1 to 7A-12 in Chapter 7A.

The with-project analysis results obtained from the Natomas @Risk model indicate that 26% of the damages are reduced by just fixing reach NAT D (first levee reach improvement); that 93% of the damages are reduced by fixing up to NAT H (sixth levee reach improvement); and that most of the damages are reduced with any type of raises. For each levee reach improvement, the percent of damages reduced results obtained from using the @Risk model follow closely with those obtained from the with-project analysis using the HEC-FDA results (Chapter 6); the major difference is the absolute value of those damages reduced. Table 7B-3 shows a comparison of the HEC-FDA results and the @Risk results. As is displayed in this table, without-project EAD is reduced by 66% (two-thirds), or from $1.363 billion to $462 million.

Table 7B-2 below shows the net benefit analysis for both the fix-in-place and adjacent levee alternatives. It should be noted that the costs used for this analysis are the same ones used in Chapter 7A as the costs, unlike the benefits, have not been adjusted. Table 7B-2 indicates that net benefits continue to rise for all levee reach improvements just like in the HEC-FDA analysis; however, the net benefits do begin to level off starting from the levee reach improvement of NAT H, and the difference in net benefits between the sixth and twelth levee reach improvement are relatively minimal (as compared to the difference in net benefits between the without-project and the sixth levee reach improvement). As in the case with the with-project analysis using HEC-FDA, there are no additiona benefits with fixing NAT I until raises in other reaches occur.

Figures 7B-1, 7B-2, and 7B-3 show in graphical form the total annual benefits, total annual costs, and net benefits for each alternative type displayed in Table 7B-2. The adjacent levee alternative, as previously determined in the HEC-FDA analysis, is still the alternative that is the most efficient (greater net benefits and least costs), albeit the difference between the adjacent levee alternative and fix-in-place alternative is very minimal, as is demonstrated by their almost-identical net benefit curves in Figure 7B-3.

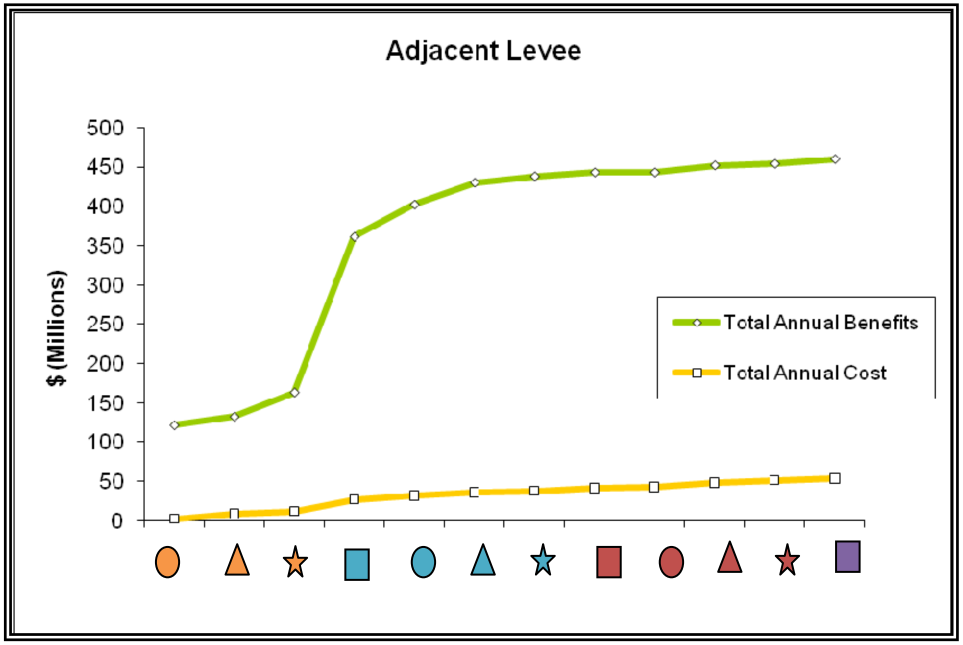
Table 7B-1
Natomas @Risk Model – With-Project Analysis Results
Major and Minor Impact Areas
AEP, EAD, and Annual Benefits, in $Millions and Oct 2010 Price Level

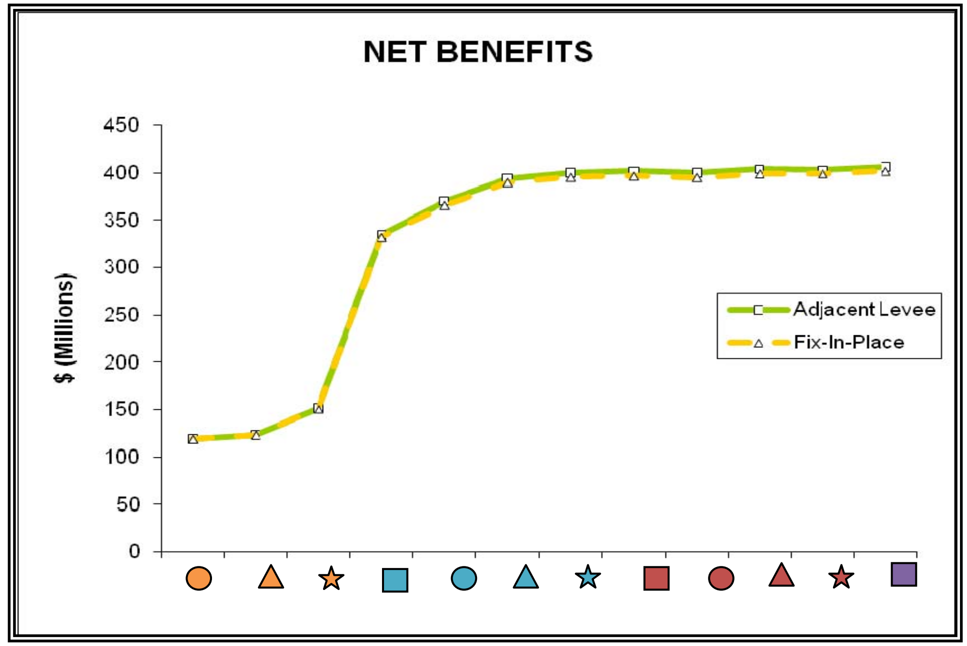
MEASURE	EAD			AEP		ANN BEN	% DAM REDUCED
	Major	Minor	Total	Major	Minor		
Without	346	116	462	.21	.30	--	--
Fix D	239	102	341	.21	.30	121	26%
Fix D+A	228	102	330	.18	.30	132	29%
Fix D+A+E	197	102	299	.12	.30	163	35%
Fix D+A+E+B	84	17	101	.04	.30	361	78%
Fix D+A+E+B+C	45	15	60	.04	.30	402	87%
Fix D+A+E+B+C+H	18	14	32	.015	.30	430	93%
Fix D+A+E+B+C+H+G	18	6	24	.015	.30	438	95%
Fix D+A+E+B+C+H+G+F	18	1	19	.015	.023	443	96%
Fix D+A+E+B+C+H+G+F+I	18	1	19	.015	.023	443	96%
Fix all and raise D, B, E, and F	9	1	10	.008	.006	452	98%
Fix all and raise D, B, E, F, A, C, I, G	7	1	8	.006	.004	454	98%
Fix all and raise all	1	1	2	.001	.002	460	99%

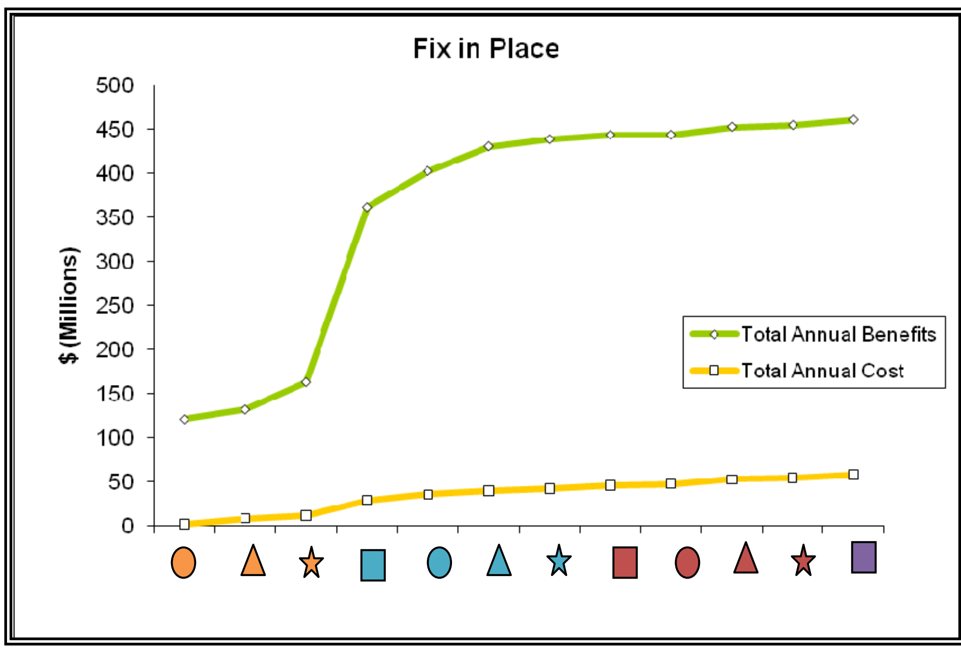
Table 7B-2
Natomas @Risk Model -- Net Benefit and Benefit-to-Cost Analyses
In $Millions, October 2010 Prices, 4.375% Interest Rate, 50-yr Period of Analysis

GROUPS	ALTERNATIVE TYPE	EXPECTED ANNUAL DAMAGES	ANNUAL BENEFITS	ANNUAL COST	NET BENEFITS	B/C RATIO
WITHOUT-PROJECT	-	462	-	-	-	-
FIX D	Adjacent Levee	341	121	2.0	119	61.7
	Fix-in-Place			2.0	119	61.7
FIX D, A	Adjacent Levee	330	132	8.3	124	15.9
	Fix-in-Place			8.6	123	15.4
FIX D, A, E	Adjacent Levee	299	163	11.5	152	14.2
	Fix-in-Place			12.0	151	13.6
FIX D, A, E, B	Adjacent Levee	101	361	26.7	334	13.5
	Fix-in-Place			29.2	332	12.4
FIX D, A, E, B, C	Adjacent Levee	60	402	31.7	370	12.7
	Fix-in-Place			36.0	366	11.2
FIX D, A, E, B, C, H	Adjacent Levee	32	430	35.6	394	12.1
	Fix-in-Place			39.9	390	10.8
FIX D, A, E, B, C, H, G	Adjacent Levee	24	438	37.8	400	11.6
	Fix-in-Place			42.4	396	10.3
FIX D, A, E, B, C, H, G, F	Adjacent Levee	19	443	41.3	402	10.7
	Fix-in-Place			46.1	397	9.6
FIX D, A, E, B, C, H, G, F, I	Adjacent Levee	19	443	42.7	400	10.4
	Fix-in-Place			47.6	395	9.3
FIX ALL + RAISE D, B, E, F	Adjacent Levee	10	452	48.1	404	9.4
	Fix-in-Place			52.7	399	8.6
FIX ALL + RAISE D, B, E-2, F, G, I, A, C	Adjacent Levee	8	454	51.1	403	8.9
	Fix-in-Place			54.6	399	8.3
FIX ALL + RAISE ALL	Adjacent Levee	2	460	53.5	407	8.6
	Fix-in-Place			58.1	402	7.9

Figures 7B-2, 7B-3, and 7B-4







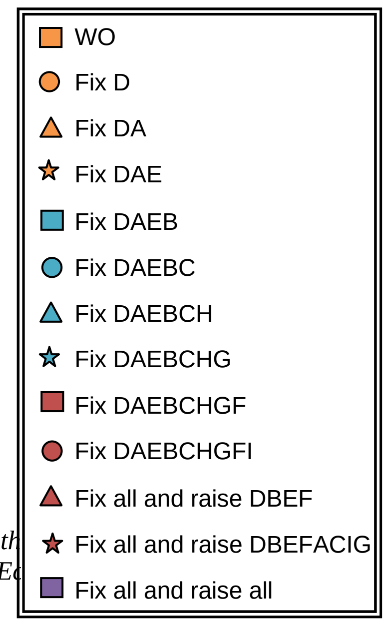


Table 7B-3
Natomas @Risk Model -- Net Benefit and Benefit-to-Cost Analyses (In $Millions and Oct 2010 Price Level)

Measures	Alternative	Expected Annual Damages		Benefits		Annual Cost	Net Benefits	
		HEC-FDA	@RISK RUNS	HEC-FDA	@RISK RUNS		HEC-FDA	@RISK RUNS
Without-Project	Adjacent Levee	1363	462	--	--	--	--	--
	Fix-in-Place					--	--	--
Fix D	Adjacent Levee	1031	341	332	121	2	330	119
	Fix-in-Place					2	330	119
Fix D+A	Adjacent Levee	1025	330	338	132	8	330	124
	Fix-in-Place					9	329	123
Fix D+A+E	Adjacent Levee	710	299	653	163	11	642	152
	Fix-in-Place					12	641	151
Fix D+A+E+B	Adjacent Levee	226	101	1137	361	27	1110	334
	Fix-in-Place					29	1108	332
Fix D+A+E+B+C	Adjacent Levee	196	60	1167	402	32	1135	370
	Fix-in-Place					36	1131	366
Fix D+A+E+B+C+H	Adjacent Levee	122	32	1241	430	36	1205	394
	Fix-in-Place					40	1201	390
Fix D+A+E+B+C+H+G	Adjacent Levee	109	24	1254	438	38	1216	400
	Fix-in-Place					42	1212	396
Fix D+A+E+B+C+H+G+F	Adjacent Levee	65	19	1298	443	41	1257	402
	Fix-in-Place					46	1252	397
Fix D+A+E+B+C+H+G+F+I	Adjacent Levee	65	19	1298	443	43	1255	400
	Fix-in-Place					48	1250	395
Fix All + Raise D,B,E,& F	Adjacent Levee	30	10	1333	452	48	1285	404
	Fix-in-Place					53	1280	399
Fix All + Raise D,B,E,F, A,C,I,& G	Adjacent Levee	11	8	1352	454	51	1301	403
	Fix-in-Place					55	1297	399
Fix All + Raise All	Adjacent Levee	6	2	1357	460	53	1304	407
	Fix-in-Place					58	1299	402

7.6 CONCLUSION

As displayed in Table 7B-3, without-project EAD is reduced from $1.363 billion to approximately $462 million. The table also shows a comparison of the benefits and net benefits for each levee reach improvement and for both the adjacent levee and fix-in-place alternatives. Based on the set of assumptions explained in the previous sections, the results of this analysis using the @Risk model indicate that even with the adjustments to EAD and benefits, the plan formulation, from a net benefits perspective, remains the same. Net benefits continue to increase until the last improvements (fix and raise all).

The Natomas Basin is considered a "closed" ring levee system, whereby flood protection is only as good as its weakest link. Table 7B-4 is a condensed version of Table 7B-3. Table 7B-4 displays the risk remaining after improvements to groups of specific reaches. The purpose of the table is to highlight the notion that the Natomas Basin is a "closed" ring levee system as well as to show the reduction in risk with each levee reach improvement in terms of the chance of flooding and consequences of flooding.

Table 7B-4
Residual Risk and Unit of Measurement
October 2010 Price Level

Unit of Measurement	Improvement	Expected Annual Damages (EAD) In $Millions	Residual Damages In $Millions	Annual Exceedance Probability (AEP)
N/A	No fixes	462	--	.21
3 of 9 reaches	Fix D, A, E	--	299	.12
6 of 9 reaches	Fix D, A, E, B, C, H	--	32	.015
COMPLETE SYSTEM	Fix All Reaches	--	19	.015
COMPLETE SYSTEM	Fix all and raise some	--	10	.008
COMPLETE SYSTEM	Fix all and raise some	--	8	.006
COMPLETE SYSTEM	Fix all and raise all	--	2	.001

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CHAPTER 8
RESIDUAL RISK ASSOCIATED WITH FUTURE DEVELOPMENT

Development within the Natomas Basin is projected to increase significantly over the next several decades. Development projections for the Natomas Basin have been estimated by the Sacramento Area Council of Governments (SACOG), which is an association of local governments in the Sacramento region. SACOG is comprised of six counties (El Dorado, Placer, Sacramento, Sutter, Yolo, and Yuba) and 22 cities, and provides transportation planning and funding for the region. Additional information about SACOG and data regarding its future development projections used for this analysis can be found on its website, www.sacog.org.

Once the level of flood protection within the Natomas Basin is increased and the current building moratorium is lifted, an increase in residual risk is expected as the Natomas Basin is developed over the next several decades. This residual risk, described in terms of the additional population at risk, the additional value of property at risk, and the additional structure and content damages incurred from a single flood event, is estimated based on SACOG's projection of the number of additional residential units for the year 2035.

In its analysis, SACOG uses geographical units called traffic analysis zones (TAZ) to aggregate the number of residential units forecasted to be built in the future in a particular TAZ. Using simplifying assumptions, the Sacramento District's Economics & Risk Analysis Section then adjusted SACOG's estimates of additional residential units to derive an estimate of the number of additional residential structures. For example, a single SFR unit was converted to a single SFR structure by dividing by one; an MFR (2-4 units as designated by SACOG) was converted to number of structures by dividing the number of units by four; and an MFR (5+ units as designated by SACOG) was converted to number of structures by dividing by 150.

Table 8-1 lists the TAZs considered for this analysis in order to assess residual risk due to future development in the Natomas Basin. The table displays the TAZ, SACOG's estimate of the number of additional units per residential type (SFR, MFR) for the year 2035, and USACE's estimate of the number of additional structures by residential type for the year 2035. It is estimated that more than 16,000 additional residential structures will be built within the Natomas Basin by the year 2035.

Table 8-1
Natomas Basin
Estimate of Additional Residential Structures Associated with Future Development

TRAFFIC ANALYSIS ZONE (TAZ)	SACOG ESTIMATE OF ADDITIONAL RESIDENTIAL UNITS (2035)			USACE ESTIMATE OF ADDITIONAL RESIDENTIAL STRUCTURES (2035) BASED ON SACOG'S UNIT PROJECTIONS		
	SFR	MFR (2-4 units)	MFR (5+ units)	SFR	MFR (2-4 units)	MFR (5+ units)
247	50	9	267	50	2	2
248	72	18	533	72	5	4
249	43	4	3	43	1	0
251	5	1	58	5	0	0
252	37	7	299	31	2	2
258	389	153	512	389	38	3
259	1,085	453	826	1,085	113	6
264	176	22	73	176	5	0
265	778	28	142	778	7	1
266	354	84	70	354	21	0
267	120	2	1	120	0	0
270	17	0	0	17	0	0
271	1,505	0	0	1,505	0	0
278	1,639	0	0	1,639	0	0
279	1,775	117	444	1,775	29	3
280	460	30	115	460	8	1
283	13	0	0	13	0	0
284	166	96	88	166	24	1
287	1,184	83	318	1,184	21	2
1104	264	110	492	264	28	3
1105	87	117	523	87	29	3
1237	35	25	21	35	6	0
1320	410	263	221	410	66	1
1323	810	247	832	810	62	6
1324	68	44	147	68	11	1
1403	495	263	330	495	66	2
1404	564	37	141	564	9	1
1431	3,209	125	834	3,209	31	6
TOTAL	**15,803**	**2,338**	**7,290**	**15,803**	**584**	**47**

Figure 8-1 shows the traffic analysis zones (TAZ) within the Natomas Basin developed by the Sacramento Area Council of Governments (SACOG).

Figure 8-1 SACOG TAZs used to estimate future development

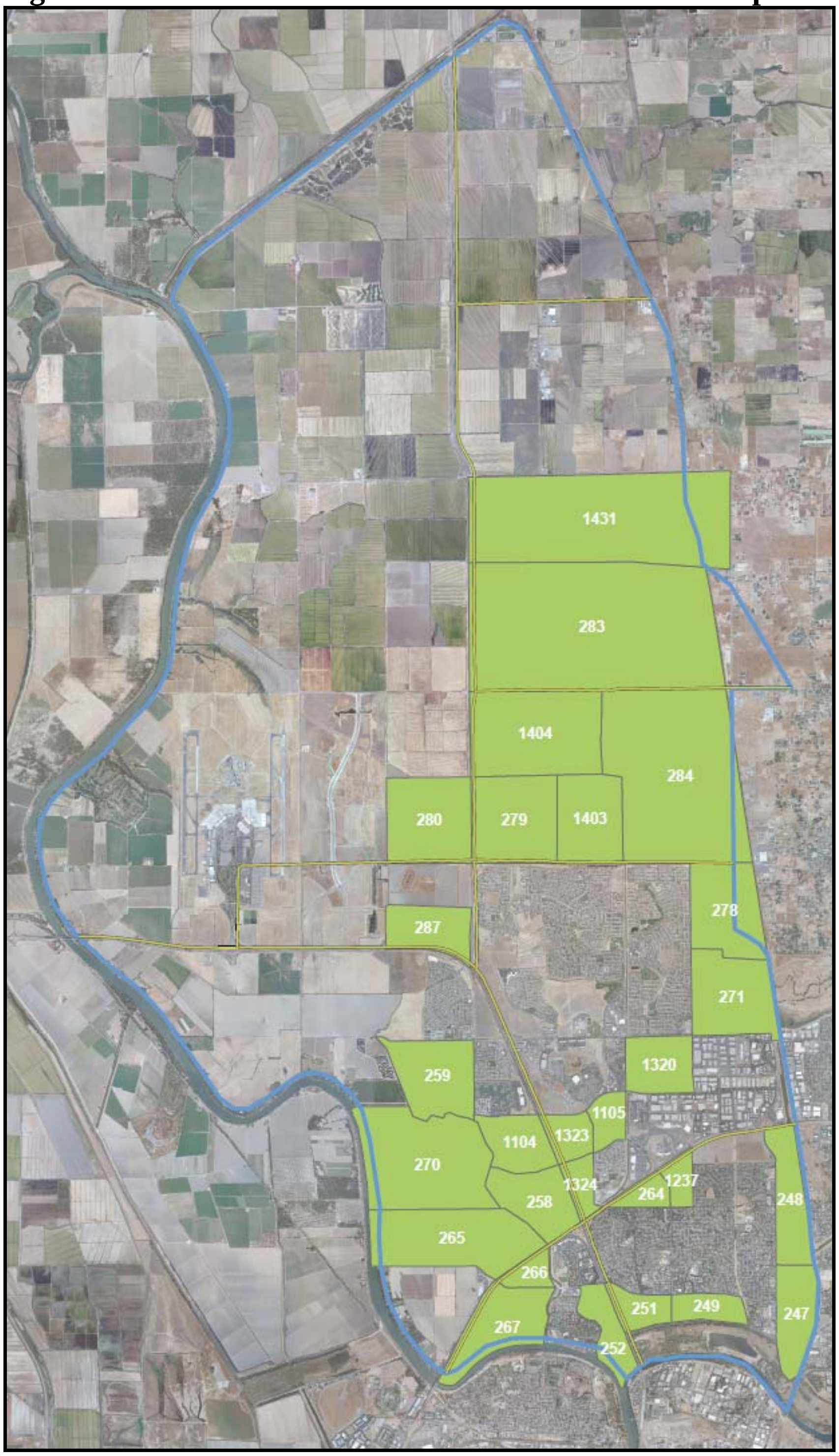

Table 8-2 below describes the residual risk associated with future development in the Natomas Basin for several project alternatives. The increase in the number of people at risk was calculated by multiplying the average number of people per residential unit in the Sacramento area obtained from the U.S. Census Bureau to the number of additional residential units projected for the Natomas Basin in the year 2035.

The increase in the value of damageable property at risk and potential flooding damages from specific frequency events were estimated using the following methodology. Each additional future structure was assigned to an existing structure by geographic location (TAZ). All of the characteristics (structure value, foundation height, etc.) associated with this existing structure were given to the future structure by using the same structure ID (assessor parcel number, APN) in HEC-FDA. Finally, each future structure was assigned to the same grid cell number (and in effect the same depths of flooding for each frequency event) as its associated existing structure, allowing for the computation of flood damages for the future structure within HEC-FDA. In all cases, more than one future structure was tied to an existing structure.

Table 8-2
Increased Residual Risk Associated with Future Development in the Natomas Basin
Population at Risk, Property at Risk, Single-Event Damages

MEASURE	INCREASE IN NUMBER OF PEOPLE AT RISK	INCREASE IN VALUE OF PROPERTY AT RISK (OCT. 2010, $MIL)	INCREASE IN FLOOD DAMAGES (PER FREQUENCY EVENT) OCT. 2010, $MILLIONS		
			100yr	200yr	500yr
Fix All + Raise D,B,E,& F	42,238	5,841	0	3,310	3,312
Fix All + Raise D,B,E,F, A,C,I,& G	42,238	5,841	0	871	3,312
Fix All + Raise All	42,238	5,841	0	871	3,312

Improving the levees in the Natomas Basin and providing flood protection sufficient enough to satisfy FEMA requirements and thereby lifting the current building moratorium would most likely result in further development in the Basin per the General Plans of the local governments. Table 8-2 displays an estimate of the increase risk by group associated with future development within the Basin should specific flood events occur. Future development would likely occur if the 90% conditional non-exceedance probability (CNP) of the 1% chance event is met. Based on the current HEC-FDA performance statistics results, this CNP requirement would be met with levee raises.

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CHAPTER 9
FUTURE ECONOMIC ANALYSES

9.1 NATIONAL ECONOMIC DEVELOPMENT (NED) CATEGORIES

This NPACR economic analysis included only the main NED categories for which the majority of damages and benefits usually can be attributed to in a typical USACE FRM economic evaluation[26]. After careful and deliberate consideration of the ambitious schedule outlined for this NPACR, it was determined that the most prudent way forward was to focus the economic analysis on the major damage and benefit categories.

It is recognized, however, that in order to paint a complete picture of the flooding problem in the Natomas Basin, the economic analyses should consider additional NED damage and benefit categories. Many of these analyses, in fact, are already underway. The intent is to include these additional categories in upcoming American River Common Features studies (e.g., GRR). Some of the categories that will be included are described briefly in the following sub-sections.

9.1.1 Emergency Costs

In March of 2009 an expert-opinion elicitation panel comprised of professionals having significant relevant experience in the field of emergency response was convened in Sacramento, California. The main purpose of this expert-opinion elicitation was to develop estimates of economic costs associated with 18 damage categories not usually quantified in USACE FRM studies. These damage categories are listed in Table 9-1 below.

[26] Estimates based on other Division studies that did include other additional categories suggest that the major damage and benefit categories (structures and contents) can comprise between 80 to 95 percent of all damages and benefits.

Table 9-1
Emergency Costs and Relief Categories

GROUP ONE: EVACUATION ACTIVITIES	EVACUATION
	Subsistence
	Reoccupation
GROUP TWO: DEBRIS REMOVAL AND CLEAN-UP	Debris Activities
GROUP THREE: PUBLIC SERVICES PATRONIZED	Education
	Public Agencies
	Library and Indoor Recreation Facilities
	Medical
GROUP FOUR: PUBLIC SERVICE PRODUCED	Police
	Incarceration
	Fire
	Legislative
	Judicial
GROUP FIVE: PUBLIC UTILITIES	Telecommunications
	Electricity
	Gas
	Water Utility
	Wastewater Treatment/Sewer

A final draft report entitled, *Emergency Cost and Relief Methodology and Concept Paper*, was completed in January of 2010. This paper lays out in detail the expert-opinion elicitation process as it occurred in March of 2009, the damage categories considered, the general methodology used to evaluate emergency costs and relief associated with flooding, the specific methodologies used to determine flood-related emergency costs associated with each loss/damage category, and the results of the analysis.

The next steps will be to use the results obtained from the expert-opinion elicitation to quantify additional NED losses/damages and benefits by category (as appropriate), with the intention to inform decision makers, through plan formulation and a more comprehensive economic analysis, as to what is the plan that maximizes net benefits from a federal perspective (i.e., the NED plan). Currently, work is being completed to format the result data in order to be able to apply it within the confines of the HEC-FDA economic model framework. This work entails developing category-specific depth-percent damage curves that can be imported directly into HEC-FDA.

9.1.2 Traffic Disruption Costs

Traffic-related costs associated with detours and extra time traveled experienced by motorists due to potential flooding in the Natomas Basin will also be evaluated in upcoming economic analysis under the GRR.

9.1.3 Agricultural Damages

Future economic analysis will consider agricultural losses within the Natomas Basin impact area, which does have measurable, but relatively insignificant, agricultural production. Major crop types grown within the Basin include rice and tomatoes. Each of these crop types is grown during the year (April to October) when flooding is least likely to occur. However, there is the potential for other agricultural-related losses, such as those related to land clean-up and restoration, should flooding occur.

9.1.4 Airline-Associated Delay Losses/Rail Freight Delay Losses

Losses associated with airline rerouting and delays and rail freight rerouting and delays within the Natomas Basin impact area will also be estimated and be incorporated into future economic analyses. It is expected that the data obtained from these analyses will be applied within the HEC-FDA model to compute EAD.

9.2 REGIONAL ECONOMIC DEVELOPMENT (RED) ANALYSIS

Regional economic development (RED) analysis will be conducted as part of the GRR and will include the Natomas Basin impact area as well as the other main Basins (American River North and American River South) within the American River Common Features study area. The RED analysis will evaluate income and employment effects within the study area from implementation of either the NED plan or Locally-Preferred Plan (LPP).

The RED analysis will quantify the impacts each alternative has on the local economy by using a regional economic impact model based on the principles of Input-Output (I-O) analysis. The direct, indirect, and induced economic effects of the NED and LPP plans will be evaluated using standard metrics often used in I-O analysis, including industry output, value added, and employment. More details about RED analysis in general and the RED analysis specifically conducted for the American River Common Features project will be provided in the upcoming GRR.

9.3 OTHER SOCIAL EFFECTS (OSE) ANALYSIS

The Other Social Effects (OSE) account describes the potential effects proposed project alternatives would have on social aspects not explicitly addressed by the NED and RED accounts, such as community impacts (e.g., growth and cohesion), public health and safety impacts, displacement (of populations, businesses, agriculture, recreation, etc.) impacts, and the potential loss of life. The OSE analysis will be completed as part of the upcoming GRR.

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CHAPTER 10
REFERENCES

1. Economic Reevaluation Report, American River Watershed Project, CA, Folsom Dam Modification and Folsom Dam Raise Projects. U.S. Army Corps of Engineers, Sacramento District, February 2008.
2. General Reevaluation Report, American River Watershed Common Features Project, Economic Appendix. U.S. Army Corps of Engineers, Sacramento District, January 2009.
3. American River Watershed Common Features Project, Natomas Post-Authorization Change, Draft Hydraulic Appendix. U.S. Army Corps of Engineers, Sacramento District, January 2010.

American River Watershed Project

Post-Authorization Change Report

American River Watershed

Common Features Project
Natomas Basin
Sacramento and Sutter Counties, California

SAFCA
Sacramento Area Flood Control Agency

CENTRAL VALLEY FLOOD PROTECTION BOARD
PUBLIC SAFETY AND FLOOD MANAGEMENT
STATE OF CALIFORNIA

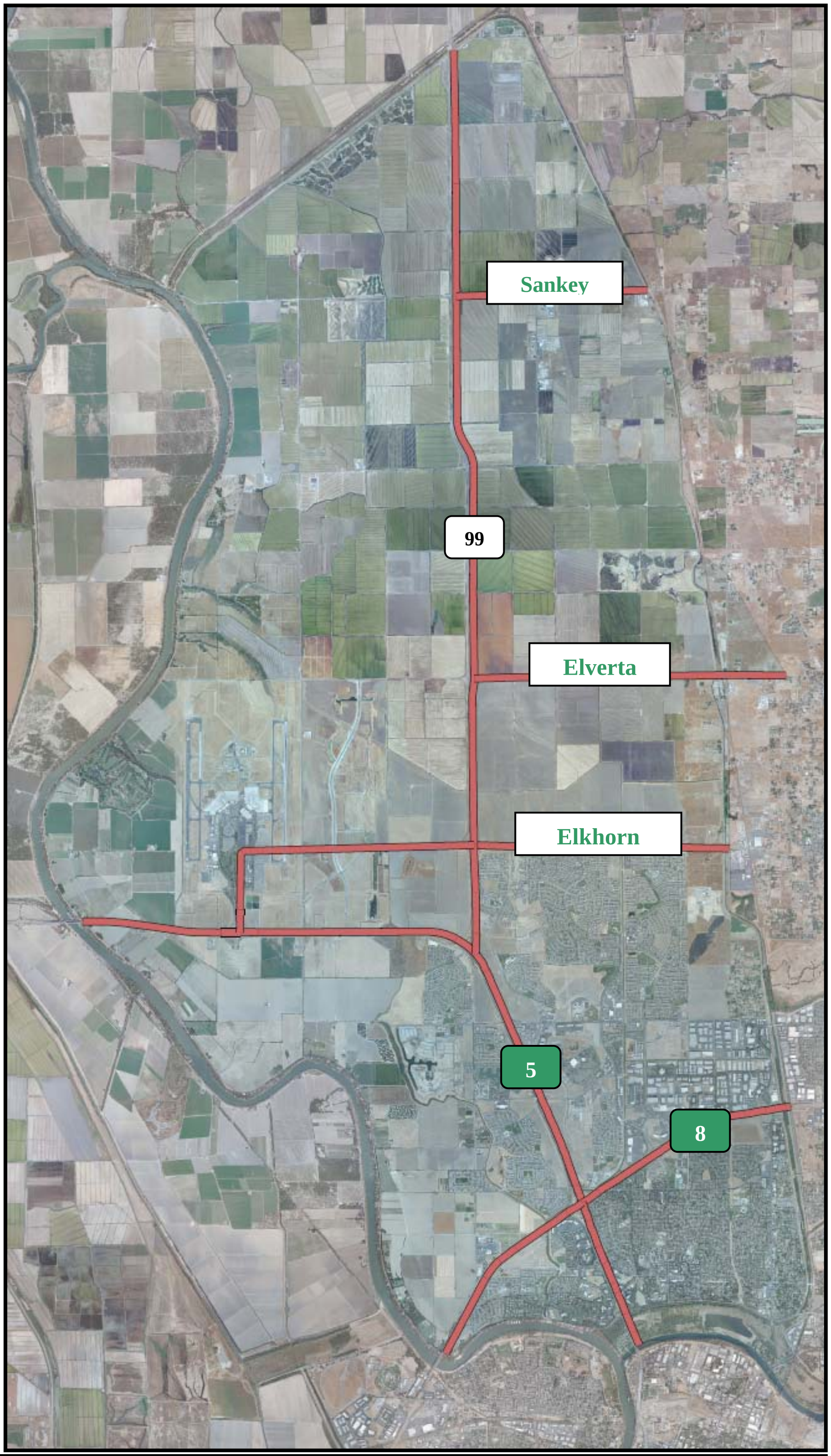
US Army Corps of Engineers®
Sacramento District

ENCLOSURES TO APPENDIX H

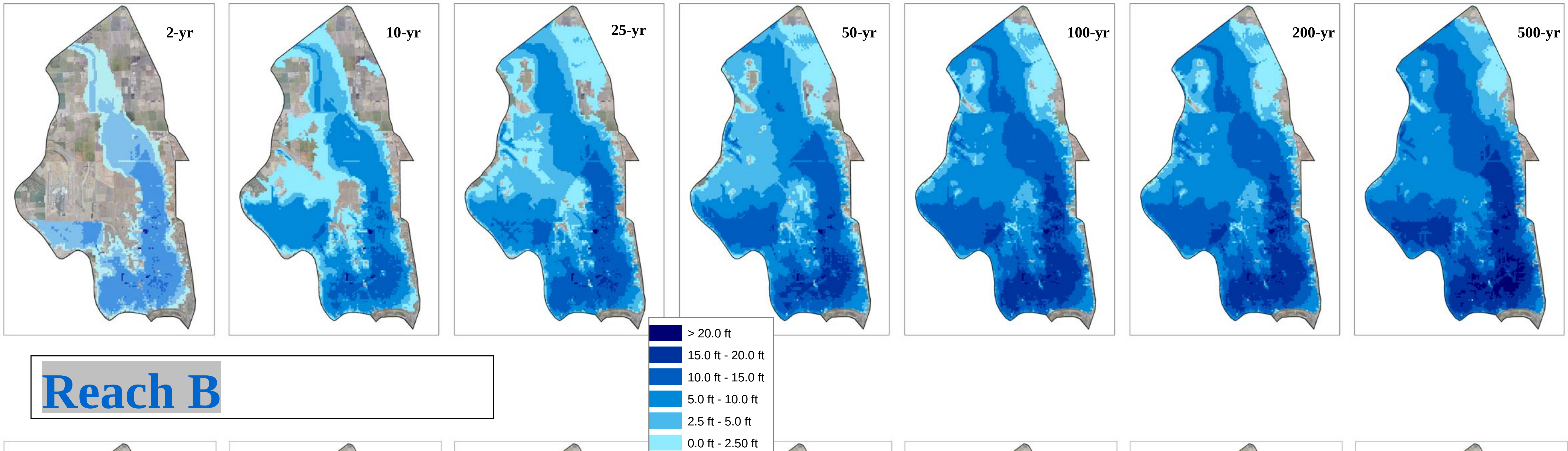
October 2010

ENCLOSURE 1

FLOODPLAIN PLATES



Reach A



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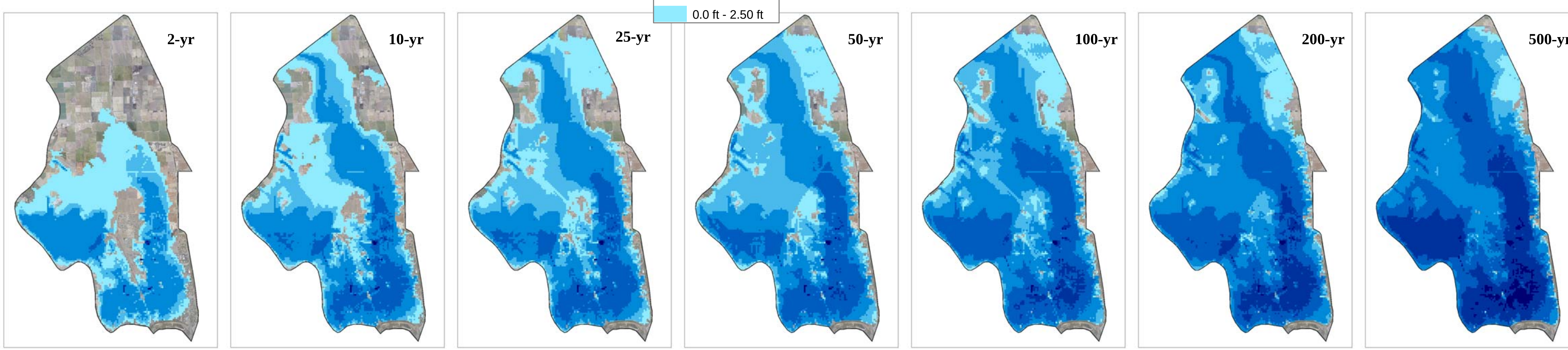

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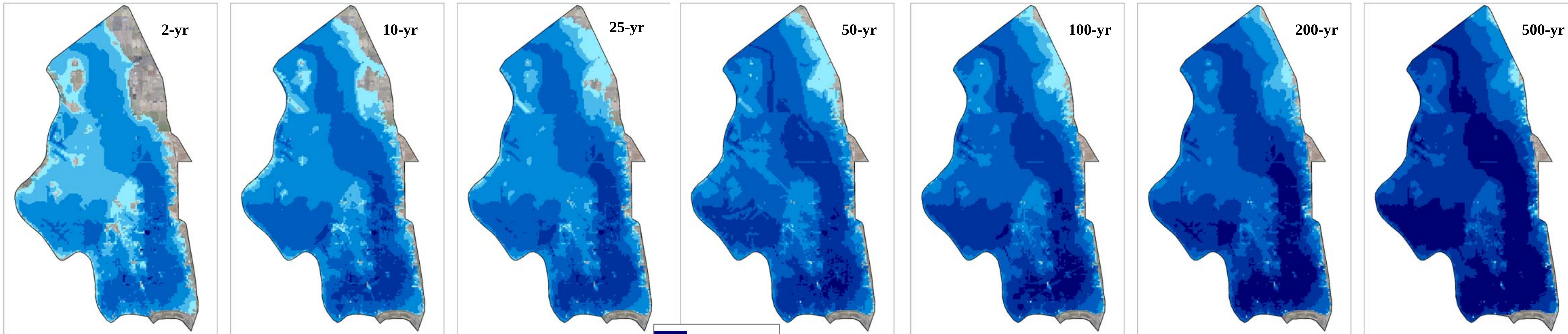

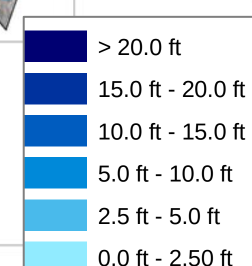

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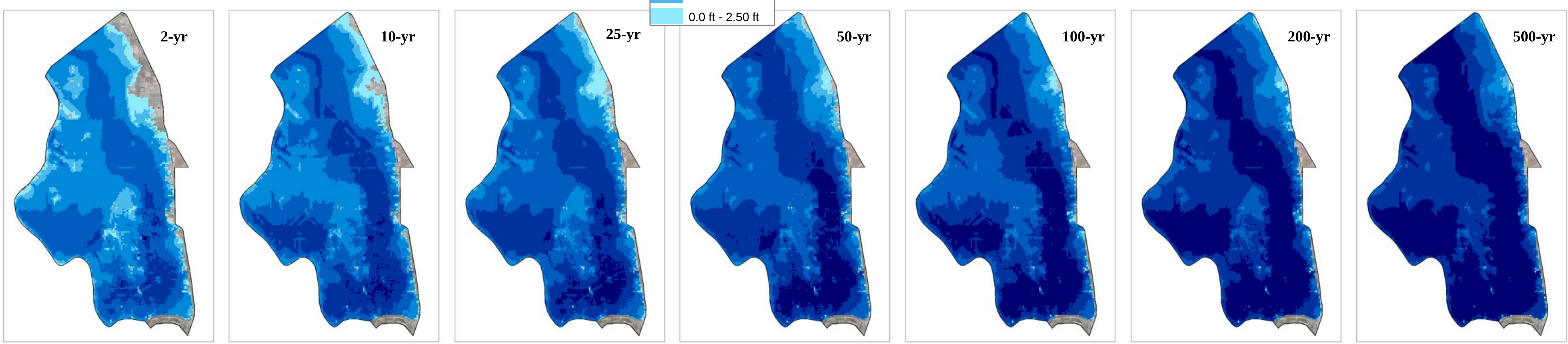

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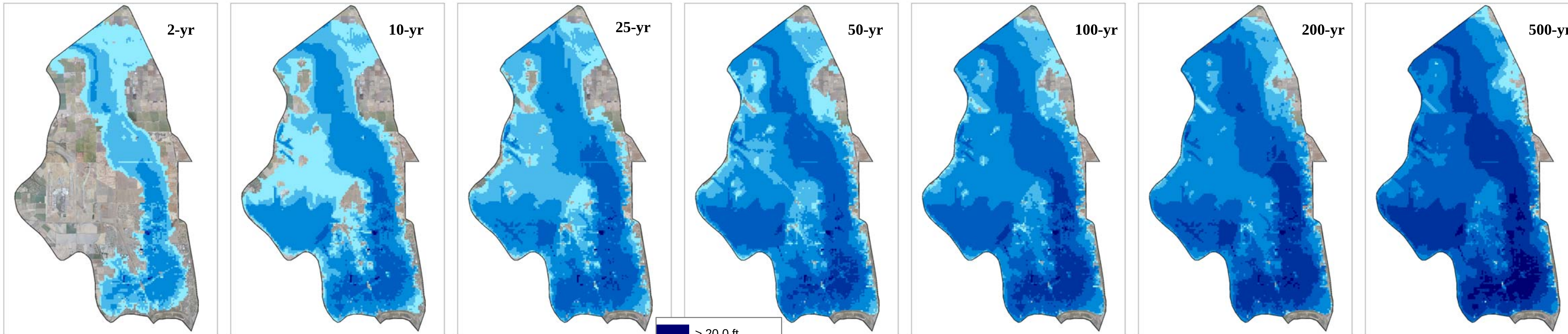

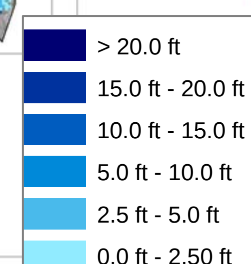

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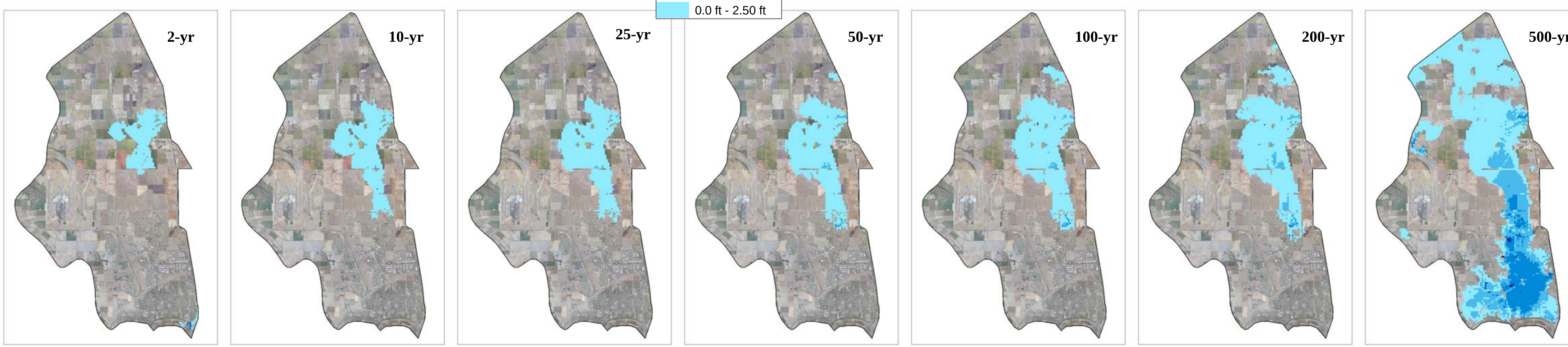
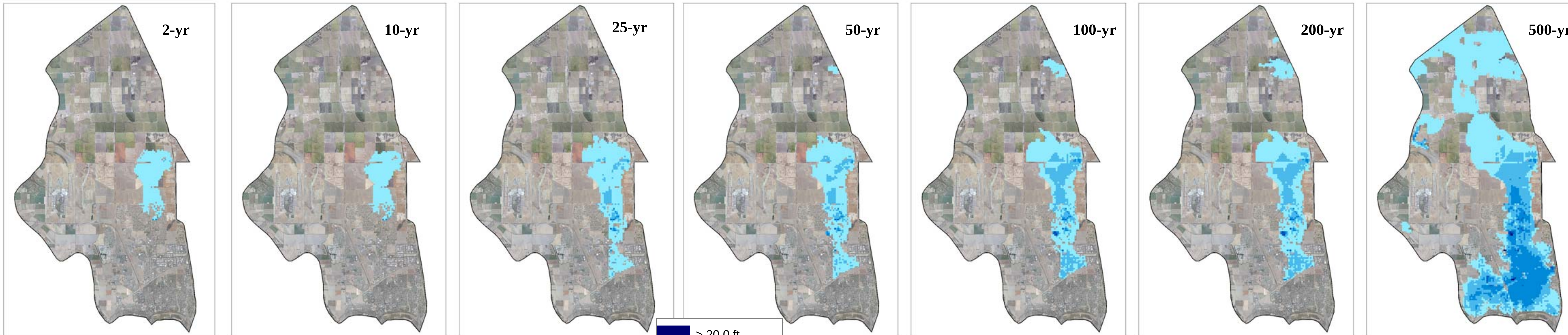
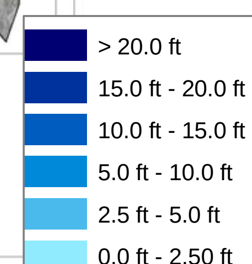


Reach G





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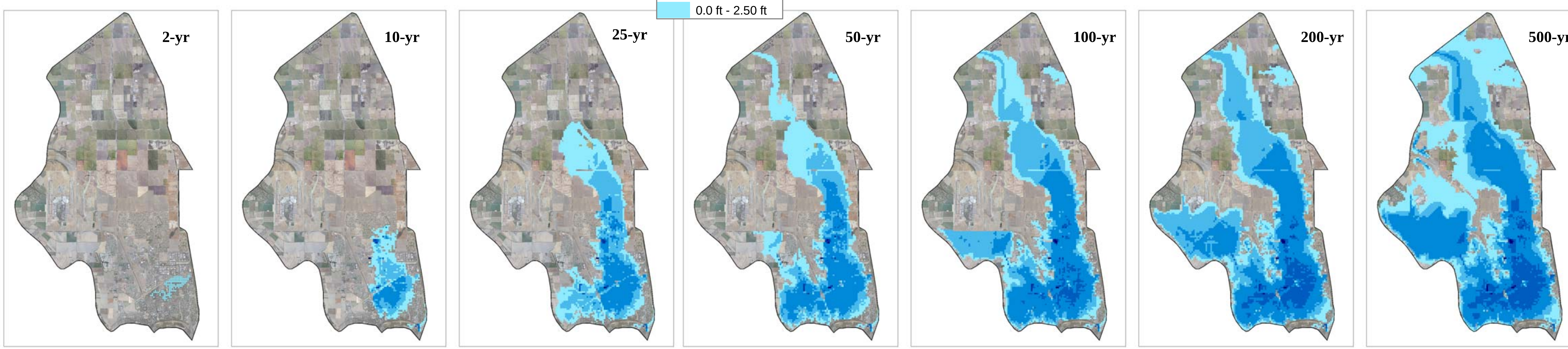

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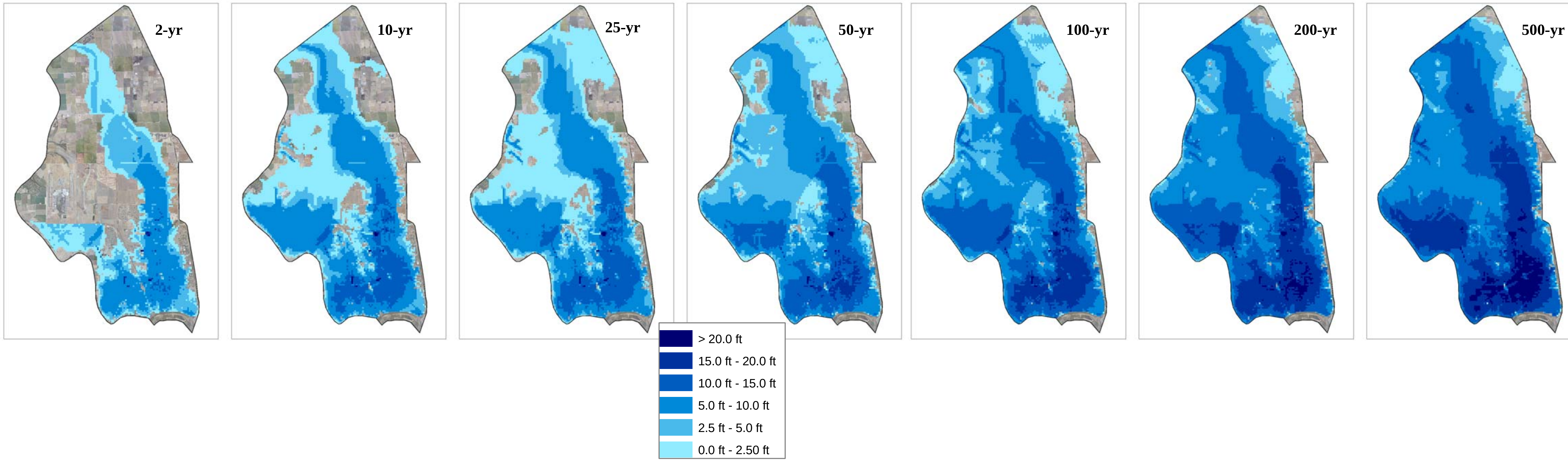
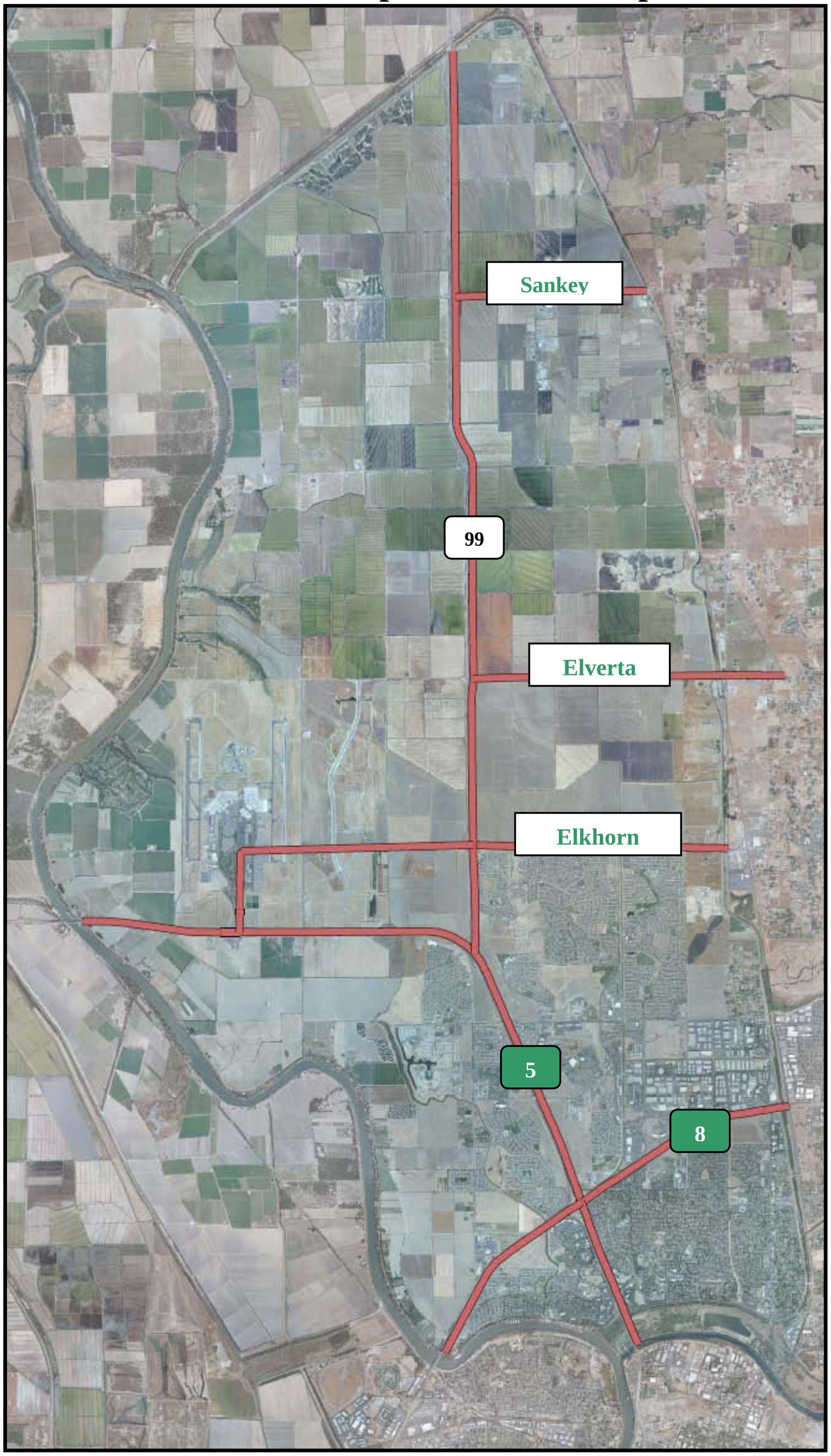

2-yr
10-yr
25-yr
50-yr
100-yr
200-yr
500-yr
> 20.0 ft
15.0 ft - 20.0 ft
10.0 ft - 15.0 ft
5.0 ft - 10.0 ft
2.5 ft - 5.0 ft
0.0 ft - 2.50 ft

Enclosure 2: HEC-FDA Input Data and Output Results



HEC-FDA WITHOUT-PROJECT FREQUENCY-DISCHARGE-STAGE CURVES

Sac R, RM 62.7519 (Natomas-Reach A)					
Without Project					
Frequency	**Inflow**	**Outflow**	**Standard Deviation (I-O)**	**Stage (ft) NAVD '88**	**Standard Deviation (Stage)**
1yr = .999	N/A	N/A	N/A	11.02	0.7
2yr = .5	N/A	N/A	N/A	25.47	0.7
10yr = .1	N/A	N/A	N/A	30.9	0.7
25yr = .04	N/A	N/A	N/A	32.93	0.7
50yr = .02	N/A	N/A	N/A	33.48	0.7
100yr = .01	N/A	N/A	N/A	34.16	0.8
200 yr = .005	N/A	N/A	N/A	36.23	0.8
500yr = .002	N/A	N/A	N/A	39.35	0.8
Equivalent Record Length = 71					

Sac R, RM 69.2511 (Natomas-Reach B)					
Without Project					
Frequency	**Inflow**	**Outflow**	**Standard Deviation (I-O)**	**Stage (ft) NAVD '88**	**Standard Deviation (Stage)**
1yr = .999	122,600	22,733	0	16.87	0.7
2yr = .5	186,545	55,415	6,200	30.07	0.7
10yr = .1	337,227	86,567	9,310	33.65	0.7
25yr = .04	455,133	93,308	12,800	35.88	0.8
50yr = .02	479,646	97,924	13,200	36.56	0.8
100yr = .01	551,819	104,079	14,200	37.43	0.8
200 yr = .005	690,355	110,145	14,300	38.91	0.8
500yr = .002	917,069	118,164	16,300	40.26	0.8
Equivalent Record Length = 71					

Sac R, RM 76.7497 (Natomas-Reach C)					
Without Project					
Frequency	Inflow	Outflow	Standard Deviation (I-O)	Stage (ft) NAVD '88	Standard Deviation (Stage)
1yr = .999	122,600	22,525	0	20.16	0.7
2yr = .5	186,545	55,625	6,200	33.36	0.7
10yr = .1	337,227	86,592	9,310	38.3	0.7
25yr = .04	455,133	93,422	12,800	40.25	0.8
50yr = .02	479,646	98,050	13,200	41.04	0.8
100yr = .01	551,819	104,259	14,200	42.05	0.8
200 yr = .005	690,355	113,524	14,300	43.46	0.8
500yr = .002	917,069	133,795	16,300	44.5	0.8
Equivalent Record Length = 71					

CC, RM 2.63 (Natomas-Reach D)					
Without Project					
Frequency	Inflow	Outflow	Standard Deviation (I-O)	Stage (ft) NAVD '88	Standard Deviation (Stage)
1yr = .999	N/A	N/A	N/A	20.27	0.8
2yr = .5	N/A	N/A	N/A	33.47	0.8
10yr = .1	N/A	N/A	N/A	38.47	0.8
25yr = .04	N/A	N/A	N/A	40.41	0.9
50yr = .02	N/A	N/A	N/A	41.21	0.9
100yr = .01	N/A	N/A	N/A	42.22	0.9
200 yr = .005	N/A	N/A	N/A	43.66	0.9
500yr = .002	N/A	N/A	N/A	44.68	0.9
Equivalent Record Length = 25					

NEMDEC , Storage Area Conn. (Reach E)					
Without Project					
Frequency	**Inflow**	**Outflow**	**Standard Deviation (I-O)**	**Stage (ft) NAVD '88**	**Standard Deviation (Stage)**
1yr = .999	N/A	N/A	N/A	20.27	0.8
2yr = .5	N/A	N/A	N/A	33.47	0.8
10yr = .1	N/A	N/A	N/A	38.46	0.8
25yr = .04	N/A	N/A	N/A	40.4	0.9
50yr = .02	N/A	N/A	N/A	41.23	0.9
100yr = .01	N/A	N/A	N/A	42.23	0.9
200 yr = .005	N/A	N/A	N/A	43.57	0.9
500yr = .002	N/A	N/A	N/A	44.84	0.9
Equivalent Record Length = 25					

NEMDC, RM 12.624 (Natomas-Reach F)					
Without Project					
Frequency	**Inflow**	**Outflow**	**Standard Deviation (I-O)**	**Stage (ft) NAVD '88**	**Standard Deviation (Stage)**
1yr = .999	N/A	N/A	N/A	26.03	0.9
2yr = .5	N/A	N/A	N/A	33.98	0.9
10yr = .1	N/A	N/A	N/A	35.36	0.7
25yr = .04	N/A	N/A	N/A	36.89	0.7
50yr = .02	N/A	N/A	N/A	37.73	0.7
100yr = .01	N/A	N/A	N/A	38.53	0.7
200 yr = .005	N/A	N/A	N/A	39.26	0.7
500yr = .002	N/A	N/A	N/A	40.98	0.7
Equivalent Record Length = 25					

NEMDC, RM 8.589 (Natomas-Reach G)					
Without Project					
Frequency	**Inflow**	**Outflow**	**Standard Deviation (I-O)**	**Stage (ft) NAVD '88**	**Standard Deviation (Stage)**
1yr = .999	N/A	N/A	N/A	25.57	0.9
2yr = .5	N/A	N/A	N/A	32.2	0.9
10yr = .1	N/A	N/A	N/A	35.32	0.7
25yr = .04	N/A	N/A	N/A	36.9	0.7
50yr = .02	N/A	N/A	N/A	37.74	0.7
100yr = .01	N/A	N/A	N/A	38.54	0.7
200 yr = .005	N/A	N/A	N/A	39.27	0.7
500yr = .002	N/A	N/A	N/A	40.99	0.7
Equivalent Record Length = 25					

NEMDC, RM 4.319 (Natomas-Reach H)					
Without Project					
Frequency	**Inflow**	**Outflow**	**Standard Deviation (I-O)**	**Stage (ft) NAVD '88**	**Standard Deviation (Stage)**
1yr = .999	N/A	N/A	N/A	25.25	0.7
2yr = .5	N/A	N/A	N/A	29.53	0.7
10yr = .1	N/A	N/A	N/A	32.46	0.8
25yr = .04	N/A	N/A	N/A	34.6	0.8
50yr = .02	N/A	N/A	N/A	35.86	0.8
100yr = .01	N/A	N/A	N/A	37.46	0.9
200 yr = .005	N/A	N/A	N/A	38.92	0.8
500yr = .002	N/A	N/A	N/A	44.4	0.7
Equivalent Record Length = 25					

NEMDC, RM 1 (Natomas-Reach I)					
Without Project					
Frequency	**Inflow**	**Outflow**	**Standard Deviation (I-O)**	**Stage (ft) NAVD '88**	**Standard Deviation (Stage)**
1yr = .999	9,600	9,600	20	10.44	0.7
2yr = .5	29,751	27,541	20	24.89	0.7
10yr = .1	77,300	75,446	130	30.77	0.7
25yr = .04	124,073	116,470	320	33.94	0.7
50yr = .02	129,325	116,982	350	34.44	0.7
100yr = .01	131,637	117,000	550	35.05	0.8
200 yr = .005	163,502	147,641	20,000	36.94	0.8
500yr = .002	573,257	249,831	23,700	40.67	0.8
Equivalent Record Length = 87					

HEC-FDA WITH-PROJECT FREQUENCY-DISCHARGE-STAGE CURVES

Sac R, RM 62.7519 (Natomas-Reach A)					
With Project (with selected levee raise SLR)					
Frequency	**Inflow**	**Outflow**	**Standard Deviation (I-O)**	**Stage (ft) NAVD '88**	**Standard Deviation (Stage)**
1yr = .999	NA	NA	NA	11.02	.0.7
2yr = .5	NA	NA	NA	25.47	0.7
10yr = .1	NA	NA	NA	30.90	0.7
25yr = .04	NA	NA	NA	32.93	0.7
50yr = .02	NA	NA	NA	33.48	0.7
100yr = .01	NA	NA	NA	34.16	0.8
200 yr = .005	NA	NA	NA	36.23	0.8
500yr = .002	NA	NA	NA	39.35	0.8
Equivalent Record Length = 71					

Sac R, RM 69.2511 (Natomas-Reach B)					
With Project (with selected levee raise SLR)					
Frequency	**Inflow**	**Outflow**	**Standard Deviation (I-O)**	**Stage (ft) NAVD '88**	**Standard Deviation (Stage)**
1yr = .999	122,600	22,733	6,200	19.32	0.7
2yr = .5	186,545	55,415	6,200	32.52	0.7
10yr = .1	337,227	86,606	9,310	37.21	0.7
25yr = .04	455,133	94,165	12,800	39.33	0.8
50yr = .02	479,646	98,470	13,200	40.04	0.8
100yr = .01	551,819	104,254	14,200	40.95	0.8
200 yr = .005	690,355	108,300	14,300	42.38	0.8
500yr = .002	917,069	113,649	16,300	43.16	0.8
Equivalent Record Length = 71					

Sac R, RM 76.7497 (Natomas-Reach C)					
With Project (with selected levee raise SLR)					
Frequency	**Inflow**	**Outflow**	**Standard Deviation (I-O)**	**Stage (ft) NAVD '88**	**Standard Deviation (Stage)**
1yr = .999	122,600	22,384	6,200	19.3	0.7
2yr = .5	186,545	55,446	6,200	32.5	0.7
10yr = .1	34	86,628	9,310	37.2	0.8
25yr = .04	455,133	94,365	12,800	39.3	0.8
50yr = .02	479,646	98,526	13,200	40.0	0.8
100yr = .01	551,819	104,395	14,200	41.0	0.8
200 yr = .005	690,355	113,126	14,300	42.4	0.8
500yr = .002	917,069	131,173	16,300	43.2	0.8
Equivalent Record Length = 71					

CC, RM 2.63 (Natomas-Reach D)					
With Project (with selected levee raise SLR)					
Frequency	**Inflow**	**Outflow**	**Standard Deviation (I-O)**	**Stage (ft) NAVD '88**	**Standard Deviation (Stage)**
1yr = .999	NA	NA	NA	20.27	0.8
2yr = .5	NA	NA	NA	33.47	0.8
10yr = .1	NA	NA	NA	38.47	0.8
25yr = .04	NA	NA	NA	40.55	0.9
50yr = .02	NA	NA	NA	41.41	0.9
100yr = .01	NA	NA	NA	42.31	0.9
200 yr = .005	NA	NA	NA	43.3	0.8
500yr = .002	NA	NA	NA	44.9	0.7
Equivalent Record Length = 25					

NEMDEC , Storage Area Conn. (Reach E)					
With Project (with selected levee raise SLR)					
Frequency	**Inflow**	**Outflow**	**Standard Deviation (I-O)**	**Stage (ft) NAVD '88**	**Standard Deviation (Stage)**
1yr = .999	NA	NA	NA	20.27	0.8
2yr = .5	NA	NA	NA	33.47	0.8
10yr = .1	NA	NA	NA	38.47	0.8
25yr = .04	NA	NA	NA	40.55	0.9
50yr = .02	NA	NA	NA	41.41	0.9
100yr = .01	NA	NA	NA	42.31	0.9
200 yr = .005	NA	NA	NA	43.83	0.8
500yr = .002	NA	NA	NA	44.90	0.7
Equivalent Record Length = 25					

NEMDC, RM 12.624 (Natomas-Reach F)					
With Project (with selected levee raise SLR)					
Frequency	**Inflow**	**Outflow**	**Standard Deviation (I-O)**	**Stage (ft) NAVD '88**	**Standard Deviation (Stage)**
1yr = .999	NA	NA	NA	26.03	0.9
2yr = .5	NA	NA	NA	33.94	0.9
10yr = .1	NA	NA	NA	35.24	0.7
25yr = .04	NA	NA	NA	36.8	0.7
50yr = .02	NA	NA	NA	37.66	0.7
100yr = .01	NA	NA	NA	38.53	0.7
200 yr = .005	NA	NA	NA	39.32	0.7
500yr = .002	NA	NA	NA	42.59	0.7
Equivalent Record Length = 25					

NEMDC, RM 8.589 (Natomas-Reach G)					
With Project (with selected levee raise SLR)					
Frequency	**Inflow**	**Outflow**	**Standard Deviation (I-O)**	**Stage (ft) NAVD '88**	**Standard Deviation (Stage)**
1yr = .999	NA	NA	NA	25.57	0.9
2yr = .5	NA	NA	NA	31.93	0.9
10yr = .1	NA	NA	NA	35.18	0.7
25yr = .04	NA	NA	NA	36.8	0.7
50yr = .02	NA	NA	NA	37.66	0.7
100yr = .01	NA	NA	NA	38.54	0.7
200 yr = .005	NA	NA	NA	39.33	0.7
500yr = .002	NA	NA	NA	42.60	0.7
Equivalent Record Length = 25					

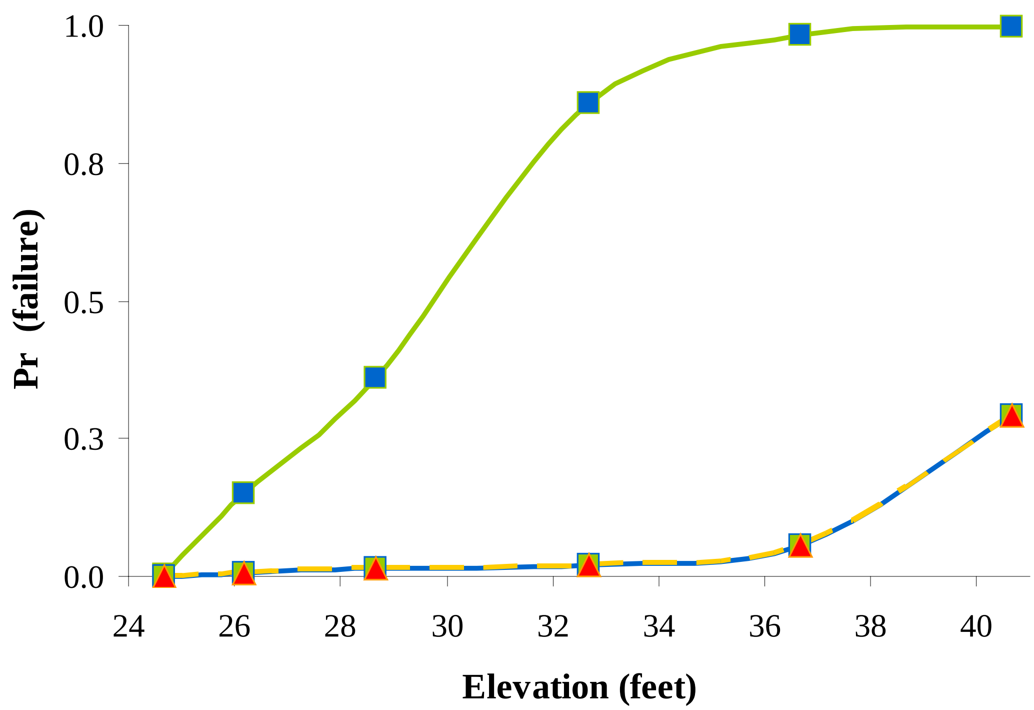
NEMDC, RM 4.319 (Natomas-Reach H)					
With Project (with selected levee raise SLR)					
Frequency	**Inflow**	**Outflow**	**Standard Deviation (I-O)**	**Stage (ft) NAVD '88**	**Standard Deviation (Stage)**
1yr = .999	NA	NA	NA	25.25	0.7
2yr = .5	NA	NA	NA	29.51	0.7
10yr = .1	NA	NA	NA	32.46	0.8
25yr = .04	NA	NA	NA	34.59	0.8
50yr = .02	NA	NA	NA	35.79	0.8
100yr = .01	NA	NA	NA	37.46	0.9
200 yr = .005	NA	NA	NA	38.97	0.8
500yr = .002	NA	NA	NA	43.97	0.7
Equivalent Record Length = 25					

NEMDC, RM 1 (Natomas-Reach I)					
With Project (with selected levee raise SLR)					
Frequency	**Inflow**	**Outflow**	**Standard Deviation (I-O)**	**Stage (ft) NAVD '88**	**Standard Deviation (Stage)**
1yr = .999	9600	9600	20	10.44	0.7
2yr = .5	29751	27525	20	24.89	0.7
10yr = .1	77300	75444	130	30.77	0.7
25yr = .04	124073	116562	320	34.03	0.7
50yr = .02	129325	119327	350	34.52	0.7
100yr = .01	131637	119400	550	35.08	0.8
200 yr = .005	163502	166125	20000	37.64	0.8
500yr = .002	573257	313999	23700	43.30	0.8
Equivalent Record Length = 87					

WITHOUT-PROJECT & WITH-PROJECT GRU CURVES

Without-Project & With-Project Geotechnical Risk & Uncertainty Curve

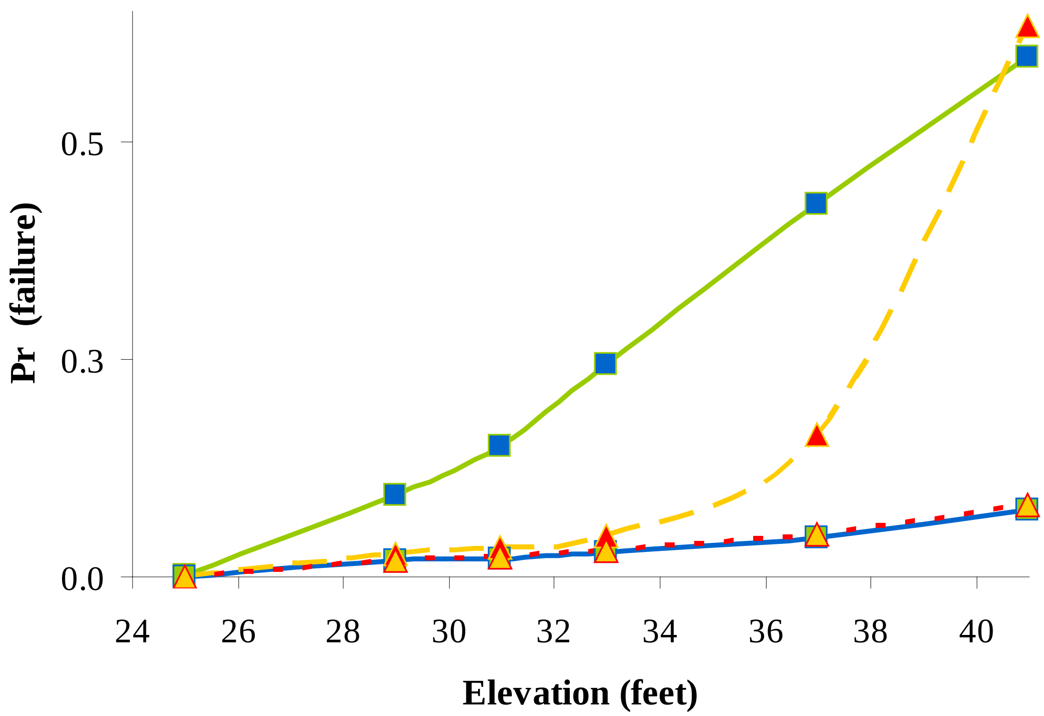
NATOMAS BASIN REACH A



Elevation	Probability of Failure		
	WO	W-SCB CW	W-CB CW
24.67	0.00178	0.00000	0.00000
26.17	0.15000	0.00584	0.00584
28.67	0.35859	0.01407	0.01407
32.67	0.85814	0.02010	0.02010
36.67	0.98247	0.05635	0.05635
40.67	0.99836	0.29149	0.29149

Without-Project & With-Project
Geotechnical Risk & Uncertainty Curve

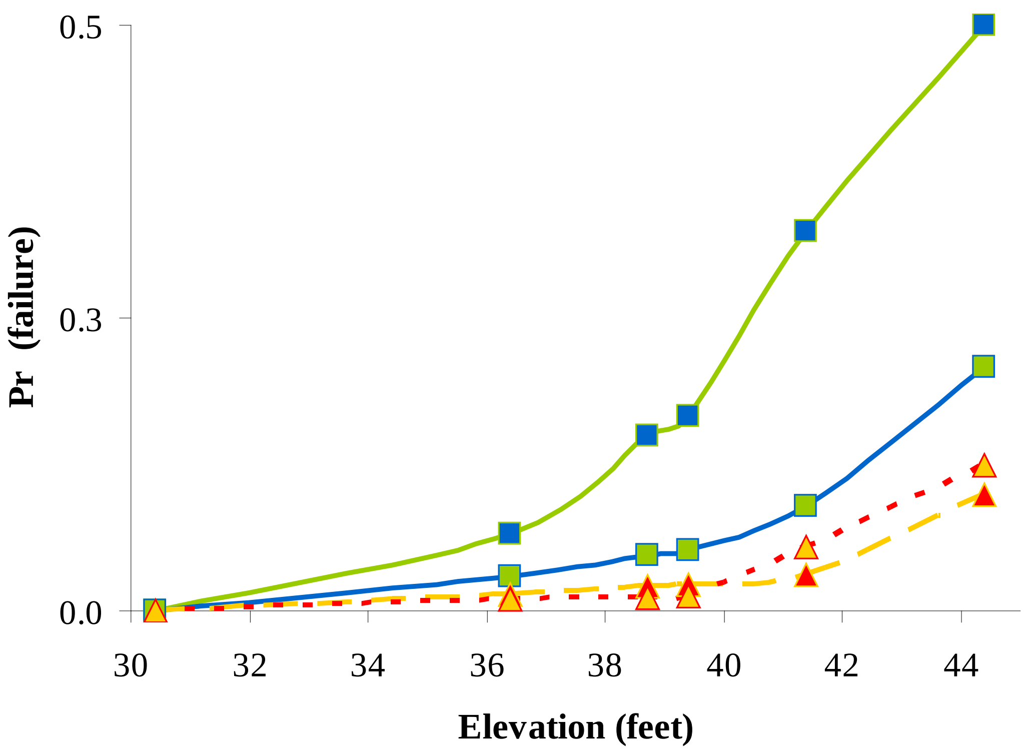
NATOMAS BASIN REACH B



Elevation	Probability of Failure			
	WO	AL-SB CW	DSB	W-SCB CW
24.98	0.00226	0.00000	0.00000	0.00000
28.98	0.09370	0.01785	0.02721	0.01908
30.98	0.15000	0.02136	0.03429	0.02305
32.98	0.24427	0.02725	0.04614	0.02969
36.98	0.42765	0.04507	0.16257	0.04867
40.98	0.59710	0.07794	0.63360	0.08258

Without-Project & With-Project
Geotechnical Risk & Uncertainty Curve

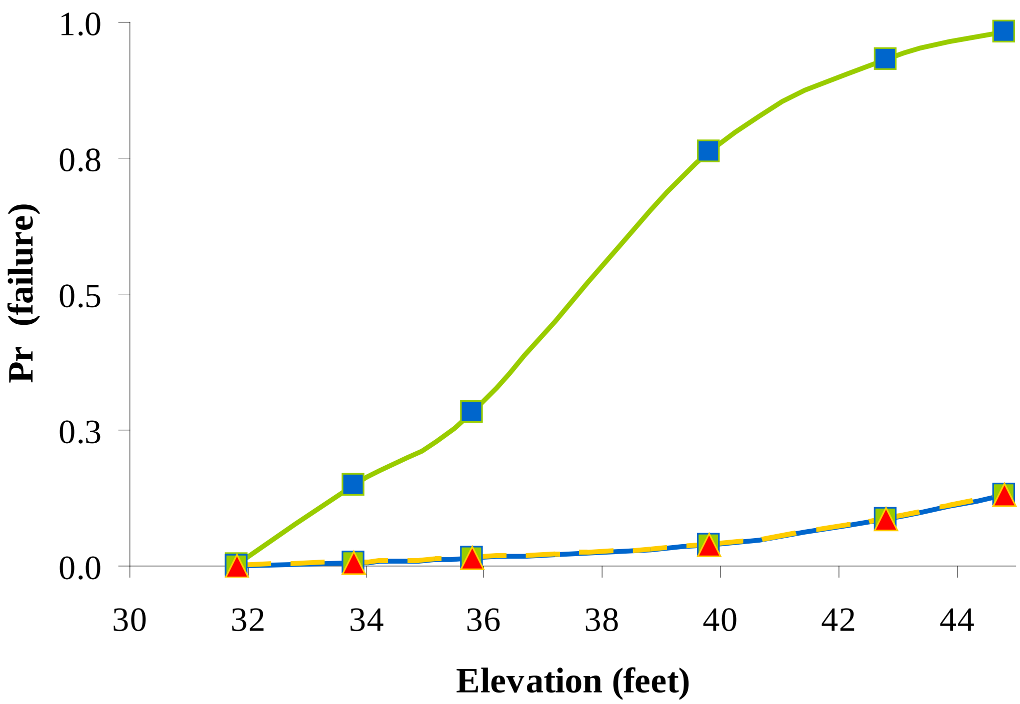
NATOMAS BASIN REACH C



Elevation	Probability of Failure			
	WO	D-SB CWP	SB CWP	AL-SB CW
30.4	0.00000	0.00000	0.00000	0.00000
36.4	0.06600	0.02967	0.01401	0.01000
38.7	0.15000	0.04745	0.02067	0.01167
39.4	0.16679	0.05100	0.02200	0.01200
41.4	0.32352	0.08901	0.03096	0.05432
44.4	0.49969	0.20741	0.09857	0.12434

Without-Project & With-Project
Geotechnical Risk & Uncertainty Curve

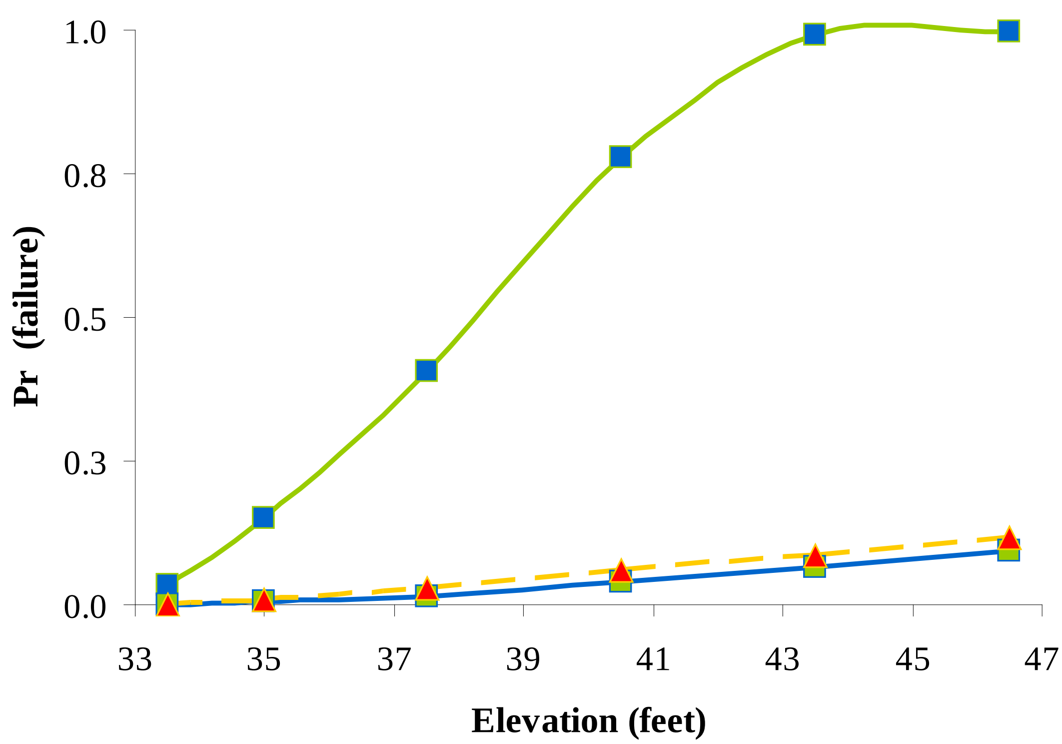
NATOMAS BASIN REACH D



Elevation	Probability of Failure		
	WO	SB/SCB CWP (F)	SB/SCB CWP
31.8	0.00269	0.00000	0.00000
33.8	0.15000	0.00736	0.00736
35.8	0.28324	0.01401	0.01401
39.8	0.76297	0.03982	0.03982
42.8	0.93273	0.08504	0.08504
44.8	0.98191	0.13115	0.13115

Without-Project & With-Project
Geotechnical Risk & Uncertainty Curve

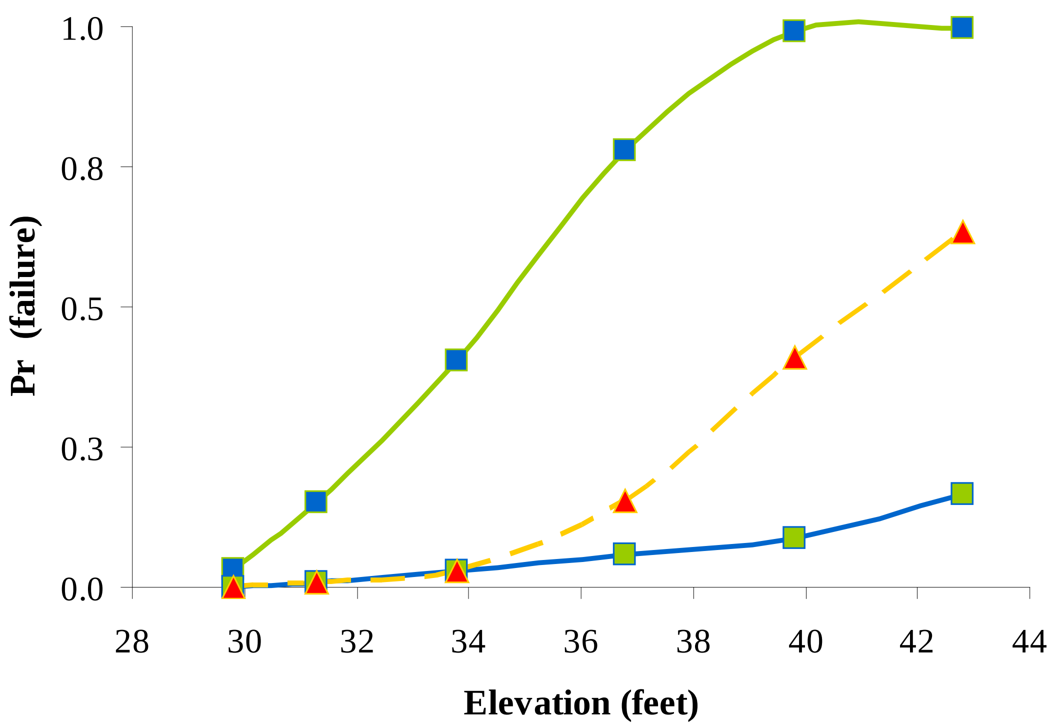
NATOMAS BASIN REACH E



Elevation	Probability of Failure		
	WO	SB CWP	DSB
33.5	0.03323	0.00000	0.00000
35	0.15000	0.00443	0.00908
37.5	0.40517	0.01412	0.02891
40.5	0.77815	0.03948	0.05869
43.5	0.99163	0.06531	0.08634
46.5	0.99775	0.09306	0.11574

Without-Project & With-Project
Geotechnical Risk & Uncertainty Curve

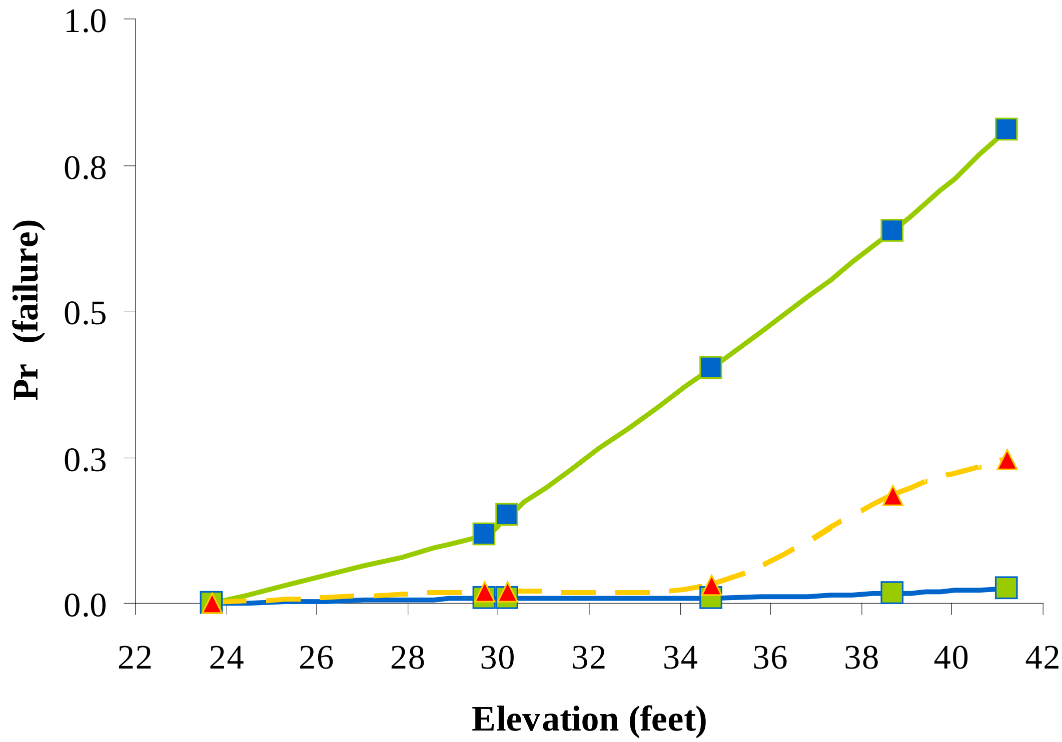
NATOMAS BASIN REACH F



Elevation	Probability of Failure		
	WO	DStB	FL LS
29.8	0.03323	0.00000	0.00000
31.3	0.15000	0.00908	0.00908
33.8	0.40517	0.02891	0.02891
36.8	0.77815	0.05869	0.15341
39.8	0.99163	0.08634	0.40915
42.8	0.99750	0.16538	0.63471

Without-Project & With-Project
Geotechnical Risk & Uncertainty Curve

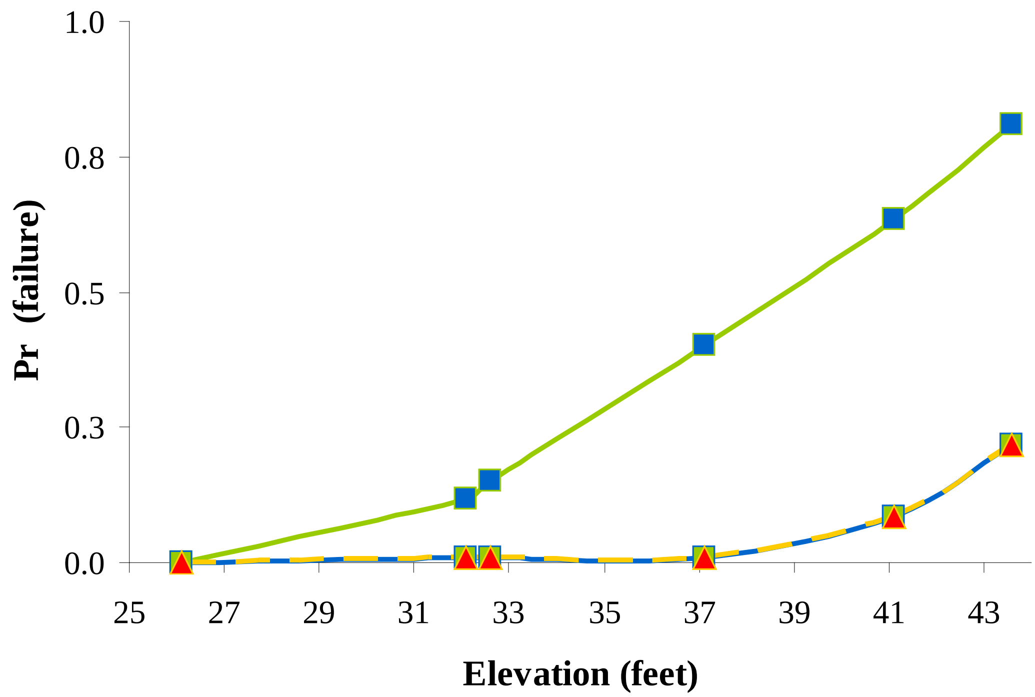
NATOMAS BASIN REACH G-2



Elevation	Probability of Failure		
	WO	SB CWP	DSB
23.7	0.00000	0.00000	0.00000
29.7	0.11704	0.00866	0.01910
30.2	0.15000	0.00876	0.02031
34.7	0.40137	0.00952	0.02958
38.7	0.63587	0.01612	0.18345
41.2	0.80940	0.02480	0.24658

Without-Project & With-Project
Geotechnical Risk & Uncertainty Curve

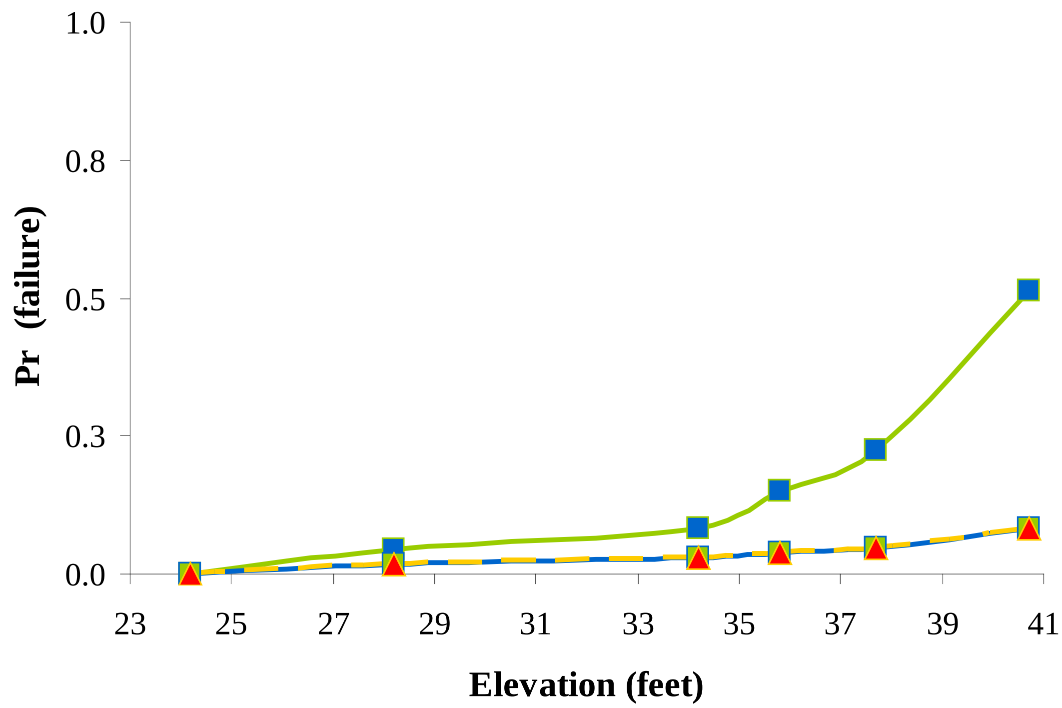
NATOMAS BASIN REACH H



Elevation	Probability of Failure		
	WO	SB CWP	SCB CWP
26.1	0.00000	0.00000	0.00000
32.1	0.11704	0.00865	0.00865
32.6	0.15000	0.00875	0.00875
37.1	0.40137	0.00952	0.00952
41.1	0.63587	0.08333	0.08333
43.6	0.80940	0.21741	0.21741

Without-Project & With-Project
Geotechnical Risk & Uncertainty Curve

NATOMAS BASIN REACH I



Elevation	Probability of Failure		
	WO	SB CWP	SCB CWP
24.2	0.00000	0.00000	0.00000
28.2	0.04421	0.01908	0.01908
34.2	0.08180	0.02969	0.02969
35.8	0.15000	0.03878	0.03878
37.7	0.22428	0.04867	0.04867
40.7	0.51416	0.08258	0.08258

STRUCTURE AND CONTENT VALUE UNCERTAINTY

USE CATEGORY	UNCERTAINTY IN VALUE (INPUT TO HEC-FDA)	
	Structure SD/Mean	**Content SD/Mean**
Residential (SFR & MFR)	17%	12%
Mobile Homes	14%	12%
Office 2-Story	17%	14%
Office 1-Story	17%	16%
Retail	17%	18%
Retail-Furniture	17%	20%
Auto Dealerships	12%	12%
Hotel	12%	16%
Food Stores	21%	27%
Restaurants	19%	3%
Restaurants-Fast Food	19%	13%
Medical	13%	46%
Hospitals	21%	46%
Shopping Centers	20%	23%
Large Grocery Stores	20%	4%
Service (Auto)	17%	4%
Warehouse	17%	31%
Light Ind.	21%	19%
Heavy Ind.	21%	31%
Government	31%	16%
Schools	15%	33%
Religious	19%	40%
Recreation	19%	13%
Farms	20%	8%
Automobiles	15%	N/A

The following tables display the depth-percent damage curves for the 53 occupancy types found within the structure inventory and used in the HEC-FDA modeling. The far left column indicates water depth in feet. The remaining two columns show the corresponding structure and content damage expressed as a percentage of structure value (residential categories) or as a percentage of structure value and content value, respectively (non-residential categories).

Table 1

C-RET1		
Commercial Retail 1-story		
Stage	Structure	Content
-8	0	0
-7	0	0
-6	0	0
-5	0	0
-4	0	0
-3	0	0
-2	0	0
-1	0	0
-0.5	3.5	0
0	7	0
0.5	14.4	42.71
1	21.73	79.83
1.5	26	94.79
2	30.19	100
3	31.22	100
4	32.44	100
5	32.44	100
6	39.82	100
7	42.76	100
8	51.72	100
9	53.1	100
10	54.09	100
11	61.78	100
12	64.77	100
13	64.77	100
14	65.49	100
15	86.06	100

Table 2

C-RET2		
Commercial Retail 2-story		
Stage	Structure	Content
-8	0	0
-7	0	0
-6	0	0
-5	0	0
-4	0	0
-3	0	0
-2	0	0
-1	0	0
-0.5	2.5	0
0	5	0
0.5	10.1	20.49
1	15.26	38.31
1.5	17.1	49.61
2	18.88	55.97
3	21.48	55.97
4	22.8	55.97
5	22.8	55.97
6	24.05	55.97
7	26.1	55.97
8	40.4	66.87
9	43.25	66.87
10	46.2	66.87
11	46.2	69.29
12	49.05	96.33
13	49.05	100
14	55.16	100
15	80.05	100

Table 3

C-DEAL1		
Full Service Auto Dealership 1-Story		
Stage	Structure	Content
-8	0	0
-7	0	0
-6	0	0
-5	0	0
-4	0	0
-3	0	0
-2	0	0
-1	0	5.75
-0.5	3.5	5.81
0	7	5.81
0.5	14.4	41.07
1	21.73	80.26
1.5	26	97.18
2	30.19	100
3	31.22	100
4	32.44	100
5	32.44	100
6	39.82	100
7	42.76	100
8	51.72	100
9	53.1	100
10	54.09	100
11	61.78	100
12	64.77	100
13	64.77	100
14	65.49	100
15	86.06	100

Table 4

C-DEAL2		
Full Service Auto Dealership 2-Story		
Stage	Structure	Content
-8	0	0
-7	0	0
-6	0	0
-5	0	0
-4	0	0
-3	0	0
-2	0	0
-1	0	2.76
-0.5	2.5	2.79
0	5	2.79
0.5	10.1	19.71
1	15.26	38.52
1.5	17.1	50.86
2	18.88	55.97
3	21.48	55.97
4	22.8	55.97
5	22.8	55.97
6	24.05	55.97
7	26.1	55.97
8	40.4	66.87
9	43.25	66.87
10	46.2	66.87
11	46.2	69.29
12	49.05	96.33
13	49.05	100
14	55.16	100
15	80.05	100

Table 5

C-FURN1		
Furniture Store 1-Story		
Stage	Structure	Content
-8	0	0
-7	0	0
-6	0	0
-5	0	0
-4	0	0
-3	0	0
-2	0	0
-1	0	0
-0.5	3.5	0
0	7	0
0.5	14.4	89.48
1	21.73	98.2
1.5	26	100
2	30.19	100
3	31.22	100
4	32.44	100
5	32.44	100
6	39.82	100
7	42.76	100
8	51.72	100
9	53.1	100
10	54.09	100
11	61.78	100
12	64.77	100
13	64.77	100
14	65.49	100
15	86.06	100

Table 6

C-FURN2		
Furniture Store 2-Story		
Stage	Structure	Content
-8	0	0
-7	0	0
-6	0	0
-5	0	0
-4	0	0
-3	0	0
-2	0	0
-1	0	0
-0.5	2.5	0
0	5	0
0.5	10.1	42.94
1	15.26	47.13
1.5	17.1	52.33
2	18.88	55.97
3	21.48	55.97
4	22.8	55.97
5	22.8	55.97
6	24.05	55.97
7	26.1	55.97
8	40.4	66.87
9	43.25	66.87
10	46.2	66.87
11	46.2	69.29
12	49.05	96.33
13	49.05	100
14	55.16	100
15	80.05	100

Table 7

C-HOS1		
Hospital 1-Story		
Stage	Structure	Content
-8	0	0
-7	0	0
-6	0	0
-5	0	0
-4	0	0
-3	0	0
-2	0	0
-1	0	0
-0.5	3.5	0
0	7	0
0.5	14.4	50
1	21.73	75.49
1.5	26	100
2	30.19	100
3	31.22	100
4	32.44	100
5	32.44	100
6	39.82	100
7	42.76	100
8	51.72	100
9	53.1	100
10	54.09	100
11	61.78	100
12	64.77	100
13	64.77	100
14	65.49	100
15	86.06	100

Table 8

C-HOS2		
Hospital 2-Story		
Stage	Structure	Content
-8	0	0
-7	0	0
-6	0	0
-5	0	0
-4	0	0
-3	0	0
-2	0	0
-1	0	0
-0.5	2.5	0
0	5	0
0.5	10.1	24
1	15.26	36.23
1.5	17.1	52.33
2	18.88	55.97
3	21.48	55.97
4	22.8	55.97
5	22.8	55.97
6	24.05	55.97
7	26.1	55.97
8	40.4	66.87
9	43.25	66.87
10	46.2	66.87
11	46.2	69.29
12	49.05	96.33
13	49.05	100
14	55.16	100
15	80.05	100

Table 9

C-AUTO1		
Commercial Auto Sales 1-Story		
Stage	Structure	Content
-8	0	0
-7	0	0
-6	0	0
-5	0	0
-4	0	0
-3	0	0
-2	0	0
-1	0	0
-0.5	3.5	0
0	7	0
0.5	14.4	48.39
1	21.73	96.78
1.5	26	100
2	30.19	100
3	31.22	100
4	32.44	100
5	32.44	100
6	39.82	100
7	42.76	100
8	51.72	100
9	53.1	100
10	54.09	100
11	61.78	100
12	64.77	100
13	64.77	100
14	65.49	100
15	86.06	100

Table 10

C-AUTO2		
Commercial Auto Sales 2-Story		
Stage	Structure	Content
-8	0	0
-7	0	0
-6	0	0
-5	0	0
-4	0	0
-3	0	0
-2	0	0
-1	0	0
-0.5	2.5	0
0	5	0
0.5	10.1	42.89
1	15.26	46.44
1.5	17.1	52.33
2	18.88	55.97
3	21.48	55.97
4	22.8	55.97
5	22.8	55.97
6	24.05	55.97
7	26.1	55.97
8	40.4	66.87
9	43.25	66.87
10	46.2	66.87
11	46.2	69.29
12	49.05	96.33
13	49.05	100
14	55.16	100
15	80.05	100

Table 11

C-HOTEL1		
Hotel 1-Story		
Stage	Structure	Content
-8	0	0
-7	0	0
-6	0	0
-5	0	0
-4	0	0
-3	0	0
-2	0	0
-1	0	0
-0.5	3.5	0
0	7	0
0.5	14.4	47.36
1	21.73	91.34
1.5	26	100
2	30.19	100
3	31.22	100
4	32.44	100
5	32.44	100
6	39.82	100
7	42.76	100
8	51.72	100
9	53.1	100
10	54.09	100
11	61.78	100
12	64.77	100
13	64.77	100
14	65.49	100
15	86.06	100

Table 12

C-HOTEL2		
Hotel 2-Story		
Stage	Structure	Content
-8	0	0
-7	0	0
-6	0	0
-5	0	0
-4	0	0
-3	0	0
-2	0	0
-1	0	0
-0.5	2.5	0
0	5	0
0.5	10.1	22.73
1	15.26	43.83
1.5	17.1	52.33
2	18.88	55.97
3	21.48	55.97
4	22.8	55.97
5	22.8	55.97
6	24.05	55.97
7	26.1	55.97
8	40.4	66.87
9	43.25	66.87
10	46.2	66.87
11	46.2	69.29
12	49.05	96.33
13	49.05	100
14	55.16	100
15	80.05	100

Table 13

C-FOOD1		
Commercial Food-Retail 1-Story		
Stage	Structure	Content
-8	0	0
-7	0	0
-6	0	0
-5	0	0
-4	0	0
-3	0	0
-2	0	0
-1	0	0
-0.5	3.5	0
0	7	0.5
0.5	14.4	56.98
1	21.73	78.33
1.5	26	94.47
2	30.19	100
3	31.22	100
4	32.44	100
5	32.44	100
6	39.82	100
7	42.76	100
8	51.72	100
9	53.1	100
10	54.09	100
11	61.78	100
12	64.77	100
13	64.77	100
14	65.49	100
15	86.06	100

Table 14

C-FOOD2		
Commercial Food-Retail 2-Story		
Stage	Structure	Content
-8	0	0
-7	0	0
-6	0	0
-5	0	0
-4	0	0
-3	0	0
-2	0	0
-1	0	0
-0.5	2.5	0
0	5	0.24
0.5	10.1	27.35
1	15.26	37.59
1.5	17.1	49.44
2	18.88	55.97
3	21.48	55.97
4	22.8	55.97
5	22.8	55.97
6	24.05	55.97
7	26.1	55.97
8	40.4	66.87
9	43.25	66.87
10	46.2	66.87
11	46.2	69.29
12	49.05	96.33
13	49.05	100
14	55.16	100
15	80.05	100

Table 15

C-RESTFF1		
Commercial Fast Food Rest 1-Story		
Stage	Structure	Content
-8	0	0
-7	0	0
-6	0	0
-5	0	0
-4	0	0
-3	0	0
-2	0	0
-1	0	0
-0.5	3.5	0
0	7	0
0.5	14.4	45.1
1	21.73	87.8
1.5	26	100
2	30.19	100
3	31.22	100
4	32.44	100
5	32.44	100
6	39.82	100
7	42.76	100
8	51.72	100
9	53.1	100
10	54.09	100
11	61.78	100
12	64.77	100
13	64.77	100
14	65.49	100
15	86.06	100

Table 16

C-RESTFF2		
Commercial Fast Food Rest 2-Story		
Stage	Structure	Content
-8	0	0
-7	0	0
-6	0	0
-5	0	0
-4	0	0
-3	0	0
-2	0	0
-1	0	0
-0.5	2.5	0
0	5	0
0.5	10.1	21.64
1	15.26	42.14
1.5	17.1	52.33
2	18.88	55.97
3	21.48	55.97
4	22.8	55.97
5	22.8	55.97
6	24.05	55.97
7	26.1	55.97
8	40.4	66.87
9	43.25	66.87
10	46.2	66.87
11	46.2	69.29
12	49.05	96.33
13	49.05	100
14	55.16	100
15	80.05	100

Table 17

C-GROC1		
Commercial Grocery Store 1-Story		
Stage	Structure	Content
-8	0	0
-7	0	0
-6	0	0
-5	0	0
-4	0	0
-3	0	0
-2	0	0
-1	0	0
-0.5	3.5	0
0	7	0
0.5	14.4	61.04
1	21.73	87.33
1.5	26	94.38
2	30.19	100
3	31.22	100
4	32.44	100
5	32.44	100
6	39.82	100
7	42.76	100
8	51.72	100
9	53.1	100
10	54.09	100
11	61.78	100
12	64.77	100
13	64.77	100
14	65.49	100
15	86.06	100

Table 18

C-GROC2		
Commercial Grocery Store 2-Story		
Stage	Structure	Content
-8	0	0
-7	0	0
-6	0	0
-5	0	0
-4	0	0
-3	0	0
-2	0	0
-1	0	0
-0.5	2.5	0
0	5	0
0.5	10.1	29.29
1	15.26	41.91
1.5	17.1	49.39
2	18.88	55.97
3	21.48	55.97
4	22.8	55.97
5	22.8	55.97
6	24.05	55.97
7	26.1	55.97
8	40.4	66.87
9	43.25	66.87
10	46.2	66.87
11	46.2	69.29
12	49.05	96.33
13	49.05	100
14	55.16	100
15	80.05	100

Table 19

C-MED1		
Commercial Medical 1-Story		
Stage	Structure	Content
-8	0	0
-7	0	0
-6	0	0
-5	0	0
-4	0	0
-3	0	0
-2	0	0
-1	0	0
-0.5	3.5	0
0	7	0
0.5	14.4	50
1	21.73	75.49
1.5	26	100
2	30.19	100
3	31.22	100
4	32.44	100
5	32.44	100
6	39.82	100
7	42.76	100
8	51.72	100
9	53.1	100
10	54.09	100
11	61.78	100
12	64.77	100
13	64.77	100
14	65.49	100
15	86.06	100

Table 20

C-MED2		
Commercial Medical 2-Story		
Stage	Structure	Content
-8	0	0
-7	0	0
-6	0	0
-5	0	0
-4	0	0
-3	0	0
-2	0	0
-1	0	0
-0.5	2.5	0
0	5	0
0.5	10.1	24
1	15.26	36.23
1.5	17.1	52.33
2	18.88	55.97
3	21.48	55.97
4	22.8	55.97
5	22.8	55.97
6	24.05	55.97
7	26.1	55.97
8	40.4	66.87
9	43.25	66.87
10	46.2	66.87
11	46.2	69.29
12	49.05	96.33
13	49.05	100
14	55.16	100
15	80.05	100

Table 21

C-OFF1		
Commercial Office 1-Story		
Stage	Structure	Content
-8	0	0
-7	0	0
-6	0	0
-5	0	0
-4	0	0
-3	0	0
-2	0	0
-1	0	0
-0.5	3.5	0
0	7	0
0.5	14.4	48.39
1	21.73	96.78
1.5	26	100
2	30.19	100
3	31.22	100
4	32.44	100
5	32.44	100
6	39.82	100
7	42.76	100
8	51.72	100
9	53.1	100
10	54.09	100
11	61.78	100
12	64.77	100
13	64.77	100
14	65.49	100
15	86.06	100

Table 22

C-OFF2		
Commercial Office 2-Story		
Stage	Structure	Content
-8	0	0
-7	0	0
-6	0	0
-5	0	0
-4	0	0
-3	0	0
-2	0	0
-1	0	0
-0.5	2.5	0
0	5	0
0.5	10.1	42.89
1	15.26	46.44
1.5	17.1	52.33
2	18.88	55.97
3	21.48	55.97
4	22.8	55.97
5	22.8	55.97
6	24.05	55.97
7	26.1	55.97
8	40.4	66.87
9	43.25	66.87
10	46.2	66.87
11	46.2	69.29
12	49.05	96.33
13	49.05	100
14	55.16	100
15	80.05	100

Table 23

C-SHOP1		
Commercial Shopping Center 1-Story		
Stage	Structure	Content
-8	0	0
-7	0	0
-6	0	0
-5	0	0
-4	0	0
-3	0	0
-2	0	0
-1	0	0
-0.5	3.5	0
0	7	0
0.5	14.4	76.45
1	21.73	95.92
1.5	26	100
2	30.19	100
3	31.22	100
4	32.44	100
5	32.44	100
6	39.82	100
7	42.76	100
8	51.72	100
9	53.1	100
10	54.09	100
11	61.78	100
12	64.77	100
13	64.77	100
14	65.49	100
15	86.06	100

Table 24

C-SHOP2		
Commercial Shopping Center 2-Story		
Stage	Structure	Content
-8	0	0
-7	0	0
-6	0	0
-5	0	0
-4	0	0
-3	0	0
-2	0	0
-1	0	0
-0.5	2.5	0
0	5	0
0.5	10.1	36.69
1	15.26	46.03
1.5	17.1	52.33
2	18.88	55.97
3	21.48	55.97
4	22.8	55.97
5	22.8	55.97
6	24.05	55.97
7	26.1	55.97
8	40.4	66.87
9	43.25	66.87
10	46.2	66.87
11	46.2	69.29
12	49.05	96.33
13	49.05	100
14	55.16	100
15	80.05	100

Table 25

C-REST1		
Commercial Restaurant 1-Story		
Stage	Structure	Content
-8	0	0
-7	0	0
-6	0	0
-5	0	0
-4	0	0
-3	0	0
-2	0	0
-1	0	0
-0.5	3.5	0
0	7	0
0.5	14.4	47.36
1	21.73	91.34
1.5	26	100
2	30.19	100
3	31.22	100
4	32.44	100
5	32.44	100
6	39.82	100
7	42.76	100
8	51.72	100
9	53.1	100
10	54.09	100
11	61.78	100
12	64.77	100
13	64.77	100
14	65.49	100
15	86.06	100

Table 26

C-REST2		
Commercial Restaurant 2-Story		
Stage	Structure	Content
-8	0	0
-7	0	0
-6	0	0
-5	0	0
-4	0	0
-3	0	0
-2	0	0
-1	0	0
-0.5	2.5	0
0	5	0
0.5	10.1	22.73
1	15.26	43.83
1.5	17.1	52.33
2	18.88	55.97
3	21.48	55.97
4	22.8	55.97
5	22.8	55.97
6	24.05	55.97
7	26.1	55.97
8	40.4	66.87
9	43.25	66.87
10	46.2	66.87
11	46.2	69.29
12	49.05	96.33
13	49.05	100
14	55.16	100
15	80.05	100

Table 27

C-SERV1		
Commercial Service-Auto 1-Story		
Stage	Structure	Content
-8	0	0
-7	0	0
-6	0	0
-5	0	0
-4	0	0
-3	0	0
-2	0	0
-1	0	9.91
-0.5	3.5	10
0	7	10
0.5	14.4	38.69
1	21.73	73.51
1.5	26	97.44
2	30.19	100
3	31.22	100
4	32.44	100
5	32.44	100
6	39.82	100
7	42.76	100
8	51.72	100
9	53.1	100
10	54.09	100
11	61.78	100
12	64.77	100
13	64.77	100
14	65.49	100
15	86.06	100

Table 28

C-SERV1		
Commercial Service-Auto 2-Story		
Stage	Structure	Content
-8	0	0
-7	0	0
-6	0	0
-5	0	0
-4	0	0
-3	0	0
-2	0	0
-1	0	4.75
-0.5	2.5	4.8
0	5	4.8
0.5	10.1	18.57
1	15.26	35.28
1.5	17.1	50.99
2	18.88	55.97
3	21.48	55.97
4	22.8	55.97
5	22.8	55.97
6	24.05	55.97
7	26.1	55.97
8	40.4	66.87
9	43.25	66.87
10	46.2	66.87
11	46.2	69.29
12	49.05	96.33
13	49.05	100
14	55.16	100
15	80.05	100

Table 29

I-LT1		
Industrial Light 1-Story		
Stage	Structure	Content
-8	0	0
-7	0	0
-6	0	0
-5	0	0
-4	0	0
-3	0	0
-2	0	0
-1	0	0
-0.5	3.5	0
0	7	0.19
0.5	14.4	45.36
1	21.73	87.64
1.5	26	92.79
2	30.19	96.39
3	31.22	98.97
4	32.44	100
5	32.44	100
6	39.82	100
7	42.76	100
8	51.72	100
9	53.1	100
10	54.09	100
11	61.78	100
12	64.77	100
13	64.77	100
14	65.49	100
15	86.06	100

Table 30

I-LT2		
Industrial Light 2-Story		
Stage	Structure	Content
-8	0	0
-7	0	0
-6	0	0
-5	0	0
-4	0	0
-3	0	0
-2	0	0
-1	0	0
-0.5	2.5	0
0	5	0.19
0.5	10.1	21.77
1	15.26	42.06
1.5	17.1	48.56
2	18.88	53.95
3	21.48	55.97
4	22.8	55.97
5	22.8	55.97
6	24.05	55.97
7	26.1	55.97
8	40.4	66.87
9	43.25	66.87
10	46.2	66.87
11	46.2	69.29
12	49.05	96.33
13	49.05	100
14	55.16	100
15	80.05	100

Table 31

I-HV1		
Industrial Heavy Manufacture 1-Story		
Stage	Structure	Content
-8	0	0
-7	0	0
-6	0	0
-5	0	0
-4	0	0
-3	0	0
-2	0	0
-1	0	0
-0.5	3.5	0
0	7	0
0.5	14.4	12.18
1	21.73	32.69
1.5	26	53.81
2	30.19	69.95
3	31.22	77.48
4	32.44	100
5	32.44	100
6	39.82	100
7	42.76	100
8	51.72	100
9	53.1	100
10	54.09	100
11	61.78	100
12	64.77	100
13	64.77	100
14	65.49	100
15	86.06	100

Table 32

I-HV2		
Industrial Heavy Manufacture 2-Story		
Stage	Structure	Content
-8	0	0
-7	0	0
-6	0	0
-5	0	0
-4	0	0
-3	0	0
-2	0	0
-1	0	0
-0.5	2.5	0
0	5	0
0.5	10.1	5.85
1	15.26	15.69
1.5	17.1	28.16
2	18.88	39.15
3	21.48	43.37
4	22.8	55.97
5	22.8	55.97
6	24.05	55.97
7	26.1	55.97
8	40.4	66.87
9	43.25	66.87
10	46.2	66.87
11	46.2	69.29
12	49.05	96.33
13	49.05	100
14	55.16	100
15	80.05	100

Table 33

I-WH1		
Industrial Warehouse 1-Story		
Stage	Structure	Content
-8	0	0
-7	0	0
-6	0	0
-5	0	0
-4	0	0
-3	0	0
-2	0	0
-1	0	0
-0.5	3.5	0
0	7	0
0.5	14.4	41.32
1	21.73	84.19
1.5	26	94.42
2	30.19	100
3	31.22	100
4	32.44	100
5	32.44	100
6	39.82	100
7	42.76	100
8	51.72	100
9	53.1	100
10	54.09	100
11	61.78	100
12	64.77	100
13	64.77	100
14	65.49	100
15	86.06	100

Table 34

I-WH2		
Industrial Warehouse 2-Story		
Stage	Structure	Content
-8	0	0
-7	0	0
-6	0	0
-5	0	0
-4	0	0
-3	0	0
-2	0	0
-1	0	0
-0.5	2.5	0
0	5	0
0.5	10.1	19.83
1	15.26	40.4
1.5	17.1	49.41
2	18.88	55.97
3	21.48	55.97
4	22.8	55.97
5	22.8	55.97
6	24.05	55.97
7	26.1	55.97
8	40.4	66.87
9	43.25	66.87
10	46.2	66.87
11	46.2	69.29
12	49.05	96.33
13	49.05	100
14	55.16	100
15	80.05	100

Table 35

P-CH1		
Public Church 1-Story		
Stage	Structure	Content
-8	0	0
-7	0	0
-6	0	0
-5	0	0
-4	0	0
-3	0	0
-2	0	0
-1	0	0
-0.5	3.5	0
0	7	0
0.5	14.4	47.33
1	21.73	73.35
1.5	26	83.86
2	30.19	98.82
3	31.22	98.82
4	32.44	98.82
5	32.44	98.82
6	39.82	98.82
7	42.76	98.82
8	51.72	98.82
9	53.1	98.82
10	54.09	98.82
11	61.78	98.82
12	64.77	100
13	64.77	100
14	65.49	100
15	86.06	100

Table 36

P-CH2		
Public Church 2-Story		
Stage	Structure	Content
-8	0	0
-7	0	0
-6	0	0
-5	0	0
-4	0	0
-3	0	0
-2	0	0
-1	0	0
-0.5	2.5	0
0	5	0
0.5	10.1	22.71
1	15.26	35.2
1.5	17.1	43.88
2	18.88	55.31
3	21.48	55.31
4	22.8	55.31
5	22.8	55.31
6	24.05	55.31
7	26.1	55.31
8	40.4	66.08
9	43.25	66.08
10	46.2	66.08
11	46.2	68.47
12	49.05	96.33
13	49.05	100
14	55.16	100
15	80.05	100

Table 37

P-GOV1		
Public Government Building 1-Story		
Stage	Structure	Content
-8	0	0
-7	0	0
-6	0	0
-5	0	0
-4	0	0
-3	0	0
-2	0	0
-1	0	0
-0.5	3.5	0
0	7	0
0.5	14.4	48.39
1	21.73	96.78
1.5	26	100
2	30.19	100
3	31.22	100
4	32.44	100
5	32.44	100
6	39.82	100
7	42.76	100
8	51.72	100
9	53.1	100
10	54.09	100
11	61.78	100
12	64.77	100
13	64.77	100
14	65.49	100
15	86.06	100

Table 38

P-GOV2		
Public Government Building 1-Story		
Stage	Structure	Content
-8	0	0
-7	0	0
-6	0	0
-5	0	0
-4	0	0
-3	0	0
-2	0	0
-1	0	0
-0.5	2.5	0
0	5	0
0.5	10.1	40.87
1	15.26	45.43
1.5	17.1	51.23
2	18.88	55.88
3	21.48	55.88
4	22.8	55.88
5	22.8	55.88
6	24.05	55.88
7	26.1	55.88
8	40.4	68.08
9	43.25	68.08
10	46.2	68.08
11	46.2	69.4
12	49.05	100
13	49.05	100
14	55.16	100
15	80.05	100

Table 39

P-REC1		
Public Recreation/Assembly 1-Story		
Stage	Structure	Content
-8	0	0
-7	0	0
-6	0	0
-5	0	0
-4	0	0
-3	0	0
-2	0	0
-1	0	0
-0.5	3.5	0
0	7	0
0.5	14.4	50
1	21.73	97.95
1.5	26	100
2	30.19	100
3	31.22	100
4	32.44	100
5	32.44	100
6	39.82	100
7	42.76	100
8	51.72	100
9	53.1	100
10	54.09	100
11	61.78	100
12	64.77	100
13	64.77	100
14	65.49	100
15	86.06	100

Table 40

P-REC2		
Public Recreation/Assembly 2-Story		
Stage	Structure	Content
-8	0	0
-7	0	0
-6	0	0
-5	0	0
-4	0	0
-3	0	0
-2	0	0
-1	0	0
-0.5	2.5	0
0	5	0
0.5	10.1	24
1	15.26	47.01
1.5	17.1	52.33
2	18.88	55.97
3	21.48	55.97
4	22.8	55.97
5	22.8	55.97
6	24.05	55.97
7	26.1	55.97
8	40.4	66.87
9	43.25	66.87
10	46.2	66.87
11	46.2	69.29
12	49.05	96.33
13	49.05	100
14	55.16	100
15	80.05	100

Table 41

P-SCH1		
Public and Private Schools 1-Story		
Stage	Structure	Content
-8	0	0
-7	0	0
-6	0	0
-5	0	0
-4	0	0
-3	0	0
-2	0	0
-1	0	0
-0.5	3.5	0
0	7	0
0.5	14.4	50
1	21.73	87.78
1.5	26	100
2	30.19	100
3	31.22	100
4	32.44	100
5	32.44	100
6	39.82	100
7	42.76	100
8	51.72	100
9	53.1	100
10	54.09	100
11	61.78	100
12	64.77	100
13	64.77	100
14	65.49	100
15	86.06	100

Table 42

P-SCH2		
Public and Private Schools 2-Story		
Stage	Structure	Content
-8	0	0
-7	0	0
-6	0	0
-5	0	0
-4	0	0
-3	0	0
-2	0	0
-1	0	0
-0.5	2.5	0
0	5	0
0.5	10.1	24
1	15.26	42.12
1.5	17.1	52.33
2	18.88	55.97
3	21.48	55.97
4	22.8	55.97
5	22.8	55.97
6	24.05	55.97
7	26.1	55.97
8	40.4	66.87
9	43.25	66.87
10	46.2	66.87
11	46.2	69.29
12	49.05	96.33
13	49.05	100
14	55.16	100
15	80.05	100

Table 43

FARM		
Farm Buildings Including Primary RES		
Stage	Structure	Content
-8	0	0
-7	0	0
-6	0	0
-5	0	0
-4	0	0
-3	0	0
-2	0	0
-1	0	0
-0.5	3.5	0
0	7	0
0.5	14.4	29.67
1	21.73	56.23
1.5	26	69.84
2	30.19	93.46
3	31.22	99.58
4	32.44	100
5	32.44	100
6	39.82	100
7	42.76	100
8	51.72	100
9	53.1	100
10	54.09	100
11	61.78	100
12	64.77	100
13	64.77	100
14	65.49	100
15	86.06	100

Table 44

SFRB1		
Single Family Residential 1-story W/Basement		
Stage	Structure	Content
-8	0	0
-7	0	0
-6	0	0
-5	0	0
-4	5.2	5.7
-3	9	8
-2	13.8	10.5
-1	19.4	13.2
-0.5	22.5	14.6
0	25.5	16
0.5	28.8	17.5
1	32	18.9
1.5	35.4	20.4
2	38.7	21.8
3	45.5	24.7
4	52.2	27.4
5	58.6	30
6	64.5	32.4
7	69.8	34.5
8	74.2	36.3
9	77.7	37.7
10	80.1	38.6
11	81.1	39.1
12	81.1	39.1
13	81.1	39.1
14	81.1	39.1
15	81.1	39.1

Table 45

SFRB2		
Single Family Residential 2-story W/Basement		
Stage	Structure	Content
-8	0	0
-7	0	0
-6	0	0
-5	0	0
-4	4.7	5.2
-3	7.2	6.8
-2	10.2	8.4
-1	13.9	10.1
-0.5	15.9	11
0	17.9	11.9
0.5	20.1	12.9
1	22.3	13.8
1.5	24.7	14.8
2	27	15.7
3	31.9	17.7
4	36.9	19.8
5	41.9	22
6	46.9	24.3
7	51.8	26.7
8	56.4	29.1
9	60.8	31.7
10	64.8	34.4
11	68.4	37.2
12	71.4	40
13	73.7	43
14	75.4	46.1
15	76.4	49.3

Table 46

SFRBS		
Single Family Residential Split-Level W/Basement		
Stage	Structure	Content
-8	0	0
-7	0	0
-6	0	0
-5	0	0
-4	4.7	3.8
-3	7.2	5.4
-2	10.4	7.3
-1	14.2	9.4
-0.5	16.4	10.5
0	18.5	11.6
0.5	20.9	12.7
1	23.2	13.8
1.5	25.7	15
2	28.2	16.1
3	33.4	18.2
4	38.6	20.2
5	43.8	22.1
6	48.8	23.6
7	53.5	24.9
8	57.8	25.8
9	61.6	26.3
10	64.8	26.3
11	67.2	26.3
12	68.8	26.3
13	69.3	26.3
14	69.3	26.3
15	69.3	26.3

Table 47

SFR1		
Single Family Residential 1-Story		
Stage	Structure	Content
-8	0	0
-7	0	0
-6	0	0
-5	0	0
-4	0	0
-3	0	0
-2	0	0
-1	2.5	2.4
-0.5	8	5.3
0	13.4	8.1
0.5	18.4	10.7
1	23.3	13.3
1.5	27.7	15.6
2	32.1	17.9
3	40.1	22
4	47.1	25.7
5	53.2	28.8
6	58.6	31.5
7	63.2	33.8
8	67.2	35.7
9	70.5	37.2
10	73.2	38.4
11	75.4	39.2
12	77.2	39.7
13	78.5	40
14	79.5	40
15	80.2	40

Table 48

SFR2		
Single Family Residential 2-Story		
Stage	Structure	Content
-8	0	0
-7	0	0
-6	0	0
-5	0	0
-4	0	0
-3	0	0
-2	0	0
-1	3	1
-0.5	6.2	3
0	9.3	5
0.5	12.3	6.9
1	15.2	8.7
1.5	18.1	10.5
2	20.9	12.2
3	26.3	15.5
4	31.4	18.5
5	36.2	21.3
6	40.7	23.9
7	44.9	26.3
8	48.8	28.4
9	52.4	30.3
10	55.7	32
11	58.7	33.4
12	61.4	34.7
13	63.8	35.6
14	65.9	36.4
15	67.7	36.9

Table 49

SFRS		
Single Family Residential Split-Level		
Stage	Structure	Content
-8	0	0
-7	0	0
-6	0	0
-5	0	0
-4	0	0
-3	0	0
-2	0	0
-1	6.4	2.2
-0.5	6.8	2.6
0	7.2	2.9
0.5	8.3	3.8
1	9.4	4.7
1.5	11.2	6.1
2	12.9	7.5
3	17.4	11.1
4	22.8	15.3
5	28.9	20.1
6	35.5	25.2
7	42.3	30.5
8	49.2	35.7
9	56.1	40.9
10	62.6	45.8
11	68.6	50.2
12	73.9	54.1
13	78.4	57.2
14	81.7	59.4
15	83.8	60.5

Table 50

MFR1		
Multi-Family Residential 1-Story		
Stage	Structure	Content
-8	0	0
-7	0	0
-6	0	0
-5	0	0
-4	0	0
-3	0	0
-2	0	0
-1	2.5	2.4
-0.5	8	5.3
0	13.4	8.1
0.5	18.4	10.7
1	23.3	13.3
1.5	27.7	15.6
2	32.1	17.9
3	40.1	22
4	47.1	25.7
5	53.2	28.8
6	58.6	31.5
7	63.2	33.8
8	67.2	35.7
9	70.5	37.2
10	73.2	38.4
11	75.4	39.2
12	77.2	39.7
13	78.5	40
14	79.5	40
15	80.2	40

Table 51

MFR2		
Multi-Family Residential 2-Story		
Stage	Structure	Content
-8	0	0
-7	0	0
-6	0	0
-5	0	0
-4	0	0
-3	0	0
-2	0	0
-1	3	1
-0.5	6.2	3
0	9.3	5
0.5	12.3	6.9
1	15.2	8.7
1.5	18.1	10.5
2	20.9	12.2
3	26.3	15.5
4	31.4	18.5
5	36.2	21.3
6	40.7	23.9
7	44.9	26.3
8	48.8	28.4
9	52.4	30.3
10	55.7	32
11	58.7	33.4
12	61.4	34.7
13	63.8	35.6
14	65.9	36.4
15	67.7	36.9

Table 52

MH		
Mobile Home Single/Double		
Stage	Structure	Content
-8	0	0
-7	0	0
-6	0	0
-5	0	0
-4	0	0
-3	0	0
-2	0	0
-1	6.4	0
-0.5	7.3	0
0	9.9	0
0.5	43.4	85
1	44.7	85
1.5	45	90
2	45.7	95
3	96.5	99
4	96.5	99
5	96.5	99
6	96.5	99
7	96.5	99
8	96.5	99
9	96.5	99
10	96.5	99
11	96.5	99
12	96.5	99
13	96.5	99
14	96.5	99
15	96.5	99

Table 53

AUTO		
Automobiles		
Stage	Structure	Content
-8	0	0
-7	0	0
-6	0	0
-5	0	0
-4	0	0
-3	0	0
-2	0	0
-1	0	0
-0.5	0	0
0	0	0
0.5	2.8	0
1	21.8	0
1.5	31.15	0
2	40.5	0
3	56.9	0
4	71.1	0
5	83.2	0
6	91.9	0
7	96.1	0
8	99.2	0
9	100	0
10	100	0
11	100	0
12	100	0
13	100	0
14	100	0
15	100	0

NAT A Project Performance Results

PLAN NAME	STREAM NAME	DAMAGE REACH NAME	DAMAGE REACH DESCRIPTION	TARGET STAGE	TARGET STAGE ANNUAL EXCEEDANCE PROBABILITY	LONG-TERM RISK (YEARS)			CONDITIONAL NON-EXCEEDANCE PROBABILITY BY EVENTS					
					Expected	10	30	50	10%	4%	2%	1%	0.4%	0.2%
Without	Sac River	Natomas A	RM 62.7519	levee	0.2117	.2029	.8965	.9966	1.000	.3610	.2258	.1850	.1429	.0588
Fix 1	Sac River	Natomas A	RM 62.7519	levee	0.0071	.0071	.0693	.1643	.3015	.9799	.9661	.9580	.9457	.8115
Fix 2	Sac River	Natomas A	RM 62.7519	levee	0.0071	.0071	.0693	.1643	.3015	.9799	.9661	.9580	.9457	.8115
Levee Raise 1	Sac River	Natomas A	RM 62.7519	levee	0.0056	.0032	.0312	.0762	.1466	.9935	.9731	.9647	.9521	.8406

NAT B Project Performance Results

PLAN NAME	STREAM NAME	DAMAGE REACH NAME	DAMAGE REACH DESCRIPTION	TARGET STAGE	TARGET STAGE ANNUAL EXCEEDANCE PROBABILITY	LONG-TERM RISK (YEARS)			CONDITIONAL NON-EXCEEDANCE PROBABILITY BY EVENTS					
					Expected	10	30	50	10%	4%	2%	1%	0.4%	0.2%
Without	Sac River	Natomas B	RM 69.2511	levee	.1183	.7162	.9571	.9982	.7048	.5913	.5629	.4881	.3522	.2894
Fix 1	Sac River	Natomas B	RM 69.2511	levee	.0166	.1539	.3414	.5663	.9557	.8499	.8178	.7255	.5715	.5009
Fix 2	Sac River	Natomas B	RM 69.2511	levee	.0355	.3036	.5953	.8362	.9102	.7901	.7557	.6645	.5178	.4526
Fix 3	Sac River	Natomas B	RM 69.2511	levee	.0166	.1539	.3414	.5663	.9557	.8499	.8178	.7255	.5715	.5009
Levee Raise 1	Sac River	Natomas B	RM 69.2511	levee	.0059	.0578	.1384	.2576	.9658	.8508	.8171	.7230	.5673	.4980

NAT C Project Performance Results

PLAN NAME	STREAM NAME	DAMAGE REACH NAME	DAMAGE REACH DESCRIPTION	TARGET STAGE	TARGET STAGE ANNUAL EXCEEDANCE PROBABILITY	LONG-TERM RISK (YEARS)			CONDITIONAL NON-EXCEEDANCE PROBABILITY BY EVENTS					
					Expected	10	30	50	10%	4%	2%	1%	0.4%	0.2%
Without	Sac River	Natomas C	RM 79	levee	.0406	.3397	.6457	.8744	.8522	.7344	.7080	.6352	.4825	.4044
Fix 1	Sac River	Natomas C	RM 79	levee	.0171	.1581	.3496	.5769	.9494	.8833	.8639	.8056	.6527	.5651
Fix 2	Sac River	Natomas C	RM 79	levee	.0099	.0951	.2210	.3932	.9769	.9291	.9121	.8580	.7061	.6148
Fix 3	Sac River	Natomas C	RM 79	levee	.0073	.0709	.1680	.3077	.9866	.9549	.9437	.8974	.6869	.5322
Levee Raise 1	Sac River	Natomas C	RM 79	levee	.0046	.0452	.1091	.2063	.9996	.9559	.9378	.8883	.7908	.7298
Levee Raise 2	Sac River	Natomas C	RM 79	levee	****	****	****	****	****	****	****	****	****	****
Levee Raise 3	Sac River	Natomas C	RM 79	levee	****	****	****	****	****	****	****	****	****	****

NAT D Project Performance Results

PLAN NAME	STREAM NAME	DAMAGE REACH NAME	DAMAGE REACH DESCRIPTION	TARGET STAGE	TARGET STAGE ANNUAL EXCEEDANCE PROBABILITY	LONG-TERM RISK (YEARS)			CONDITIONAL NON-EXCEEDANCE PROBABILITY BY EVENTS					
					Expected	10	30	50	10%	4%	2%	1%	0.4%	0.2%
Without	Sac River	Natomas D	NCC	levee	.2061	.9005	.9969	1.000	.4251	.2690	.2121	.1532	.0808	.5920
Fix 1	Sac River	Natomas D	NCC	levee	.0155	.1444	.3228	.5414	.9644	.9203	.8806	.8051	.5993	.5038
Fix 2	Sac River	Natomas D	NCC	levee	.1550	.1444	.3228	.5414	.9644	.9203	.8806	.8051	.5993	.5038
Levee Raise 1	Sac River	Natomas D	NCC	levee	.0053	.0517	.1244	.2333	.9834	.9365	.9011	.8382	.6714	.5935
Levee Raise 2	Sac River	Natomas D	NCC	levee	****	****	****	****	****	****	****	****	****	****
Levee Raise 3	Sac River	Natomas D	NCC	levee	****	****	****	****	****	****	****	****	****	****
Levee Raise 4	Sac River	Natomas D	NCC	levee	****	****	****	****	****	****	****	****	****	****

NAT E Project Performance Results

PLAN NAME	STREAM NAME	DAMAGE REACH NAME	DAMAGE REACH DESCRIPTION	TARGET STAGE	TARGET STAGE ANNUAL EXCEEDANCE PROBABILITY	LONG-TERM RISK (YEARS)			CONDITIONAL NON-EXCEEDANCE PROBABILITY BY EVENTS					
					Expected	10	30	50	10%	4%	2%	1%	0.4%	0.2%
Without	Sac River	Natomas E	@ PGCC	levee	.1751	.8542	.9919	.9999	.4581	.2814	.2159	.1501	.0733	.0460
Fix 1	Sac River	Natomas E	@ PGCC	levee	.0194	.1782	.3877	.6251	.9585	.9338	.9073	.8582	.7080	.6243
Levee Raise 1	Sac River	Natomas E	@ PGCC	levee	.0071	.0691	.1639	.3010	.9693	.9358	.9065	.8569	.7040	.6220
Levee Raise 2	Sac River	Natomas E	@ PGCC	levee	.0014	.0140	.0346	.0681	.9980	.9733	.9406	.8847	.7155	.6296

NAT F Project Performance Results

PLAN NAME	STREAM NAME	DAMAGE REACH NAME	DAMAGE REACH DESCRIPTION	TARGET STAGE	TARGET STAGE ANNUAL EXCEEDANCE PROBABILITY	LONG-TERM RISK (YEARS)			CONDITIONAL NON-EXCEEDANCE PROBABILITY BY EVENTS					
					Expected	10	30	50	10%	4%	2%	1%	0.4%	0.2%
Without	Sac River	Natomas F	PGCC	levee	.3034	.9731	.9999	1.000	.4113	.2473	.1617	.1135	.0608	.0019
Fix 1	Sac River	Natomas F	PGCC	levee	.0226	.2046	.4357	.6815	.9586	.9562	.9562	.9560	.9382	.4994
Fix 2	Sac River	Natomas F	PGCC	levee	.0450	.3693	.6840	.9002	.9138	.9089	.9088	.9086	.8892	.4647
Levee Raise 1	Sac River	Natomas F	PGCC	levee	.0015	.0146	.0362	.0711	1.000	1.000	1.000	.9999	.9921	.6827
Levee Raise 2	****	****	****	****	****	****	****	****	****	****	****	****	****	****
Levee Raise 3	****	****	****	****	****	****	****	****	****	****	****	****	****	****

NAT G Project Performance Results

PLAN NAME	STREAM NAME	DAMAGE REACH NAME	DAMAGE REACH DESCRIPTION	TARGET STAGE	TARGET STAGE ANNUAL EXCEEDANCE PROBABILITY	LONG-TERM RISK (YEARS)			CONDITIONAL NON-EXCEEDANCE PROBABILITY BY EVENTS					
					Expected	10	30	50	10%	4%	2%	1%	0.4%	0.2%
Without	Sac River	Natomas G	NEMDC	levee	.2024	.8958	.9965	1.000	.5367	.4688	.4267	.3719	.2773	.1748
Fix 1	Sac River	Natomas G	NEMDC	levee	.0061	.5900	.1410	.2621	.9901	.9847	.9749	.9320	.7070	.2469
Levee Raise 1	Sac River	Natomas G	NEMDC	levee	.0044	.0434	.1051	.1991	.9920	.9885	.9863	.9746	.8451	.4015
Levee Raise 2	Sac River	Natomas G	NEMDC	levee	****	****	****	****	****	****	****	****	****	****
Levee Raise 3	Sac River	Natomas G	NEMDC	levee	****	****	****	****	****	****	****	****	****	****
Levee Raise 4	Sac River	Natomas G	NEMDC	levee	****	****	****	****	****	****	****	****	****	****

NAT H Project Performance Results

PLAN NAME	STREAM NAME	DAMAGE REACH NAME	DAMAGE REACH DESCRIPTION	TARGET STAGE	TARGET STAGE ANNUAL EXCEEDANCE PROBABILITY	LONG-TERM RISK (YEARS)			CONDITIONAL NON-EXCEEDANCE PROBABILITY BY EVENTS					
					Expected	10	30	50	10%	4%	2%	1%	0.4%	0.2%
Without	Sac River	Natomas H	NEMDC	levee	.0420	.3491	.6581	.8831	.8525	.7299	.6746	.5773	.4046	.1336
Fix 1	Sac River	Natomas H	NEMDC	levee	.0042	.0411	.0997	.1895	.9943	.9897	.9832	.9666	.8686	.3992
Fix 2	Sac River	Natomas H	NEMDC	levee	.0042	.0411	.0997	.1895	.9943	.9897	.9832	.9666	.8686	.3992
Levee Raise 1	Sac River	Natomas H	NEMDC	levee	.0022	.0223	.0548	.1067	1.000	1.000	1.000	.9994	.9302	.4472

NAT I Project Performance Results

PLAN NAME	STREAM NAME	DAMAGE REACH NAME	DAMAGE REACH DESCRIPTION	TARGET STAGE	TARGET STAGE ANNUAL EXCEEDANCE PROBABILITY	LONG-TERM RISK (YEARS)			CONDITIONAL NON-EXCEEDANCE PROBABILITY BY EVENTS					
					Expected	10	30	50	10%	4%	2%	1%	0.4%	0.2%
Without	Sac River	Natomas I	AR	levee	.0152	.1420	.3180	.5349	.9416	.9020	.8926	.8883	.7503	.3705
Fix 1	Sac River	Natomas I	AR	levee	.0081	.0782	.1841	.3343	.9756	.9665	.9647	.9639	.9064	.1344
Fix 2	Sac River	Natomas I	AR	levee	.0081	.0782	.1841	.3343	.9756	.9665	.9647	.9639	.9064	.1344
Levee Raise 1	Sac River	Natomas I	AR	levee	.0015	.0149	.0370	.0725	.9999	.9792	.9753	.9738	.9407	.5640

Incremental Project Performance
Major Area

PLAN NAME	STREAM NAME	DAMAGE REACH NAME	DAMAGE REACH DESCRIPTION	TARGET STAGE	TARGET STAGE ANNUAL EXCEEDANCE PROBABILITY	LONG-TERM RISK (YEARS)			CONDITIONAL NON-EXCEEDANCE PROBABILITY BY EVENTS					
					Expected	10	30	50	10%	4%	2%	1%	0.4%	0.2%
Without	Sac River	+Nat D	NCC	levee	.21	.9005	.9969	1.0000	.4251	.2691	.2123	.1534	.0811	.0595
Fix D cip A(.21)	Sac River	+Nat D	NCC	levee	.21	.9073	.9974	1.0000	.3609	.2258	.1850	.1429	.0588	.0267
Fix A cip E (.18)	Sac River	+Nat D	NCC	levee	.18	.8673	.9936	1.0000	.3691	.2335	.1937	.1541	.0784	.0586
Fix E cip B (.12)	Sac River	+Nat D	NCC	levee	.11	.6827	.9433	.9968	.7036	.5862	.5588	.4874	.3470	.2820
Fix B cip C (.04)	Sac River	+Nat D	NCC	levee	.04	.3421	.6489	.8767	.8509	.7333	.7068	.6344	.4815	.4035
Fix C cip H (.04)	Sac River	+Nat D	NCC	levee	.04	.3503	.6598	.8843	.8526	.7298	.6738	.5780	.4053	.1362
Fix H cip D(.015)	Sac River	+Nat D	NCC	levee	.015	.1405	.3151	.5309	.9656	.9193	.8795	.8034	.5983	.5027
Raise B cip E (.019)	Sac River	+Nat D	NCC	levee	.0189	.1733	.3786	.6139	.9581	.9330	.9059	.8583	.7050	.6232
Raise E cip E (.007)	Sac River	+Nat D	NCC	levee	.0071	.0685	.1626	.2987	.9697	.9365	.9078	.8592	.7052	.6233
Raise D icp B (.019)	Sac River	+Nat D	NCC	levee	.0211	.1919	.4130	.6554	.9620	.9102	.8949	.8552	.7896	.7621
Raise B icp I (.016)	Sac River	+Nat D	NCC	levee	.0164	.1521	.3380	.5618	.9426	.8999	.8906	.8862	.7521	.3979
Fix I icp E (.02)	Sac River	+Nat D	NCC	levee	.0189	.1733	.3786	.6139	.9581	.9330	.9059	.8583	.7050	.6232

Incremental Project Performance
Minor Area

PLAN NAME	STREAM NAME	DAMAGE REACH NAME	DAMAGE REACH DESCRIPTION	TARGET STAGE	TARGET STAGE ANNUAL EXCEEDANCE PROBABILITY	LONG-TERM RISK (YEARS)			CONDITIONAL NON-EXCEEDANCE PROBABILITY BY EVENTS					
					Expected	10	30	50	10%	4%	2%	1%	0.4%	0.2%
Without	Sac River	NAT F PGCC	PGCC	levee	.30	.9715	.9999	1.000	.4156	.2508	.1655	.1166	.0619	.0201
Fix D	Sac River	NAT F PGCC	PGCC	levee	.30	.9715	.9999	1.000	.4156	.2508	.1655	.1166	.0619	.0201
Fix A	Sac River	NAT F PGCC	PGCC	levee	.30	.9715	.9999	1.000	.4156	.2508	.1655	.1166	.0619	.0201
Fix E	Sac River	NAT F PGCC	PGCC	levee	.30	.9715	.9999	1.000	.4156	.2508	.1655	.1166	.0619	.0201
Fix B	Sac River	NAT F PGCC	PGCC	levee	.30	.9735	.9999	1.000	.4192	.2513	.1658	.1158	.0615	.0194
Fix C	Sac River	NAT F PGCC	PGCC	levee	.30	.9732	.9999	1.000	.4183	.2507	.1655	.1153	.0614	.0194
Fix H	Sac River	NAT F PGCC	PGCC	levee	.30	.9732	.9999	1.000	.4183	.2507	.1655	.1153	.0614	.0194
Fix G	Sac River	NAT F PGCC	PGCC	levee	.30	.9739	.9999	1.000	.4139	.2491	.1642	.1146	.0605	.0190
Fix F	Sac River	NAT F PGCC	PGCC	levee	.023	.2096	.4446	.6916	.9578	.9551	.9550	.9548	.9364	.5178
Raise F-1	Sac River	NAT F PGCC	PGCC	levee	.001	.0056	.0139	.0276	1.000	1.000	1.000	1.000	.9919	.6821
Raise F-2	Sac River	NAT F PGCC	PGCC	levee	.001	.0056	.0139	.0276	1.000	1.000	1.000	1.000	.9919	.6821

ENCLOSURE 3
MEMORANDUM FOR FILE DOCUMENTING POST-F3 CONFERENCE SENSITIVITY ANALYSIS

CESPK-PD-WE **SEPTEMBER 2009**

MEMORANDUM FOR FILE

SUBJECT: American River – Common Features (Natomas Basin)
- Revised Expected Annual Damages (EAD) Results
- Revised Annual Exceedance Probability (AEP) Results
- Geotechnical Fragility Curve Sensitivity Analysis
- Probability-Stage Curve Sensitivity Analysis

1. PURPOSE

The purposes of this memorandum are to 1) describe the effect on expected annual damages (EAD) and annual exceedance probability (AEP) in the Natomas Basin impact area due to revisions to the HEC-FDA engineering input data and to report the updated without-project (F3) EAD and AEP numbers 2) document the sensitivity analysis performed to determine the impact on EAD/AEP from changes to the fragility curve 3) document the sensitivity analysis performed to determine whether or not upstream levee failures (as measured by reductions in stages at the Natomas index point) have a significant impact on EAD and AEP results. Key points are:

- A revision was made to the geotechnical fragility curve used as input into the economic analysis and EAD/AEP computations; this curve represents the probability of poor performance at various water surface elevations and has been revised based on information obtained from a geotechnical expert elicitation panel conference held at the Corps' Sacramento District office in June 2009. More information about this conference can be obtained from the Geotechnical Section (USACE Sacramento District).

- Based on updated geotechnical fragility and probability-stage curves, updated without-project floodplains, and the addition of an economic damage category (automobiles), revised without-project EAD for the Natomas Basin impact area is estimated to be approximately $262 million (compared to $2.4 billion reported in the F3 Economic Appendix); AEP is estimated to be .0398 (compared to .3856 as previously reported). These results and input data served as the baseline for performing the sensitivity analysis.

- A sensitivity analysis was performed using a modified fragility curve, in which the probabilities of poor performance at water surface elevations at the landside levee toe, 6 feet above the landside levee toe elevation, and 9 feet above the landside levee toe elevation have a risk reduction of 50%, 30%, and 10%, respectively. Expected annual damages and AEP results did change with these modifications to the probability of failure values, but only minimally.

- A sensitivity analysis (i.e., modifications to the probability-stage curve used as input into the economic analysis and EAD/AEP computations) was performed to gage the effects these changes would have on EAD and AEP. A modified probability-stage curve, which incorporated changes to stages at the Natomas index point (river mile 79 near Verona) due to levee failures at locations upstream of the Natomas index point, was based on levee failures that actually occurred during past flooding events. A second modified probability-stage curve, which does not have any historical basis, was used as an additional test to see the effects even greater stage changes (than what has actually been seen during past flooding events) have on EAD/AEP. Both sensitivity tests demonstrated that nominal changes to stages in the probability-stage curve to account for possible upstream levee failures only have negligible impacts on EAD and AEP results.

2. CHANGES TO EAD/AEP

Revisions to the HEC-FDA input data, including the probability-stage curve and the geotechnical fragility curve, have resulted in changes to EAD and AEP originally reported in the F3 Economic Appendix. The following sections describe how revisions to the HEC-FDA input data have resulted in changes to the EAD and AEP results.

a. Original F3 Analysis

The F3 analysis resulted in an EAD of approximately $2.4 billion and an AEP of .3856, or about a 39% chance of flooding in any given year. The analysis used the following probability-stage and geotechnical fragility curves:

Table PS-1
Original F3 Analysis
Probability-Stage Curve

EXCEEDANCE PROBABILITY	EXTERIOR STAGE (NGVD 29, FT)
.999	32.3
.500	33.8
.100	36.01
.040	37.93
.020	38.74
.010	39.81
.005	40.61
.002	41.07

Table GF-1
Original F3 Analysis
Geotechnical Fragility Curve (Sacramento River Mile 79)

EXTERIOR STAGE (NGVD 29, FT)	PROBABILITY OF FAILURE
33	.23
36	.51
39	.82
42	.98

It is important to note that the elevations used in both the probability-stage and geotechnical fragility curves for the original F3 analysis were in NGVD 29. The HEC-RAS data (probability-stage curve) was developed using NGVD 29 datum; the geotechnical fragility curve was developed using NAVD 88 datum and then converted to NGVD 29 to be consistent with the elevation data in the probability-stage curve.

b. Revision to .999 Probability Stage on the Probability-Stage Curve

Subsequent to the F3 analysis and conference, it was determined that the .999 probability stage (32.3) used in the analysis was incorrect. This value was estimated by the Economics and Risk Analysis Section through extrapolation using the FDA graphical plot of the probability-stage curve. In most analyses the .999 probability stage does not have a significant impact on EAD and AEP since flooding in most urban areas does not occur from such high frequency events (e.g., 1-year to 5-year events). However, the Natomas area differs in that, at the time of the F3 analysis, there was a relatively high probability of levee failure from high frequency (low stage) events, as reflected in the geotechnical fragility curve. In order to isolate the effects the .999 probability stage change has on EAD and AEP, the .999 probability stage value in the probability-stage curve was changed from 32.3 to 22.8 and the original geotechnical fragility curve was not changed:

Table PS-2
Original F3 Analysis
Probability-Stage Curve

EXCEEDANCE PROBABILITY	EXTERIOR STAGE (NGVD 29, FT)
.999	**22.8**
.500	33.8
.100	36.01
.040	37.93
.020	38.74
.010	39.81
.005	40.61
.002	41.07

Table GF-2
Original F3 Analysis
Geotechnical Fragility Curve (Sacramento River Mile 79)

EXTERIOR STAGE (NGVD 29, FT)	PROBABILITY OF FAILURE
33	.23
36	.51
39	.82
42	.98

With this change in the .999 probability stage, EAD is reduced to approximately $1.61 billion (from $2.4 billion) and AEP is reduced to .2541 (from .3856), or about a 25% chance of flooding in any given year.

c. Updated Probability-Stage Curve (NAVD 88), Geotechnical Fragility Curve (NAVD 88) and Without-Project Floodplains, and the Inclusion of Automobile Damages in the Economics

Following the F3 conference, updated probability-stage (NAVD 88) and geotechnical fragility (NAVD 88) curves were developed and used within the economic model (HEC-FDA) to compute EAD and AEP. These curves are shown below in Tables PS-3 and GF-3, respectively.

Also, without-project floodplains were also updated for this analysis based on new assumptions regarding breach size and timing. A more detailed description of the assumptions used to generate the without-project floodplains can be obtained from the Hydraulic Design Section (USACE Sacramento District).

Finally, automobiles were added to the economic inventory for the Natomas Basin impact area. This damage category had been left out of the F3 analysis. Automobile damages increase total EAD by approximately 5%.

Table PS-3
Revised F3 Analysis
Probability-Stage Curve

EXCEEDANCE PROBABILITY	EXTERIOR STAGE (NAVD 88, FT)
.999	20.16
.500	33.36
.100	38.42
.040	40.36
.020	41.15
.010	42.14
.005	43.50
.002	44.49

Table GF-3
Geotechnical Fragility Curve (Sacramento River Mile 79)

EXTERIOR STAGE (NAVD 88, FT)	PROBABILITY OF FAILURE
36.4	.066
39.4	.167
41.4	.324
44.4	.500

Using these curves in the analysis resulted in an EAD of $262 million and an AEP of .0398, or about a 4% chance of flooding in any given year. The revised curves represent the current state of the analysis and will serve as the baseline for performing the sensitivity analysis (i.e., impact to EAD and AEP) associated with modifications to the geotechnical fragility and probability-stage curves. The sensitivity analysis is described in the following sections.

3. SENSITIVITY ANALYSIS

Sensitivity analyses were performed to see the effect modifications to the geotechnical fragility curve and probability-stage curve has on EAD and AEP results. The most current curves (Tables PS-3 and GF-3) were used as the baseline data.

a. Geotechnical Fragility Curve

A modified geotechnical fragility curve was developed to represent the actual risk of levee failure (versus poor performance) at specific water surface elevations. The modified curve assumed a 50% risk reduction at the landside levee toe elevation, a 30% risk reduction at 6 feet above the landside levee toe, and a 10% risk reduction at 9 feet above the landside levee toe. Table GF-4 displays this curve along side the baseline fragility curve.

Table GF-4
Geotechnical Fragility Curves (Sacramento River Mile 79)

POOR PERFORMANCE		RISK OF FAILURE	
Exterior Stage (NAVD 88)	P(f)	Exterior Stage (NAVD 88)	P(f)
36.4	.066	36.4	.046
39.4	.167	39.4	.151
41.4	.324	41.4	.324
44.4	.500	44.4	.500

The modifications to the fragility curve show a minimal impact on EAD and AEP results. Expected annual damages are estimated to be $240 million and AEP is estimated to be .0363. This compares to the baseline results of $262 million and .0398.

b. Probability-Stage Curve

Modifications to the probability-stage curve were made to account for the effects on index point stages from possible upstream levee failures. Reductions in stages at the Natomas index point were based on empirical data from historical upstream levee failures that occurred during past flood events. For more details regarding the methodology used to generate the historical probability-stage curves please refer to the memo from the Hydraulic Design Section.

Two modified probability-stage curves were run for the sensitivity analysis. In the first run, stages associated with probability events at or above the .01 probability event were reduced by .37 feet. This modification was based on empirical data from historical upstream levee failures that occurred during past flood events. The modified probability curve is shown in Table PS-4 below. The baseline geotechnical fragility curve, re-displayed in Table GF-5, was used for this analysis.

Table PS-4
Sensitivity Analysis
Probability-Stage Curve
Constant .37 Feet Reduction in Stages at or above .01 Probability Event

EXCEEDANCE PROBABILITY	STAGE (NAVD 88, FT)
.999	20.16
.500	33.36
.100	38.42
.040	40.36
.020	41.15
.010	41.77
.005	43.13
.002	44.12

Table GF-5
Geotechnical Fragility Curve (Sacramento River Mile 79)

EXTERIOR STAGE (NAVD 88, FT)	PROBABILITY OF FAILURE
36.4	.066
39.4	.167
41.4	.324
44.4	.500

These changes resulted in an EAD of $258 million and an AEP of .0392 -- suggesting only negligible impacts on EAD and AEP when compared to the baseline EAD and AEP results ($262 million, .0398).

In the second run, stages associated with probability events at or above the .01 probability event were reduced by an increasing factor of .37 feet. This modified probability-stage curve does not have an historical basis but was used primarily as an additional sensitivity test. The modified probability-stage curve is shown in Table PS-5 below. As in the first run, the baseline geotechnical fragility curve was used in the analysis (Table GF-5).

Table PS-5
Sensitivity Analysis
Probability-Stage Curve
Increasing .37 Feet Factor Reduction for Stages at or above .01 Probability Event

EXCEEDANCE PROBABILITY	STAGE (NAVD 88, FT)
.999	20.16
.500	33.36
.100	38.42
.040	40.36
.020	41.15
.010	41.77
.005	42.76
.002	43.38

These changes resulted in an EAD of $252 million and an AEP of .0384 – again suggesting only neglible impacts on EAD and AEP when compared to the baseline results. The following tables summarize the results of the sensitivity analysis.

Table 6
Summary of Sensitivity Analysis Results
Expected Annual Damages (EAD)

SENSITIVITY ANALYSIS RESULTS COMPARISON OF EAD		GEOTECHNICAL FRAGILITY CURVE	
		Baseline (Poor Performance)	Modified (Risk of Failure)
PROBABILITY-STAGE CURVE	Baseline	$262 million	$240 million
	Constant .37 ft. decrease	$258 million	NA
	Increasing .37 ft. factor decrease	$252 million	NA

Table 7
Summary of Sensitivity Analysis Results
Annual Exceedance Probability (AEP)

SENSITIVITY ANALYSIS RESULTS COMPARISON OF AEP		GEOTECHNICAL FRAGILITY CURVE	
		Baseline (Poor Performance)	**Modified (Risk of Failure)**
PROBABILITY-STAGE CURVE	**Baseline**	.0398	.0363
	Constant .37 ft. decrease	.0392	NA
	Increasing .37 ft. factor decrease	.0384	NA

4. SUMMARY OF HEC-FDA INPUTS & RESULTS

Revisions to the HEC-FDA input data, including a change to the .999 probability event stage (probability-stage curve), an updated probability-stage curve, and a revised geotechnical fragility curve results in an updated without-project EAD of approximately $262 million and an AEP of .0398. These values have changed considerably from those originally reported (EAD of $2.4 billion and AEP of .3856) at the F3 Conference. Table 8 shows the evolution of the geotechnical fragility curve; Table 9 shows the evolution of the probability-stage curves; Table 10 summarizes the original curves, the new curves, and the associated EAD and AEP results.

Table 8
Evolution of Geotechnical Fragility Curves Used in HEC-FDA

ORIGINAL (F3)		NEW	
Stage (NGVD 29)	**P(f)**	**Stage (NAVD 88)**	**P(f)**
33	.23	36.4	.066
36	.51	39.4	.167
39	.82	41.4	.324
42	.98	44.4	.500

Table 9
Evolution of Probability-Stage Curves Used in HEC-FDA

ORIGINAL (F3)		REVISED .999 STAGE		NEW	
Probability	**Stage (NGVD 29)**	**Probability**	**Stage (NGVD 29)**	**Probability**	**Stage (NAVD 88)**
.999	32.3	.999	22.8	.999	20.16
.5	33.8	.5	33.8	.5	33.36
.1	36.01	.1	36.01	.1	38.42
.04	37.93	.04	37.93	.04	40.36
.02	38.74	.02	38.74	.02	41.15
.01	39.81	.01	39.81	.01	42.14
.005	40.61	.005	40.61	.005	43.50
.002	41.07	.002	41.07	.002	44.49

Table 10
Summary of Probability-Stage & Fragility Curves and Results

ORIGINAL CURVES (NGVD 29)				NEW CURVES (NAVD 88)			
Probability-Stage		**Fragility (RM 79)**		**Probability-Stage**		**Fragility (RM 79)**	
Prob.	**Stage**	**Stage**	**P(f)**	**Prob.**	**Stage**	**Stage**	**P(f)**
.999	32.30	33	.23	.999	20.16	36.5	.066
.500	33.80	36	.51	.500	33.36	39.5	.167
.100	36.01	39	.82	.100	38.42	41.5	.324
.040	37.93	42	.98	.040	40.36	44.5	.500
.020	38.74			.020	41.15		
.010	39.81			.010	42.14		
.005	40.61			.005	43.50		
.002	41.07			.002	44.49		
EAD = $2.4 billion				**EAD = $262 million**			
AEP = .3856				**AEP = .0398**			

Finally, a sensitivity analysis shows that a modified geotechnical fragility curve representing the risk of actual levee failure has a minimal impact on EAD and AEP, and that nominal changes to the probability-stage curve reflecting consideration of possible upstream levee failures have only negligible o EAD and AEP.

ENCLOSURE 4
HECFDA USER GUIDELINES AND FILE DESCRIPTION

HECFDA USER GUIDELINES

Instructions for Using the HECFDA Program

Introduction

The HECFDA program will format the FLO-2D model output data (grid element ground elevation and water surface elevation) into the HEC-FDA file format for evaluating flood damage cost. The program is a stand alone Fortran program and no other software is necessary. The data and output files are in ASCII format. All the data and output files have to be in the same subdirectory. It is necessary to run the FLO-2D model project simulations to generate the maximum water surface elevation files (MAXWSELEV.OUT) for each required discharge profile. The MAXWSELEV.OUT must be renamed with a number ranging from 1 to 8 (e.g. MAXWSELEV1.OUT to MAXWSELEV8.OUT) representing the appropriate return period profile simulation. It is necessary to put one FPLAIN.DAT file in the project subdirectory. The HECFDA.DAT file must be prepared prior to running the program.

Data Requirements

FPLAIN.DAT from one of the FLO-2D profile simulations.

HECFDA.DAT prepared according the HECFDA.DAT file format description document.

MAXWSELEV.OUT files renamed to MAXWSELEV1.OUT to MAXWSELEV8.OUT representing the eight potential FLO-2D water surface profile simulations.

User Instructions

It is necessary to complete the FLO-2D water surface profile simulations for the project before using the HECFDA program. The program is limited to 8 flood simulations profiles representing eight different return period floods. After the simulations are complete, follow these steps to generate the HEC-FDA file format:

Step 1. Create a new project subdirectory (e.g. HECFDA River 1).

Step 2. Copy the HECFDA.EXE file into the new project subdirectory.

Step 3. Copy the FPLAIN.DAT file from one of the FLO-2D profile simulations into the new project subdirectory.

Step 4. Copy MAXWSELEV.OUT file from the project subdirectory for each of the completed FLO-2D water surface profiles simulation to the new project subdirectory and rename the file to MAXWSELEV1.OUT to MAXWSELEV8.OUT according to the representative water surface profile. There will be up to eight MAXWSELEV_.OUT files in the new project folder when you are done.

Step 5. Prepare the HECFDA.DAT file according the data input file description document.

Step 6. In Windows Explorer, double click on the HECFDA.EXE program. When the program is complete (a typical run will only take a few seconds), the following dialog box will be displayed:

This dialog box will disappear after 2 seconds and the HECFDA.OUT file will have been created. HECFDA.OUT is an ASCII data file and can be reviewed with any ASCII text editor program such as WordPad or NotePad.

Important Hints

1. It is only necessary to run the FLO-2D model profile simulations and generate the MAXWSELEV.DAT files that are necessary. If a given profile(s) is not required, then the corresponding MAXWSELEV_.OUT file can be missing from the project subdirectory.

2. It is not necessary to list the actual profile discharges in the HECFDA.DAT file. These discharge values are not used and are only in the file for the user’s edification. In other words, these discharge numbers can be made up. Eight numbers are required for the data file.

3. The number of stations (grid element numbers) is unlimited but must be less than the last grid element number in the grid system. The program is limited to eight water surface profile simulations.

FILE: HECFDA.DAT

VARIABLE DESCRIPTION
(Free Format - Space Delimited)

Line 1 contains the project title.
1 **TITLE (60 characters)**

Line 2 is the reach name.
2 **REACHNAME (15 characters)**

Line 3 is the profile names.
3 **PROFILENAME(J), J = 1, 8 profiles (each name is limited to 4 characters)**

Line 4 is the profile discharge.
4 **DISCHARGE(J), J = 1, 8 profiles (discharges values are not used in the program)**

Line 5 to end is the FLO-2D grid element
5 **STATION(I), I=1, NNOD (number of specified stations, limited to the number of grid elements NNOD in the FLO-2D model)**

Note: Only 1 grid element station per line

An example of the HECFDA.DAT file:

```
HEC-FDA PROJECT TITLE
RIVER REACH
Q2       Q10       Q25    Q50      Q100    Q150      Q200    Q250
Q500
2500.    4250.   6582.   8452.   10528.   12562.    15855.  20856.
31652.
14568
14568
15484
16752
16896
17041
17365
18965
19546
20022
21454
```

ENCLOSURE 5
NON-STANDARD HEC-FDA TECHNIQUE TO INCORPORATE STAGE UNCERTAINTY

Subject: Natomas HEC-FDA Modeling Options for Various Upstream Levee Assumptions- Using Stage-Frequency Relationships.

During the FSM (SPD-F3 milestone), the American River Common Features (ARCF) PDT struggled with how to define the uncertainty of the possibility that upstream levee failures may impact the future without project conditions (FWOP) for Natomas. For the FSM documentation, the exceedance probability- stage functions were developed assuming no upstream failures (only allowing water to leave the system through overtopping). The PDT discussed possibility of developing multiple upstream scenarios, allowing for a range of stages for given events. From these, a minimum, maximum and most-likely could represent the uncertainty based on a triangular distribution. This ‘best case’, likely and ‘worst case’ scenario would be consistent with the guidance found in EM 1110-2-1619 and would support comments provided during review that: “the uncertain upstream conditions” should be explicitly described in the modeling.

HEC-FDA allows for a triangular distribution of discharges to be defined in the transform flow function (regulated vs. unregulated). The transform flow function has been used before on other studies to estimate upstream uncertainty. If our Natomas model was developed with exceedance probability-discharge functions, this approach could be applied without modification of the current software (HEC-FDA 1.2.4). Unfortunately our Natomas HEC-FDA model is defined only using exceedance probability-stage. The transform curve is not used in these ‘stage-only’ runs and the triangular distribution of possible upstream conditions cannot be entered into the model.

The proposed modeling option, is to use all three available discharge and stage relationships in HEC-FDA BUT to define all three relationships ONLY in terms of stage. The exceedance probability function would be entered using the graphical option set for discharge but stages would be entered in place of flow. The transform flow would use the stage distribution by event instead of inflow-outflow and the stage-discharge would be a dummy curve where stage=stage.

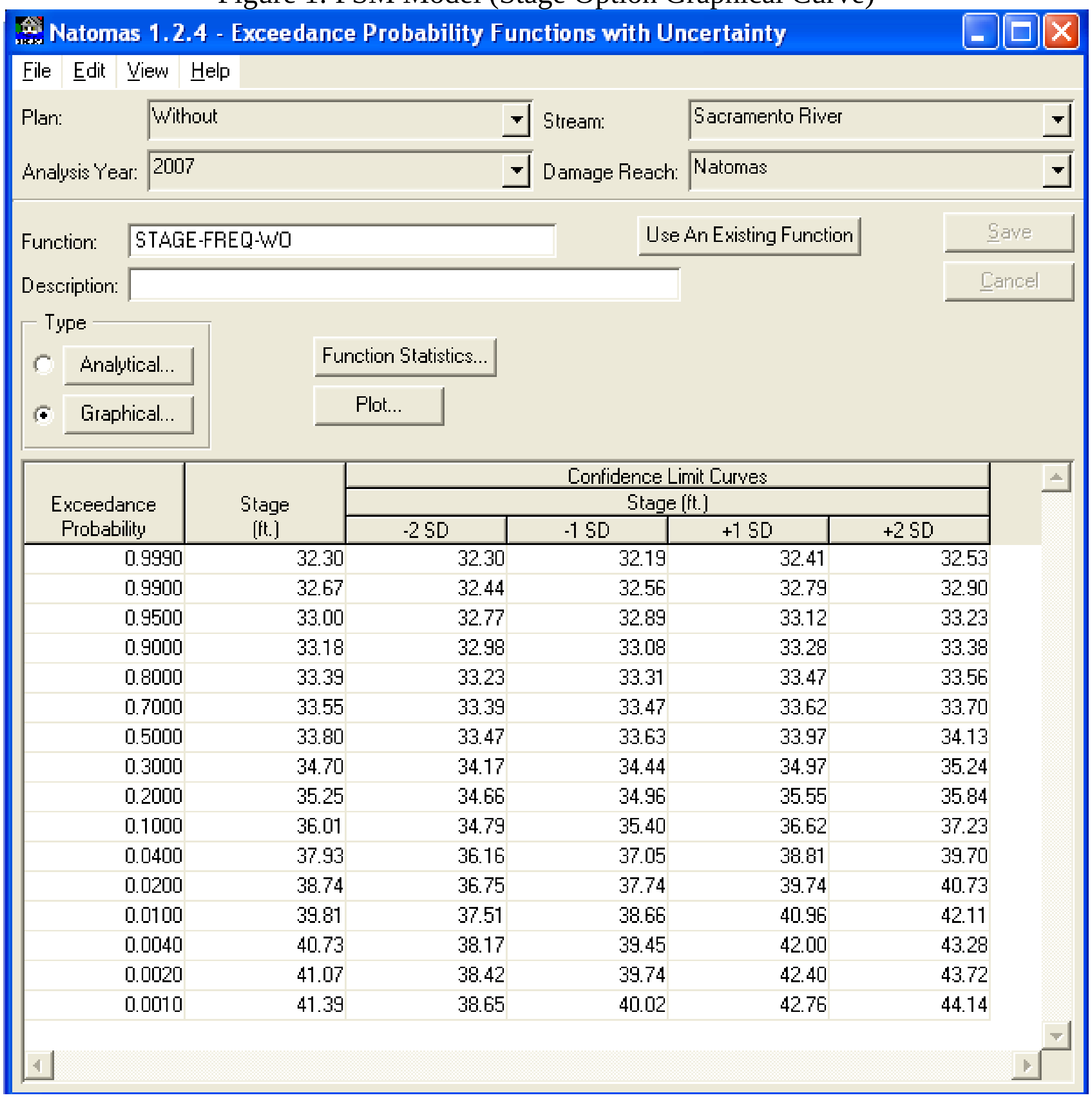
Before doing the following tests, the PDT had three primary questions:

1) Would the software operate and provide output using stages instead of flow in all the discharge functions?
2) What would be the difference in the stage errors in exceedance probability function using the discharge option instead of the stage option?
3) Could the FSM results be reasonably replicated using this proposed method (where stage=stage in the transform flow function)?

Good news on question #1: the model operates fine under the proposed modeling option. The levee curves and stage-damage functions were the same as the FSM model and only the three relationships were modified using only the stage-frequency function provided based on no upstream failures.

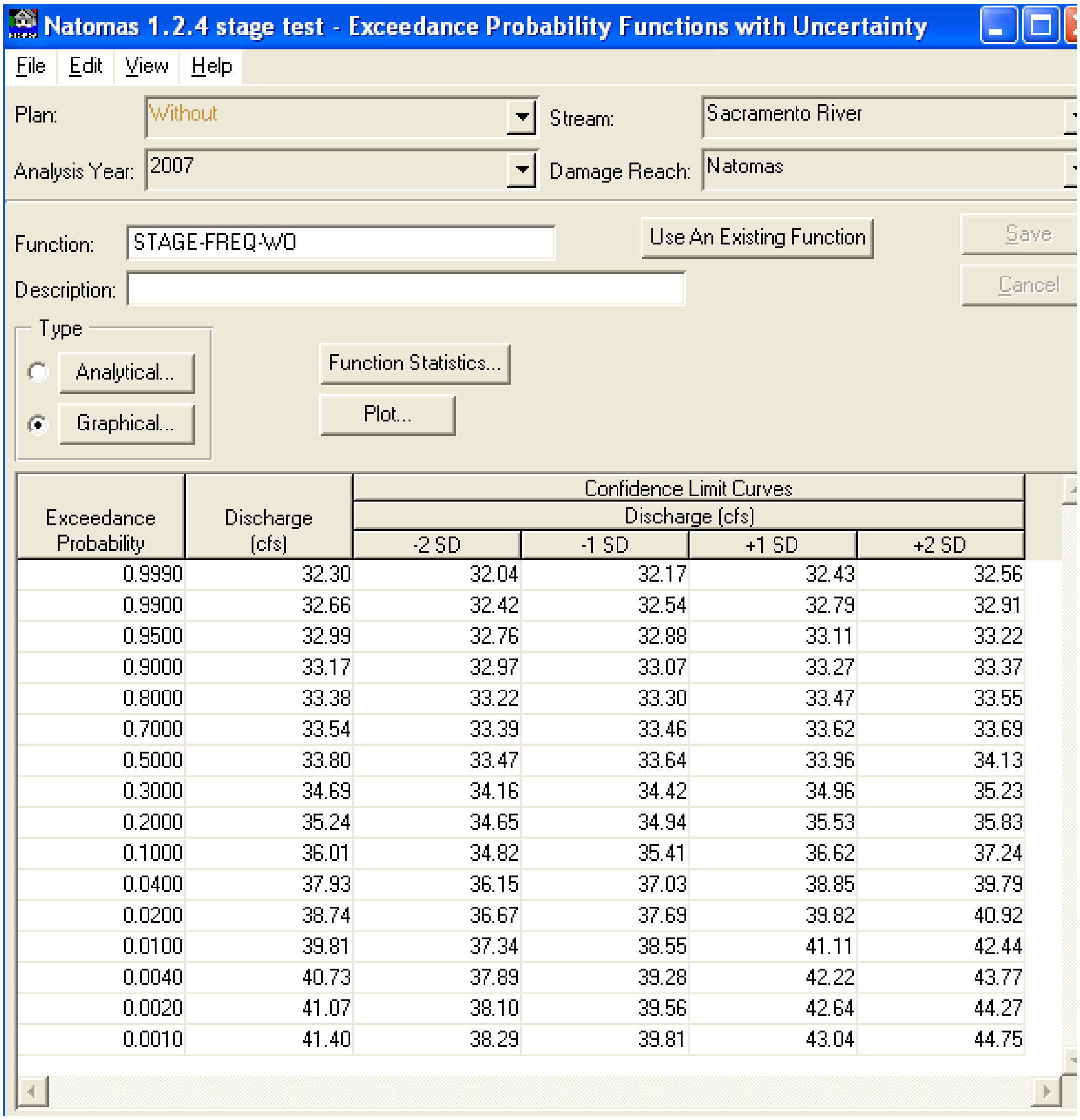
The concern regarding the second question was based on the fact that we are using HEC-FDA to define the error band based on the shape of the imputed graphical curve and the period of record. The assumption was that because HEC-FDA estimates these using different methods for discharge vs. stage, that the differences may be significant. Figure 1 below shows a table for the range of stage by exceedance probability (+- 1 and 2 standard deviations) using the FSM model. Figure 2 show the range of stage using the proposed 'stage as discharge' option.

Figure 1: FSM Model (Stage Option Graphical Curve)



Exceedance Probability	Stage (ft.)	Confidence Limit Curves Stage (ft.) -2 SD	-1 SD	+1 SD	+2 SD
0.9990	32.30	32.30	32.19	32.41	32.53
0.9900	32.67	32.44	32.56	32.79	32.90
0.9500	33.00	32.77	32.89	33.12	33.23
0.9000	33.18	32.98	33.08	33.28	33.38
0.8000	33.39	33.23	33.31	33.47	33.56
0.7000	33.55	33.39	33.47	33.62	33.70
0.5000	33.80	33.47	33.63	33.97	34.13
0.3000	34.70	34.17	34.44	34.97	35.24
0.2000	35.25	34.66	34.96	35.55	35.84
0.1000	36.01	34.79	35.40	36.62	37.23
0.0400	37.93	36.16	37.05	38.81	39.70
0.0200	38.74	36.75	37.74	39.74	40.73
0.0100	39.81	37.51	38.66	40.96	42.11
0.0040	40.73	38.17	39.45	42.00	43.28
0.0020	41.07	38.42	39.74	42.40	43.72
0.0010	41.39	38.65	40.02	42.76	44.14

Figure 2: Proposed Model (Stage as Discharge Option Graphical Curve)

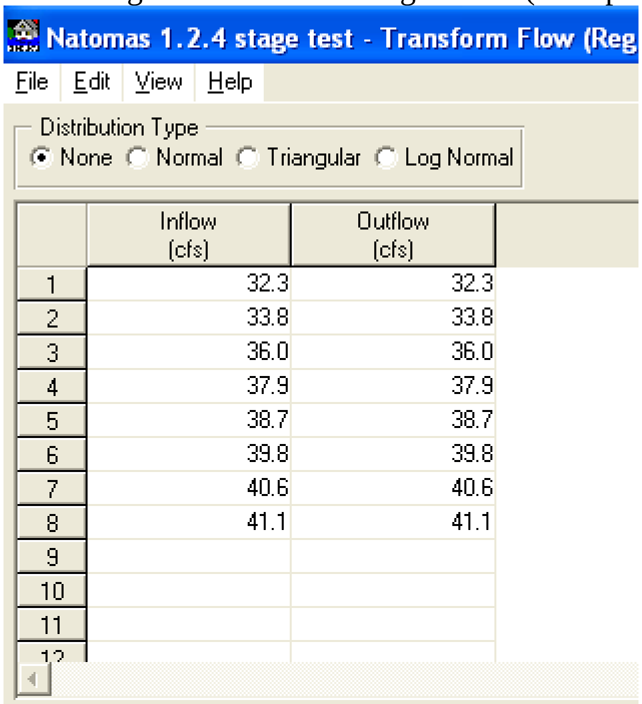


Exceedance Probability	Discharge (cfs)	Confidence Limit Curves Discharge (cfs)			
		-2 SD	-1 SD	+1 SD	+2 SD
0.9990	32.30	32.04	32.17	32.43	32.56
0.9900	32.66	32.42	32.54	32.79	32.91
0.9500	32.99	32.76	32.88	33.11	33.22
0.9000	33.17	32.97	33.07	33.27	33.37
0.8000	33.38	33.22	33.30	33.47	33.55
0.7000	33.54	33.39	33.46	33.62	33.69
0.5000	33.80	33.47	33.64	33.96	34.13
0.3000	34.69	34.16	34.42	34.96	35.23
0.2000	35.24	34.65	34.94	35.53	35.83
0.1000	36.01	34.82	35.41	36.62	37.24
0.0400	37.93	36.15	37.03	38.85	39.79
0.0200	38.74	36.67	37.69	39.82	40.92
0.0100	39.81	37.34	38.55	41.11	42.44
0.0040	40.73	37.89	39.28	42.22	43.77
0.0020	41.07	38.10	39.56	42.64	44.27
0.0010	41.40	38.29	39.81	43.04	44.75

Comparing the two figures, the difference in error in stage at the 'bottom' of the curve is minimal (less than 0.03 feet for 2 sd from 0.999 to 0.1 events). From 0.01 to 0.002, the difference is greater (maximum of 0.55 feet for 2 sd , non-symmetrical and may have some impact on the results.

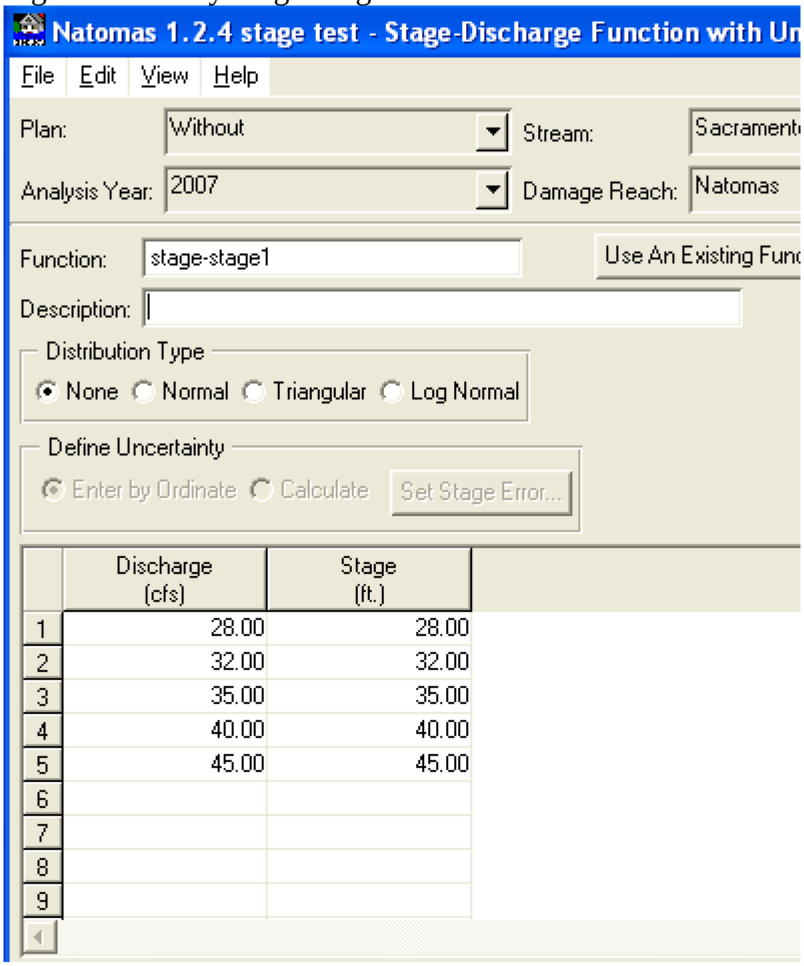
So the third question: could the FSM results be replicated using a transform flow and stage-stage dummy curve? Figures 3 and 4 show the inputs to the HEC-FDA model to complete the test.

Figure 3 Transform Stage Curve (No Upstream Levee Failures- No Uncertainty)



	Inflow (cfs)	Outflow (cfs)
1	32.3	32.3
2	33.8	33.8
3	36.0	36.0
4	37.9	37.9
5	38.7	38.7
6	39.8	39.8
7	40.6	40.6
8	41.1	41.1
9		
10		
11		
12		

Figure 4 Dummy Stage-Stage Curve



HEC-FDA Results were compared for the FSM runs and this test. EAD, AEP and CNP are shown in Table 1.

Table 1 – HEC-FDA RESULTS COMPARISON
EAD is in $ Millions

OUTPUT	FSM	TEST RUNS	DIFFERENCE
EAD-WO	2,451	2,444	-0.3 %
AEP-WO	0.3865	0.3854	-0.3 %
CNP 10%	48.2 %	48.2 %	0 %
CNP 1%	15.1 %	14.8 %	-2.0 %
WITH PROJECT – TEST (RAISE PNP TO 3 feet below TOL)			
EAD-Wp	81	78	-3.7 %
AEP-Wp	0.0124	0.0120	-3.2 %
CNP 10%	100 %	100 %	0 %
CNP 1%	54.7 %	49.1 %	-10.2 %

Based on the results, doesn’t appear to be any impact on EAD or AEP under without project. As with project alternatives get closer to reducing flood risk for the 1 % event, looks like there will be a greater difference and may impact which alternatives meet CNP criteria.

Scenarios with uncertainty in the transform ‘stage’ function were run to describe how the proposed model might be used. The only relationship that would change from our ‘test’ runs above would be the transform flow. Inflow (stage) would be represented by stage in the exceedance probability function without any upstream failure conditions. The maximum (stage) would be set equal to the inflow (stage). Then the minimum and outflow (stage) would represent the sensitivity runs. Two examples are shown below. Figure 5 lowers only the bottom points on the curve (stage 37.9 ft and below) and Figure 6 lowers the entire curve but at a decreasing rate for higher stages. Both are strictly hypothetical and do not represent any hydraulic runs. These are used only for economic and HEC-FDA model test purposes.

Figure 5 Likely Shift Transform Stage Curve (Bottom only)

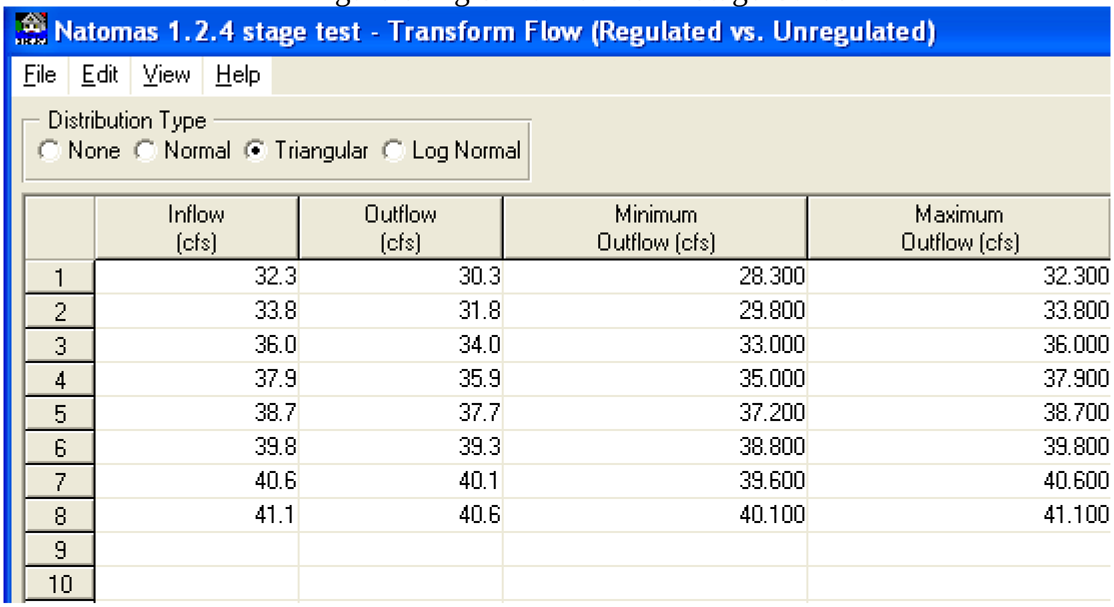
Natomas 1.2.4 stage test - Transform Flow (Regulated vs. Unregulated)

File Edit View Help

Distribution Type: ( ) None ( ) Normal (•) Triangular ( ) Log Normal

	Inflow (cfs)	Outflow (cfs)	Minimum Outflow (cfs)	Maximum Outflow (cfs)
1	32.3	30.3	30.300	32.300
2	33.8	32.8	31.800	33.800
3	36.0	35.0	34.000	36.000
4	37.9	36.9	35.900	37.900
5	38.7	38.7	38.700	38.700
6	39.8	39.8	39.800	39.800
7	40.6	40.6	40.600	40.600
8	41.1	41.1	41.100	41.100
9				
10				

Figure 6 Big Shift Transform Stage Curve



	Inflow (cfs)	Outflow (cfs)	Minimum Outflow (cfs)	Maximum Outflow (cfs)
1	32.3	30.3	28.300	32.300
2	33.8	31.8	29.800	33.800
3	36.0	34.0	33.000	36.000
4	37.9	35.9	35.000	37.900
5	38.7	37.7	37.200	38.700
6	39.8	39.3	38.800	39.800
7	40.6	40.1	39.600	40.600
8	41.1	40.6	40.100	41.100
9				
10				

The HEC-FDA 1.2.4 model was rerun using these two shifted curves and compared to the results of the test runs. Results are shown in Table 2.

Table 2 HEC-FDA RESULTS COMPARISON
EAD is in $ Millions

OUTPUT	TEST RUNS	Bottom Shift (Fig 5)	Big Shift (Fig 6)
EAD-WO	2,444	1,287	815
AEP-WO	0.3854	0.2026	0.1281
CNP 10%	48.2 %	60.3 %	65.0 %
CNP 1%	14.8 %	15.4 %	21.8 %
WITH PROJECT – TEST (RAISE PNP TO 3 feet below TOL)			
EAD-Wp	78	78	54
AEP-Wp	0.0120	0.0119	0.0083
CNP 10%	100 %	100 %	100 %
CNP 1%	49.1 %	48.7 %	66.0 %

ENLOSURE 6
PROJECT COSTS USED FOR PRELIMINARY SCREENING OF ALTERNATIVES, OCTOBER 2010 PRICE LEVEL

American River Watershed – Common Features
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Sacramento River East Levee Reaches (NAT A, NAT B, NAT C)
Fix-in-Place Alternative

REACH	ALTERNATIVE	METHOD OF FIX	WSEL (FT)	RAISE OR TO EXISTING LEVEE HIEGHT	TOTAL FIRST COSTS	INTEREST DURING CONSTRUCTION (IDC)	TOTAL INVESTMENT COST	AMORTIZED COSTS	ANNUAL OMRR&R	TOTAL AVERAGE ANNUAL COSTS
A	Fix-in-Place	Slope Flattening Soil Bentonite Cutoff Wall	39.92	Raise	$135,407,000	$24,430,000	$159,837,000	$7,920,000	$400,000	$8,320,000
			36.73	Existing	$102,869,000	$19,220,000	$122,089,000	$6,050,000	$300,000	$6,350,000
			34.70	Existing	$102,869,000	$19,220,000	$122,089,000	$6,050,000	$300,000	$6,350,000
			34.00	Existing						
			33.45	Existing						
			31.29	Existing						
B	Fix-in-Place	Soil Bentonite Cutoff Wall	39.99	Raise	$317,418,125	$24,610,000	$342,028,125	$16,970,000	$850,000	$17,820,000
			36.92	Existing	$307,337,125	$23,660,000	$330,997,125	$16,420,000	$830,000	$17,250,000
			34.98	Existing	$297,540,125	$22,900,000	$320,440,125	$15,890,000	$800,000	$16,690,000
			34.27	Existing	$275,856,625	$20,140,000	$295,996,625	$14,860,000	$740,000	$15,600,000
			33.72	Existing	$275,856,625	$20,140,000	$296,955,625	$14,730,000	$740,000	$15,470,000
			31.97	Existing	$275,856,625	$20,140,000	$295,996,625	$14,680,000	$730,000	$15,410,000
	Fix-in-Place	Drained Seepage Berm	39.99	Raise	$323,765,125	$27,160,000	$350,925,125	$17,410,000	$890,000	$18,300,000
			36.92	Existing	$298,366,125	$24,980,000	$323,346,125	$16,040,000	$800,000	$16,840,000
			34.98	Existing	$289,827,125	$24,320,000	$314,097,125	$15,570,000	$780,000	$16,350,000
			34.27	Existing	$261,391,625	$20,590,000	$281,981,625	$13,980,000	$700,000	$14,680,000
			33.72	Existing	$261,391,625	$20,590,000	$281,981,625	$13,980,000	$700,000	$14,680,000
			31.97	Existing	$261,391,625	$20,590,000	$281,981,625	$13,980,000	$680,000	$14,680,000
C	Fix-in-Place	Soil Bentonite Cutoff Wall	43.11	Raise	$140,121,900	$3,430,000	$143,551,900	$7,120,000	$350,000	$7,470,000
			42.24	Raise	$137,226,900	$3,360,000	$140,586,900	$6,970,000	$350,000	$7,320,000
			40.86	Raise	$130,866,300	$3,160,000	$134,026,300	$6,640,000	$330,000	$6,970,000
			39.95	Raise	$127,609,700	$3,070,000	$130,679,700	$6,480,000	$330,000	$6,810,000
			39.26	Existing	$127,191,700	$3,060,000	$130,251,700	$6,460,000	$330,000	$6,790,000
			37.08	Existing	$127,191,700	$3,060,000	$130,251,700	$6,460,000	$330,000	$6,790,000
	Fix-in-Place	Soil Bentonite Cutoff Wall & Drained Seepage Berm	43.11	Raise	$141,850,500	$3,540,000	$145,390,500	$7,210,000	$360,000	$7,570,000
			42.24	Raise	$138,426,500	$3,440,000	$141,866,500	$7,030,000	$360,000	$7,390,000
			40.86	Raise	$132,593,500	$3,270,000	$135,863,500	$6,730,000	$330,000	$7,060,000
			39.95	Raise	$129,338,500	$3,180,000	$132,518,500	$6,570,000	$330,000	$6,900,000
			39.26	Existing	$128,920,500	$3,170,000	$132,090,500	$6,550,000	$330,000	$6,880,000
			37.08	Existing	$128,920,500	$3,170,000	$132,090,500	$6,550,000	$330,000	$6,880,000

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Natomas Cross Canal (NAT D)
Fix-in-Place Alternative

REACH	ALTERNATIVE	METHOD OF FIX	WSEL (FT)	RAISE OR TO EXISTING LEVEE HIEGHT	TOTAL FIRST COSTS	INTEREST DURING CONSTRUCTION (IDC)	TOTAL INVESTMENT COST	AMORTIZED COSTS	ANNUAL OMRR&R	TOTAL AVERAGE ANNUAL COSTS
D	Fix-in-Place	Soil Bentonite Cutoff Wall	45.13	Raise	$85,030,000	$3,470,000	$88,500,000	$4,390,000	$130,000	$4,520,000
			44.16	Raise	$80,890,000	$3,290,000	$84,180,000	$4,170,000	$130,000	$4,300,000
			42.76	Raise	$75,900,000	$3,080,000	$78,980,000	$3,920,000	$120,000	$4,040,000
			41.80	Raise	$57,640,000	$2,290,000	$59,930,000	$2,970,000	$90,000	$3,060,000
			41.07	Existing	$36,680,000	$1,560,000	$38,240,000	$1,900,000	$60,000	$1,960,000
			38.97	Existing	$36,680,000	$1,560,000	$38,240,000	$1,900,000	$60,000	$1,960,000

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Fix-in-Place Alternative

REACH	ALTERNATIVE	METHOD OF FIX	WSEL (FT)	RAISE OR TO EXISTING LEVEE HIEGHT	TOTAL FIRST COSTS	INTEREST DURING CONSTRUCTION (IDC)	TOTAL INVESTMENT COST	AMORTIZED COSTS	ANNUAL OMRR&R	TOTAL AVERAGE ANNUAL COSTS
E	Fix-in-Place	Soil Bentonite Cutoff Wall	45.03	Raise	$61,990,000	$18,160,000	$80,150,000	$3,970,000	$120,000	$4,090,000
			43.89	Raise	$55,810,000	$16,350,000	$72,160,000	$3,580,000	$110,000	$3,690,000
			42.56	Existing	$50,790,000	$14,880,000	$65,670,000	$3,260,000	$100,000	$3,360,000
			41.56	Existing	$50,790,000	$14,880,000	$65,670,000	$3,260,000	$100,000	$3,360,000
			40.75	Existing	$50,790,000	$14,880,000	$65,670,000	$3,260,000	$100,000	$3,360,000
			38.81	Existing	$50,790,000	$14,880,000	$65,670,000	$3,260,000	$100,000	$3,360,000
F	Fix-in-Place	Drained Seepage Berm	43.03	Raise	$74,760,000	$21,900,000	$96,660,000	$4,790,000	$140,000	$4,930,000
			39.76	Raise	$63,530,000	$18,610,000	$82,140,000	$4,070,000	$120,000	$4,190,000
			38.97	Raise	$59,110,000	$17,320,000	$76,430,000	$3,790,000	$110,000	$3,900,000
			38.10	Existing	$56,190,000	$16,460,000	$72,650,000	$3,600,000	$110,000	$3,710,000
			37.24	Existing	$56,190,000	$16,460,000	$72,650,000	$3,600,000	$110,000	$3,710,000
			35.62	Existing	$56,190,000	$16,460,000	$72,650,000	$3,600,000	$110,000	$3,710,000
	Fix-in-Place	Flattened Landside Slope	43.03	Raise	$76,580,000	$22,430,000	$99,010,000	$4,910,000	$150,000	$5,060,000
			39.76	Raise	$56,360,000	$16,510,000	$72,870,000	$3,610,000	$110,000	$3,720,000
			38.97	Raise	$51,300,000	$15,030,000	$66,330,000	$3,290,000	$100,000	$3,390,000
			38.10	Existing	$46,860,000	$13,730,000	$60,590,000	$3,000,000	$90,000	$3,090,000
			37.24	Existing	$46,860,000	$13,730,000	$60,590,000	$3,000,000	$90,000	$3,090,000
			35.62	Existing	$46,860,000	$13,730,000	$60,590,000	$3,000,000	$90,000	$3,090,000
G	Fix-in-Place	Soil Bentonite Cutoff Wall	43.05	Raise	$61,240,000	$14,620,000	$75,860,000	$3,760,000	$110,000	$3,870,000
			39.78	Raise	$45,390,000	$10,840,000	$56,230,000	$2,790,000	$80,000	$2,870,000
			38.99	Raise	$43,180,000	$10,310,000	$53,490,000	$2,650,000	$80,000	$2,730,000
			38.11	Raise	$39,720,000	$9,480,000	$49,200,000	$2,440,000	$70,000	$2,510,000
			37.25	Existing	$39,720,000	$9,480,000	$49,200,000	$2,440,000	$70,000	$2,510,000
			35.63	Existing	$39,720,000	$9,480,000	$49,200,000	$2,440,000	$70,000	$2,510,000
H	Fix-in-Place	Soil Bentonite Cutoff Wall	44.37	Raise	$165,680,000	$30,950,000	$196,630,000	$9,750,000	$150,000	$9,900,000
			39.07	Existing	$73,000,000	$13,640,000	$86,640,000	$4,300,000	$130,000	$4,430,000
			37.53	Existing	$64,940,000	$12,130,000	$77,070,000	$3,820,000	$110,000	$3,930,000
			35.99	Existing	$64,940,000	$12,130,000	$77,070,000	$3,820,000	$110,000	$3,930,000
			34.93	Existing	$64,940,000	$12,130,000	$77,070,000	$3,820,000	$110,000	$3,930,000
			32.55	Existing	$64,940,000	$12,130,000	$77,070,000	$3,820,000	$110,000	$3,930,000

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American River North Levee (NAT I)
Fix-in-Place Alternative

REACH	ALTERNATIVE	METHOD OF FIX	WSEL (FT)	RAISE OR TO EXISTING LEVEE HIEGHT	TOTAL FIRST COSTS	INTEREST DURING CONSTRUCTION (IDC)	TOTAL INVESTMENT COST	AMORTIZED COSTS	ANNUAL OMRR&R	TOTAL AVERAGE ANNUAL COSTS
I	Fix-in-Place	Soil Bentonite Cutoff Wall	43.95	Raise	$27,136,750	$3,720,000	$30,856,750	$1,530,000	$80,000	$1,610,000
			38.19	Existing	$25,018,750	$3,430,000	$28,448,750	$1,410,000	$70,000	$1,480,000
			35.66	Existing	$25,018,750	$3,430,000	$28,448,750	$1,410,000	$70,000	$1,480,000
			35.06	Existing	$25,018,750	$3,430,000	$28,448,750	$1,410,000	$70,000	$1,480,000
			34.60	Existing	$25,018,750	$3,430,000	$28,448,750	$1,410,000	$70,000	$1,480,000
			31.24	Existing	$25,018,750	$3,430,000	$28,448,750	$1,410,000	$70,000	$1,480,000

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A	Adjacent Levee	Slope Flattening Soil Bentonite Cutoff Wall	39.92	Raise	$135,407,000	$24,430,000	$159,837,000	$7,920,000	$400,000	$8,320,000
			36.73	Existing	$102,869,000	$19,220,000	$122,089,000	$6,050,000	$300,000	$6,350,000
			34.70	Existing	$102,869,000	$19,220,000	$122,089,000	$6,050,000	$300,000	$6,350,000
			34.00	Existing						
			33.45	Existing						
			31.29	Existing						
B	Adjacent Levee	Soil Bentonite Cutoff Wall	39.99	Raise	$295,251,000	$22,670,000	$317,921,000	$15,770,000	$780,000	$16,550,000
			36.92	Existing	$272,575,000	$20,890,000	$293,465,000	$14,540,000	$730,000	$15,270,000
			34.98	Existing	$269,914,000	$20,770,000	$290,684,000	$14,400,000	$720,000	$15,120,000
			34.27	Existing	$253,060,000	$18,670,000	$271,730,000	$13,470,000	$680,000	$14,150,000
			33.72	Existing	$253,060,000	$18,670,000	$271,730,000	$13,470,000	$680,000	$14,150,000
			31.97	Existing	$253,060,000	$18,670,000	$271,730,000	$13,470,000	$680,000	$14,150,000
C	Adjacent Levee	Soil Bentonite Cutoff Wall	43.11	Raise	$107,140,000	$3,040,000	$110,180,000	$5,460,000	$270,000	$5,730,000
			42.24	Raise	$103,989,000	$2,950,000	$106,939,000	$5,300,000	$260,000	$5,560,000
			40.86	Raise	$97,988,000	$2,780,000	$100,768,000	$4,990,000	$250,000	$5,240,000
			39.95	Raise	$94,531,000	$2,650,000	$97,181,000	$4,820,000	$250,000	$5,070,000
			39.26	Existing	$91,855,000	$2,590,000	$94,445,000	$4,680,000	$240,000	$4,920,000
			37.08	Existing	$91,855,000	$2,590,000	$94,445,000	$4,680,000	$240,000	$4,920,000

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E	Adjacent Levee	Soil Bentonite Cutoff Wall	45.03	Raise	$56,350,000	$19,690,000	$76,040,000	$3,770,000	$190,000	$3,960,000
			43.89	Raise	$51,100,000	$17,860,000	$68,960,000	$3,420,000	$170,000	$3,590,000
			42.56	Existing	$44,870,000	$15,680,000	$60,550,000	$3,000,000	$150,000	$3,150,000
			41.56	Existing	$44,870,000	$15,680,000	$60,550,000	$3,000,000	$150,000	$3,150,000
			40.75	Existing	$44,870,000	$15,680,000	$60,550,000	$3,000,000	$150,000	$3,150,000
			38.81	Existing	$44,870,000	$15,680,000	$60,550,000	$3,000,000	$150,000	$3,150,000
F	Adjacent Levee	Drained Seepage Berm	43.03	Raise	$69,250,000	$24,200,000	$93,450,000	$4,630,000	$140,000	$4,770,000
			39.76	Raise	$59,270,000	$20,720,000	$79,990,000	$3,970,000	$200,000	$4,170,000
			38.97	Raise	$55,130,000	$19,270,000	$74,400,000	$3,690,000	$180,000	$3,870,000
			38.10	Existing	$48,910,000	$17,090,000	$66,000,000	$3,270,000	$160,000	$3,430,000
			37.24	Existing	$48,910,000	$17,090,000	$66,000,000	$3,270,000	$160,000	$3,430,000
			35.62	Existing	$48,910,000	$17,090,000	$66,000,000	$3,270,000	$160,000	$3,430,000
	Adjacent Levee	Flattened Landside Slope	43.03	Raise	$70,470,000	$24,630,000	$95,100,000	$4,720,000	$240,000	$4,960,000
			39.76	Raise	$52,050,000	$18,190,000	$70,240,000	$3,480,000	$170,000	$3,650,000
			38.97	Raise	$47,370,000	$16,560,000	$63,930,000	$3,170,000	$160,000	$3,330,000
			38.10	Existing	$33,640,000	$11,760,000	$45,400,000	$2,250,000	$110,000	$2,360,000
			37.24	Existing	$33,640,000	$11,760,000	$45,400,000	$2,250,000	$110,000	$2,360,000
			35.62	Existing	$33,640,000	$11,760,000	$45,400,000	$2,250,000	$110,000	$2,360,000
G	Adjacent Levee	Soil Bentonite Cutoff Wall	43.05	Raise	$55,010,000	$16,110,000	$71,120,000	$3,530,000	$180,000	$3,710,000
			39.78	Raise	$40,160,000	$11,760,000	$51,920,000	$2,570,000	$130,000	$2,700,000
			38.99	Raise	$38,200,000	$11,190,000	$49,390,000	$2,450,000	$120,000	$2,570,000
			38.11	Raise	$36,080,000	$10,570,000	$46,650,000	$2,310,000	$120,000	$2,430,000
			37.25	Existing	$32,930,000	$9,650,000	$42,580,000	$2,110,000	$110,000	$2,220,000
			35.63	Existing	$32,930,000	$9,650,000	$42,580,000	$2,110,000	$110,000	$2,220,000

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I	Adjacent Levee	Soil Bentonite Cutoff Wall	43.95	Raise	$34,979,000	$4,790,000	$39,769,000	$1,970,000	$100,000	$2,070,000
			38.19	Existing	$24,886,000	$3,410,000	$28,296,000	$1,400,000	$70,000	$1,470,000
			35.66	Existing	$24,886,000	$3,410,000	$28,296,000	$1,400,000	$70,000	$1,470,000
			35.06	Existing	$24,886,000	$3,410,000	$28,296,000	$1,400,000	$70,000	$1,470,000
			34.60	Existing	$24,886,000	$3,410,000	$28,296,000	$1,400,000	$70,000	$1,470,000
			31.24	Existing	$24,886,000	$3,410,000	$28,296,000	$1,400,000	$70,000	$1,470,000

APPROVAL-FOR-USE REPORT

N@RM
(Natomas @Risk Model)

U.S. Army Corps of Engineers
Sacramento District

Model Name:	Natomas @Risk Model (N@RM)
Functional Area:	Flood Risk Management, Economics Risk Analysis
Model Proponent:	Sacramento District, USACE
Model Developer/Contact:	Timi Shimabukuro and Erik Gomez
Year Developed:	May 2010

SECTION 1

INTRODUCTION

1.1 Model Purpose

N@RM (subsequently referred to as "the model") is a planning model for flood risk management studies and was developed through collaboration between the Agency Technical Review Lead and the Sacramento District's economists. The model has been designed to be an analytical tool used for the evaluation of flood risk management plans using risk analysis methods.

In accordance with Assuring Quality Planning Models (USACE Engineering Circular No. 1105-2-412, December 2009), approval is required for all planning models developed and/or used by the US Army Corps of Engineers (USACE). The objective of model approval is to ensure that models used by USACE are technically and theoretically sound, computationally accurate, and in compliance with USACE planning policy.

1.2 Model Certification

The model has been reviewed in accordance with requirements for the approval of planning models as identified in EC 1105-2-412 and "Protocols for Certification/Approval of Planning Models," under the Assuring Quality Planning Models.

Following the definitions in the EC 1105-2-412, N@RMis categorized as a **Regional/Local Model** as it was developed by the Sacramento District for specific applications that cannot be adequately addressed using available corporate models. The model addresses a unique regional/local situation and is necessary for depicting the specific characteristics of the study area. In terms of level of review required by the certification team to ensure the model is a high quality model, N@RM is falls into a **Limited Level of Review**. Accordingly, approval review will concentrate on compliance with technical quality criteria, be limited to internal reviewers and limited testing.

Additionally, N@RM will be considered for approval-for-use because it was developed by the Corps and is viewed by the vertical team (including the District, MSC, PCX, and HQ) as single-use or study-specific. Model approval is a corporate determination that the model is a technically and theoretically sound and functional tool that can be applied during the planning process by knowledgeable and trained staff for purposes consistent with the model's purposes and limitations.

The FDR-PCX is proposing to conduct a Limited Level of review based on the frequency of use of the model and a low risk of making an incorrect investment decision that could result in major negative impact. The approval of this model is specifically for the express use in computing expected annual damages related to the Natomas economic impact area currently being evaluated within the Sacramento District. This report presents the methodology and results of the review and approval process and will make recommendations affecting the level of approval appropriate for the model. N@RM is intended for approval-for-use as a USACE Regional/Local Model.

1.3 Contribution to Planning Effort

USACE requires the use of risk analysis procedures for formulating and evaluation flood risk management measures. Such projects are generally only authorized and implemented when they are economically justified, that is, when the predicted benefits can be demonstrated to exceed the estimated costs. The required analysis involves the estimation of benefits and costs under different alternatives over a project analysis period, while taking into account the probabilistic nature of storm damage, and the uncertainty regarding the measurement of many input variables. Benefits are derived by comparing the expected damages when a flood damage protection project is in place with the expected damages in the absence of any project. Although Corps Certified Model HEC-FDA provides such results, due to the unique nature (high frequency flood events) of the Natomas Basin a model that captures the economic life-cycle of the region is necessary in the estimation of benefits.

1.4 Report Organization

The report is organized as follows: An overview of the model and description of the model, its inputs, key functions, components and elements are provided in Section 2; Section 3 presents the model evaluation, including certification criteria, model testing approach and model assessment; Section 4 presents conclusions and recommendations.

SECTION 2

MODEL DESCRIPTION

2.1 Model Approach

The current corporate certified model (HEC-FDA) does not account for a post-flood rebuild period and assumes immediate rebuild/restoration following a flood event; HEC-FDA does not adjust for a declining inventory stock after flood events. The risk of flooding in the Basin is extremely high in terms of both the probability and consequences of flooding. In this high risk circumstance, HEC-FDA overstates expected annual damages by not accounting for such things as a rebuild period and declining inventory stock, which are reasonable assumptions of rational human behavior. The Natomas expected annual damages, then, should be computed to reflect the basic economic methodological premise of rational human actors.

N@RM is a model built on an EXCEL platform that uses Palisade's @Risk Excel Add-in to account for life-cycle damages; with the basis that high consequence events at a high probability of occurrence, the rebuild time period and the assumption of full replacement needs to be considered. HEC-FDA cannot make this adjustment so with the assistance of Mike Hallisy(ATR), the team collectively developed a base spreadsheet to account for present value damages followed by repair period with the series of potential additional flood events over the 50-year period of analysis. In the future, HEC-FRM will resolve this issue, however, meanwhile approval is necessary to move forward.

2.3 Model Development Process

Comments received during the Agency Technical Review (ATR) from the technical reviewer (USACE Los Angeles District, SPL) as well as from policy reviewers (USACE Headquarters and USACE SPD) , it was determined that the expected annual damages (EAD) obtained from HEC-FDA were overestimated and a post-processing method was necessary. The model developed was to be the basis for plan formulation and not just serve as a supplement to the HEC-FDA results. This model was developed in response to agency technical review comments and adjusts the EAD and benefit values by accounting for human behavior in the floodplain in the form of a rebuild period after a flood event, a loss of inventory stock as people move out of the floodplain after a flood event, and a cap to the number of flood event allowed to occur before the Natomas Basin is completely abandoned. The supplied model has been reviewed for technical quality by the development team in Sacramento District and satisfies expected economic behavior. In addition, the PDT believes that the approach to use the @RISK model to make EAD and benefits adjustments described is a necessary step in light of the fact that there is currently no other Corps-approved economic model that can do this type of analysis and also because there is no approved way to account for this EAD and benefits overestimation.

2.4 Model Capabilities and Limitations

The model incorporates two USACE approaches to flood risk management analysis—consistency with scientific understanding and a reasonable risk analysis procedure. It is able to account for human behavior in the form of a rebuilding period, a rebuilding schedule (percent rebuilt per year during the rebuild period), loss of inventory stock following a flood event, and the number of flood events allowed before floodplain occupants decide to completely abandon the Natomas Basin.

However, the model is limited in the following:

- Rebuild scenarios could be more comprehensive
- Three flood event cap

The rebuilding scenarios and three flood event cap assumptions are believed to be minuscule model shortcomings. It is thought that investment of time and resources in increasing the accuracy of such assumptions would marginally change the results and the overall value added would be minimal. A meeting with section chief, agency technical reviewer, corps economist and headquarter economist, conluded in indicating that both assumptions captures the model behavior of a rational participant.

These limitations have been noted but considering the single-use local use, it is believed that the shortcomings would only fine-tune the model. None of these issues should prevent the model from being certified as they are possible enhancements not corrections to the current capability of the model.

SECTION 3

MODEL EVALUATION

3.1 Certification Criteria

In accordance with the "Protocols for Certification/Approval of Planning Models" and EC 1105-2-412, N@RM is subject to Level 3approval/review. Being a level 3 review, it is important to emphasize that the Natomas @Risk Model (N@RM) was developed specifically for the Natomas Post-Authorization Change Interim Reevaluation Study. This model is intended to be a single-use, project-specific model, and was developed in order to more accurately quantify without-project damages and with-project benefits for the Natomas Basin study area. The primary objective for developing the model was to be able to incorporate economic assumptions which stem directly from the unique flooding characteristics of the Natomas Basin area, where there exists both a potentially high chance of flooding in any given year and extremely high expected damages, if a flood event were to occur. Currently, these assumptions cannot be captured in any existing USACE-approved planning model, including HEC-FDA.

Additionally, while the results of the N@RM were used as the basis for plan formulation, it is important to note that the analysis performed in HEC-FDA and the corresponding HEC-FDA results were not completely replaced with the analysis performed in and the results obtained from the N@RM. In fact, key data obtained from the HEC-FDA analysis or used in the initial with-project analysis served as inputs into the N@RM, including the HEC-FDA-computed stage-damage curves, the annual exceedance probability (AEP) information, and the order of levee reach improvements. In other words, the N@RM analysis is necessarily linked to the data and information derived from the HEC-FDA analysis, but expands upon the HEC-FDA analysis by incorporating additional economic assumptions pertinent specifically to the Natomas Basin study area. A comparison of the results from the HEC-FDA analysis to those from the N@RM shows that, on a relative basis, without-project and with-project benefits follow closely with one another. The main differences lie in the magnitude (that is, in absolute terms) of the without-project damages and with-project benefits. (The without-project damages using only HEC-FDA is close to $1.4 billion; the without-project damages using both HEC-FDA and the N@RM is $462 million.)

A summary of basic approval criteria is outlined below.

Technical Quality-- Analytical tools and models used to support flood risk management analysis are expected to be based on established contemporary scientific theory. The study area and how it responds to the influences that act upon it must be realistically represented by the model's components, in the form of calculations based on the application of scientific theory. The analytical requirements of the model must be identified, and the model must address these requirements. Formulas and calculation routines that form the mechanics of the model must be accurate and correctly applied, with sound relationships between variables. The model should also be able to reflect the influence or restrictions of man-made laws, policies, and practices.

The model should be logically unassailable and all assumptions whether they pertain to natural or human-induced processes, must be valid and documented. Technically correct models with rational assumptions should produce robust, reproducible results that stand up to the rigorous scrutiny in later stages of the plan formulation process.

System Quality-- System quality refers to the entire system used for model development, use and support, including software and hardware requirements, and data interoperability or compatibility with other systems. Efficiency and operation stability of the model have also been considered under system quality criteria. Factors such as appropriateness of the software or programming language, correctness of programming, and availability and quality of supporting software and hardware can be considered in the assessment of system quality. The ability to import model data and/or output into other software analysis tools is another factor associated with system quality.

Usability-- Usability refers to the overall ease and efficiency with which users are able to operate the model to obtain the relevant information required to support decisions made in the planning of flood risk management studies. The issues that can be considered during this component of the approval include:

- User friendliness of the model, including logical configuration and intuitiveness
- Availability of training and technical support for model users
- Availability of training and technical support for model users
- Ease of access in obtaining input data required to run the model
- Availability of the model programs or files to potential users
- Ability to extract understandable, relevant information from model outputs

Note that usability assessment will not be rigorous due the nature and level of review.

3.2 Technical Quality Assessment

Background

The model makes adjustments to the EAD based on the acknowledgement that the without-project damages and with-project benefits as reported by HEC-FDA may be overstated for the Natomas Basin. This acknowledgement, in turn, is based on several factors:

- The current HEC-FDA modeling results, which are based on frequency analysis and not life cycle analysis over the 50-year period of analysis, show a high annual exceedance probability (AEP of .21) and high expected annual damages (EAD of approximately $1.4 billion)
- The Natomas Basin floodplain characteristics, including the population and structure inventory
- The basic economic methodological premise that individuals will behave rationally

Taken together, the salient points above indicate that given the extremely high risk in the Natomas Basin area in terms of frequency of flooding (1 in 5 chance of flooding in any given year)[1] and consequences of flooding ($7.6 billion in damages from a 100-year event from break on the Natomas Cross Canal) coupled with the fact that the Natomas Basin contains close to 23,000 structures and nearly 80,000 residents, it is highly unlikely that people would continue to occupy the area after multiple floods, assuming they behave rationally. In order to fully consider that individuals act rationally, the damages and benefits adjustments took into account:

- A rebuild period following a flood event
- Rebuild scenarios in terms of how quickly the area would be redeveloped
- A decrease in structure inventory stock following a flood event
- A limit on the number of flood events allowed to occur; once this limit was reached, the assumption was made that floodplain occupants would choose to not live in the Natomas Basin

It is important to note that this analysis was performed using the information computed by HEC-FDA. Specifically, AEP data and single-event damage were taken and incorporated into this analysis using a newly-developed @Risk spreadsheet model.

The @Risk model developed specifically for this study was created to account for rational human behavior, which is the basic economic methodological premise in most economic studies. Rational human behavior, in the case of flooding in the Natomas Basin, was captured within the model in the form of a rebuild period, rebuild scenarios, loss of inventory stock, and a limit to the number of flood events that would occur before the Natomas Basin would be abandoned and people would decide not to live there. One drawback of HEC-FDA is that it is frequency-based, and its computational framework is not set-up to account for these factors related to human behavior; the Natomas @Risk model was set-up to be able to account for human behavior through the use of Monte Carlo simulation and life-cycle analysis.

Theory and Analytical Assumptions

[1] Although not addressed here, one cause of the high calculations of EAD/AEP in HEC-FDA may be the conservative assumptions in regard to the geotechnical risk and uncertainty (GRU) curves. Following the March 2009 F3 Conference (milestone conference which establishes the without-project condition), Sacramento District's Engineering Division attempted to address Planning Division's concerns about the GRU curves; Engineering Division held an expert elicitation as well as provided input (adjusted GRU curve at NAT C) to account for flood fighting. A sensitivity analysis, which is documented in Enclosure 3, was performed by the Economics Section using the adjusted curves. For NAT C, AEP (and EAD) were reduced significantly using the adjusted GRU curve from the expert elicitation; there was only minimal change to AEP (and EAD) using the revised GRU curves adjusted to account for flood fighting. Since the F3 Conference, additional index points were evaluated in order to better facilitate the with-project analysis; many of these points (e.g., NAT D) are producing high AEP/EAD values.

At this time, it is believed that Engineering Division has followed their process in terms of developing GRU curves and has at least considered Planning Division's concerns about the curves. The issue of high AEP/EAD values, then, has been addressed by the SPK Planning Division through this EAD/benefit adjustment.

The main purpose of the model is to adjust the EAD and benefit numbers obtained from the HEC-FDA modeling to account for human behavior by making assumptions about post-flood event rebuild periods, rebuild scenarios, floodplain inventory stock, and a reasonable assumption of the number of floods allowed to occur over the 50-year period of analysis before the Basin would be abandoned.

Several assumptions were made in order to perform the analysis. These assumptions are also indicated in Figure 7B-1, which shows a graphical snapshot of the @Risk model. Figure 7B-1 will be referred to in this section as well as in sections 7.4, 7.5, and 7.6 to explain the EAD and benefits adjustment calculation process and to point out significant details related to the model.

The major assumptions used in the model are:

- After a flood event, the floodplain inventory stock would be replaced by not more than 80% of the damaged property; this assumption captures the idea that not all floodplain occupants would choose to rebuild and live in the Natomas Basin after a flood event – some occupants would choose to leave the area. This assumption argues that a diminishing return on housing stock would occur as a result of continued flood events. If flooding were to occur in the Natomas Basin, the damages to structures would require significant rehabilitation and investment. Although insurance claims would provide some means of restoration, the notion that 100% of the inventory would return is inaccurate. The capital required to re-establish thebasin would not be available from insurance claims or investors when considering the potential risk of flooding (AEP of .21).

- A rebuild period of three (3) years (see Label 1). Rebuilding would take place over a 3-year period immediately following the flood event. The process of reducing the inventory stock to 80% of damaged property and rebuilding over a 3-year period would start all over with the next flood event.

- Four (4) rebuild scenarios were delineated (see Label 2), and range from a “slow” rebuild to an “aggressive” rebuild. For example, in the “slow” rebuild scenario (see Figure 7B-1), it was assumed that 20% of those properties damaged would be rebuilt in each of the 3 years of rebuilding. In the Natomas @Risk Model, rebuilding scenarios were held constant with successive levee reach improvement, effectively applying rebuilding assumptions only *after* a flood event occurs. In other words, it was assumed that the range of rebuilding scenarios captured under the sixth levee reach improvement would be similar to those under without-project run; under either of these scenarios, or under any other improvement for that matter, it is likely that flooding in the Natomas Basin would be catastrophic, and it was believed that decisions regarding rebuilding were less likely to be based on the perceived state of flood protection prior to a flood event. Admittedly, predicting any type of post-flood building scenario associated with flood events that may cause major destruction is complex due to the multitude of factors (e.g., resources available to rebuild, the extent of damages incurred, flood policies in place, cultural/historical significance of the area, government bureaucracy, etc.) that may influence the amount of post-flood rebuilding that may actually be realized. To compensate for this uncertainty in the amount of rebuilding that would take place, the team assumed several scenarios, ranging from a "slow" rebuild to a an "aggressive" rebuild, and incorporated these assumptions into the @Risk model.

- There is a limit of three (3) flood events that would be allowed to occur in the Basin at which point people would decide not to rebuild and live in the Basin; once this limit was reached, the model assumes that the Natomas community would abandon the region. This assumption stems from discussion with project agency technical reviewer, corps economist, and headquarter economist. Although possible discussion to incorporate a rebuild period after a certain amount of time (25-30 years) was discussed, the intricate nature of the assumptions necessary to conduct such an analysis is mostly subjective (deciding when to being rebuild, how much, and what kind of land use would develop). Also, rebuilding that far out in the future would require construction in phases and based on the repetitive nature of flooding in the area (AEP of .21) it would be difficult to quantify the level of inventory at that point in time. Natomas developed because it was the most cost effective location for housing. There were/are other areas that could potentially be developed at higher land rents. The model assumes that after three flood events (6-12 years) sufficient housing stock would occur to supply the demand of residents wanting to escape the repetitive flooding.

Input Data and Application

The model uses Monte Carlo techniques to derive outputs (e.g., in this case the outputs are EAD and benefits) based on key input variables that have uncertainty parameters attached to them; the uncertainty of key variables are described in the @RISK model through the assignment of probability distributions.

The model was developed to address the unique flooding situation in the Natomas Basin – high probability of flooding as well as high consequences (damages) if flooding were to occur – in order to account for rational human behavior. The model is set-up to calculate event damages over a 50-year period of analysis by:

- randomly selecting whether or not a flood event occurs in each year of the 50-year period of analysis; AEP information obtained from the initial HEC-FDA modeling is used as a basis to determine the likelihood of a flood event occurring in any given year
- incorporating a 3-year rebuild period following a flood event and sampling from four different rebuild scenarios to determine how much of the floodplain is rebuilt
- calculating event damages for up to 3 flood events over the 50-year period of analysis for each iteration of the @Risk simulation
- calculating EAD/benefits

The sections below describes the model developed specifically for the adjustment of Natomas EAD and benefits. The data used in the model and the application of this data within the model is explained in more detail in the subsections below. The discussion below references Figure 1.

HEC-FDA Computed Stage-Damage Curves

The damages from the stage-damage curves computed by HEC-FDA and were used to populate the frequency-damage table (point A) in Figure 1. For each impact area and for each levee reach improvement, the stages associated with each frequency event (2-year to 500-year) were pulled from the engineering frequency-stage curves also from the HEC-FDA analysis; the corresponding damages and uncertainty in damages (standard deviation of damages) at each frequency event stage were then pulled from the stage-damage curves computed by HEC-FDA. For each frequency event, the damage and standard deviation of damage data pulled from the stage-damage curves in HEC-FDA were then used to calculate in @RISK minimum and maximum damage values; a normal probability distribution was used to describe the uncertainty in damages for this @RISK run. The minimum and maximum values obtained from this run were then used as input into the cumulative probability distribution function used to compute event damages. Additionally, damage and standard deviation of damage data pulled from the stage-damage curves in HEC-FDA were used to calculate coefficient of variation (COV) information; COVs were also used as input into the cumulative probability distribution functions in @RISK.

Annual Exceedance Probability (AEP) and Randomly Generated Flood Events

Annual Exceedance Probability (AEP) data were also used as input into the model. The AEP was applied within the model as the basis for determining whether a flood event resulting in levee failure would occur in any given year over the 50-year period of analysis. For example, in the scenario shown in Figure 1 (without-project for the Major area), an AEP of .21 was entered. This AEP corresponds to the AEP obtained at the Natomas Cross Canal, which was used as the without-project baseline for the Major impact area. The model is set-up to randomly generate numbers between zero and 1 for each year of the period of analysis; a randomly generated number that was lower than .21 triggered a levee failure and a number greater than or equal to .21 did not trigger a levee failure. In other words, for the without-project and for this impact area, there was a 21% chance that a flood event resulting in levee failure would occur in any given year throughout the 50-year period of analysis.

@Risk-Computed Event Damages & Cumulative Probability Distribution

In the model, when a flood event occurs event damages for that specific event are calculated. Event damages are calculated with uncertainty using a cumulative probability distribution function. As is displayed in Figure 1 (point B), event damages for the first flood event in this example and for this iteration of the simulation is $4,217 billion. The formula used to calculate event damages is also shown at point B. In this example, minimum and maximum values were set at $4.211 billion and $5.53 billion, respectively. The cumulative probability distribution function was formed by setting the damage value at each respective frequency event shown in the frequency-damage table (point A) to a corresponding probability based on the actual event frequencies. For example, the first damage point on the cumulative probability distribution function is $4.357 billion, which is taken directly from the frequency-damage table; the corresponding probability for this damage is .5, which says that, should a flood event occur, a damage value of $4.357 billion or lower will occur 50% of the time. The last damage point on the curve is $5.33 billion, which says that, should a flood event occur, a damage value of $5.33 billion or lower will occur 100% of the time[2].

Finally, a COV was entered as part of the formula used to calculate event damages. This COV was based on the HEC-FDA computed stage-damage curves with uncertainty. Within the model, once event damages were calculated for the first flood event (and through using a cumulative probability distribution function as described previously), the uncertainty associated with these event damages were described by setting it to a normal distribution having a standard deviation equal to plus/minus the previously-computed COV. Incorporating the COV into the event damages specifically addresses the requirement of incorporating uncertainty in the first floor elevation of structures, uncertainty in structure and content values, and uncertainty in structure and content depth-damage percentages since the damage values and COVs used here were based on the HEC-FDA computed stage-damage curves with uncertainty, which already have these uncertainties factored in.

@Risk-Computed Expected Annual Damages (EAD)

The model computes EAD by discounting event damages of each flood event to the present year, summing the discounted values, and then amortizing this value over the 50-year period of analysis. In each @Risk simulation, thousands of iterations are completed, each resulting in a different EAD value; the final EAD value reported in the @Risk output results table is the average of all EAD values across all iterations.

[2] In actuality, the probability associated with the last damage point would be .998; however, 1.0 was used in order to be able to satisfy the @Risk software requirement of having a probability of 1.0 (100%) designated as the last point on the cumulative probability distribution function.

In the example shown in Figure 1, the first flood event occurs in year 3 of the period of analysis and produces damages of $4.217 billion. As can be seen in the table marked by point D, after the first year of rebuild the inventory stock is only restored to the remaining value after the flood event ($6.918 billion minus $4.217 billion = $2.701 billion) plus the amount of rebuilding (15% of damaged property, or $4.217 billion multiplied by .15 = $634 billion) assumed to occur for that year, in this case it's $3.334 billion ($2.701 billion + $633 billion). In the second year, an additional 30% of the damaged property is rebuilt to get a value of $4.599 billion; in the third year an additional 15% of the damaged property is rebuilt to get a value of $5.231 billion. This value is then carried forward as the baseline total value of damageable property for the next flood event.

Point D also shows that after the third flood event (in this example this flood event occurs in year 25), no other flood event is allowed to occur within the 50-year period of analysis. This effectively prevents any other damages to be incurred and caps the calculation of EAD to three flood events. After this third event, it is assumed that people would abandon the Natomas Basin.

Expected Annual Damages	Net Present Value	Total Value of Damageable Property	Event Damage	Percent Loss	Annual Exceedance Probability	Discount Rate	Reconstruction Scenarios
$277.08	$5,588.85	$6,918	$4,217	61%	0.21	4.375%	2

B

=(RiskCumul(4211,5530,{4357,5026,5129,5227,5281,5312,5330},{0.5,0.9,0.96,0.98,0.99,0.995,1}))*RiskNormal(1,N7)

D

Year	Event Occurrence	Beginning Prop. Damage	Damages	Post Event Value	EOY Value
0	0	6,918	$ -	6,918	6,918
1	0	6,918	$ -	6,918	6,918
2	0	6,918	$ -	6,918	6,918
3	1	6,918	$ 4,217	2,701	3,334
4	0	3,334	$ -	3,334	4,599
5	0	4,599	$ -	4,599	5,231
6	0	5,231	$ -	5,231	5,231
7	0	5,231	$ -	5,231	5,231
8	0	5,231	$ -	5,231	5,231
9	0	5,231	$ -	5,231	5,231
10	0	5,231	$ -	5,231	5,231
11	0	5,231	$ -	5,231	5,231
12	0	5,231	$ -	5,231	5,231
13	0	5,231	$ -	5,231	5,231
14	0	5,231	$ -	5,231	5,231
15	0	5,231	$ -	5,231	5,231
16	0	5,231	$ -	5,231	5,231
17	0	5,231	$ -	5,231	5,231
18	0	5,231	$ -	5,231	5,231
19	0	5,231	$ -	5,231	5,231
20	0	5,231	$ -	5,231	5,231
21	1	5,231	$ 3,189	2,042	2,521
22	0	2,521	$ -	2,521	3,477
23	0	3,477	$ -	3,477	3,956
24	0	3,956	$ -	3,956	3,956
25	1	3,956	$ 2,411	1,544	1,906
26	0	1,906	$ -	1,906	2,630
27	0	2,630	$ -	2,630	2,991
28	0	2,991	$ -	2,991	2,991
29	0	2,991	$ -	2,991	2,991
30	0	2,991	$ -	2,991	2,991
31	0	2,991	$ -	2,991	2,991
32	0	2,991	$ -	2,991	2,991
33	0	2,991	$ -	2,991	2,991
34	0	2,991	$ -	2,991	2,991
35	0	2,991	$ -	2,991	2,991
36	0	2,991	$ -	2,991	2,991
37	0	2,991	$ -	2,991	2,991

COV
1.40%

2

R.Scenario	Year I	Year II	Year III
1	20%	20%	20%
2	15%	30%	15%
3	30%	20%	10%
4	45%	10%	5%

1

1st-Year	15%
2nd-Year	30%
3rd-Year	15%

A

Inc.	Stage-Damage Relationship @ Frequency						
	2-yr	10-yr	25-yr	50-yr	100-yr	200-yr	500-yr
0	4357	5026	5129	5227	5281	5312	5330
1	2381	3590	4814	5061			
2							
3							
4							
5			1184	4086			
6							
7							
8							
9							
10							
11							
12							

C

Inc.	Cumulative Probability Distribution						
	2-yr	10-yr	25-yr	50-yr	100-yr	200-yr	500-yr
	0.5	0.1	0.04	0.02	0.01	0.005	0.002
0	0.500	0.900	0.960	0.980	0.990	0.995	1.000
1	0.500	0.900	0.960	0.980			
2							
3							
4							
5			0.960	0.980			
6							
7							
8							
9							
10							
11							
12							

Index Point	
D	
B	E
C	H

FIGURE 7B-1
Diagram of Natomas EAD Adjustment Model

Damage values are in millions of dollars.

3.3 System Quality and Usability Assessment

The system quality of the model has generally been assessed via the routine installation of the supporting software (@RISK) and the operation of the model, rather than according to a set of discrete test or components identified in advance, although some exercises were specifically undertaken to investigate certain aspects of the model associated with system quality.

@ Risk Software

The model is built on a Windows-based, menu driven MS Excel platform that uses Palisade's @RISK Software. @RISK performs risk analysis using Monte Carlo simulations. It is an add-in to Microsoft Excel, integrating completely with MS Excel spreadsheets. All @RISK functions are true Excel functions, and behave exactly as native Excel functions do.
The usability of the model depends to a great extent on the clarity and efficiency with which the supporting documentation informs the user of the data required and the process that must be followed in order to obtain the desired outputs. The main supporting document is available in the developer's user manual.
Also, Palisades provides training on the use of the software, and the concept of risk analysis. Training includes but is not limited to: regional training courses, live web training, free live webcasts, on-site training, conferences, forums, and symposiums. This training increases the user's knowledge, proficiency, ability, and skill in the use of the model. Since the software was released, maintenance and updates have been provided by Palisades.

SECTION 4

CONCLUSIONS AND RECOMMENDATIONS

4.1 General Review Summary

The following table presents a general summary of criteria used to review the model. The format mirrors the outline for model documentation provided by the Assuring Quality of Planning Models Protocols. This table is intended to provide a general overview of the more detailed discussion of the model in section 3.2.

4.2 Certification Recommendations

N@RM is a simple model that draws together theory and data from HEC-FDA to compute an EAD number consistent with economic theory. The primary aim of this review and documentation is to generate a single-use/study-specific recommendation for the approval-of-use of the model. Model approval would determine that the model is technically and theoretically sound and a functional tool that can be applied during the planning process by knowledgeable and trained staff for purposes consistent with the model's purpose and limitation.

ENCLOSURE 8: CLARK-WOLCOTT AVERAGE UNIT REPLACEMENT VALUES (PER SQUARE FOOT)

AVERAGE UNIT REPLACEMENT VALUE: RESIDENTIAL			
Description	**Range in Values (2007 Prices)**		
Single-Family Residential (SFR)	**Minimum**	**Typical**	**Maximum**
0 to 1,499 square ft (SF)	$62	$86	$122
1,500 to 1,999 SF	$60	$79	$114
2,000 to 2,999 SF	$58	$77	$111
3,000 to 3,999 SF	$56	$74	$107
>3,999 SF	$55	$72	$105
Residential Garages	**Minimum**	**Typical**	**Maximum**
0 to 299 SF	$20	$27	$36
300 to 499 SF	$14	$18	$25
>499 SF	$13	$17	$24
Multi-Family Residential (MFR)	**Minimum**	**Typical**	**Maximum**
<20,000 SF	$52	$69	$95
20,000 to 100,000 SF	$50	$67	$92
>100,000 SF	$50	$66	$90
Multiple Garages	**Minimum**	**Typical**	**Maximum**
4-car/800 +/- SF	$13	$17	$22
8-car/1,600 +/- SF	$12	$16	$21
12-car/2,400 +/- SF	$12	$15	$20
Manufactured/Mobile Home (MH)	**Minimum**	**Typical**	**Maximum**
<1,000 SF	$53	$59	$74
1,000 to 1,399 SF	$48	$54	$67
>1,399 SF	$44	$49	$61

AVERAGE UNIT REPLACEMENT VALUE: NON-RESIDENTIAL			
Description	**Range**		
	Minimum	**Typical**	**Maximum**
COMM-OFF (Office Buildings)			
One-Story	$71	$96	$129
Two-Stories (or more)	$99	$139	$161
COMM-RET (Typical retail stores)			
Non-furniture	$45	$66	$97
Furniture	$45	$66	$97
COMM-FOOD (Stores that sell perishable food items)			
Large Supermarkets	$59	$81	$94
Convenience Stores	$66	$86	$99
Gas Station Mini-Marts	$108	$131	$153
COMM-REST (Traditional restaurants/fast-food establishments)			
Non-Fast Food	$85	$144	$186
Fast Food	$83	$148	$202
COMM-MED (Medical and Dental)			
Medical/Dental Offices	$93	$118	$153
Hospitals	N/A	N/A	N/A
COMM-SHOP (Large shopping centers, box stores, malls)			
Lg. Discount/Box Stores	$44	$65	$88
Lg. Shopping Cntrs.	$71	$89	$120
Lg. Shop. Cntr. Grocery	$65	$84	$108
COMM-SERV (Repair shops, auto, full service stations)			
Garages to Auto Svc.	$40	$58	$85
IND-WH (Warehouses, storage, transportation centers)			
Distribution WH	$32	$57	$69
IND-LT (Small tool shops, light manufacturing)			
Office/WH, flex, lt. man.	$31	$52	$82
PUB-GOV (Governing buildings, county, city, state, and federally owned offices)			
Storage, WHs, Office	$32	$57	$139
PUB-SCH (Schools)			
Elem/Middle/High	$105	$133	$165
Day Care Cntr/Nursury	$84	$115	$148
PUB-RF (Religious facilities)			
Churches, sanctuaries	$83	$121	$194
PUB-REC (Recreation, assembly-clubs, theaters)			
Driv. range, halls, clubs	$62	$87	$141
FARM (Non-residential outbuildings and sheds)			
Sheds and barns	$12	$25	$33