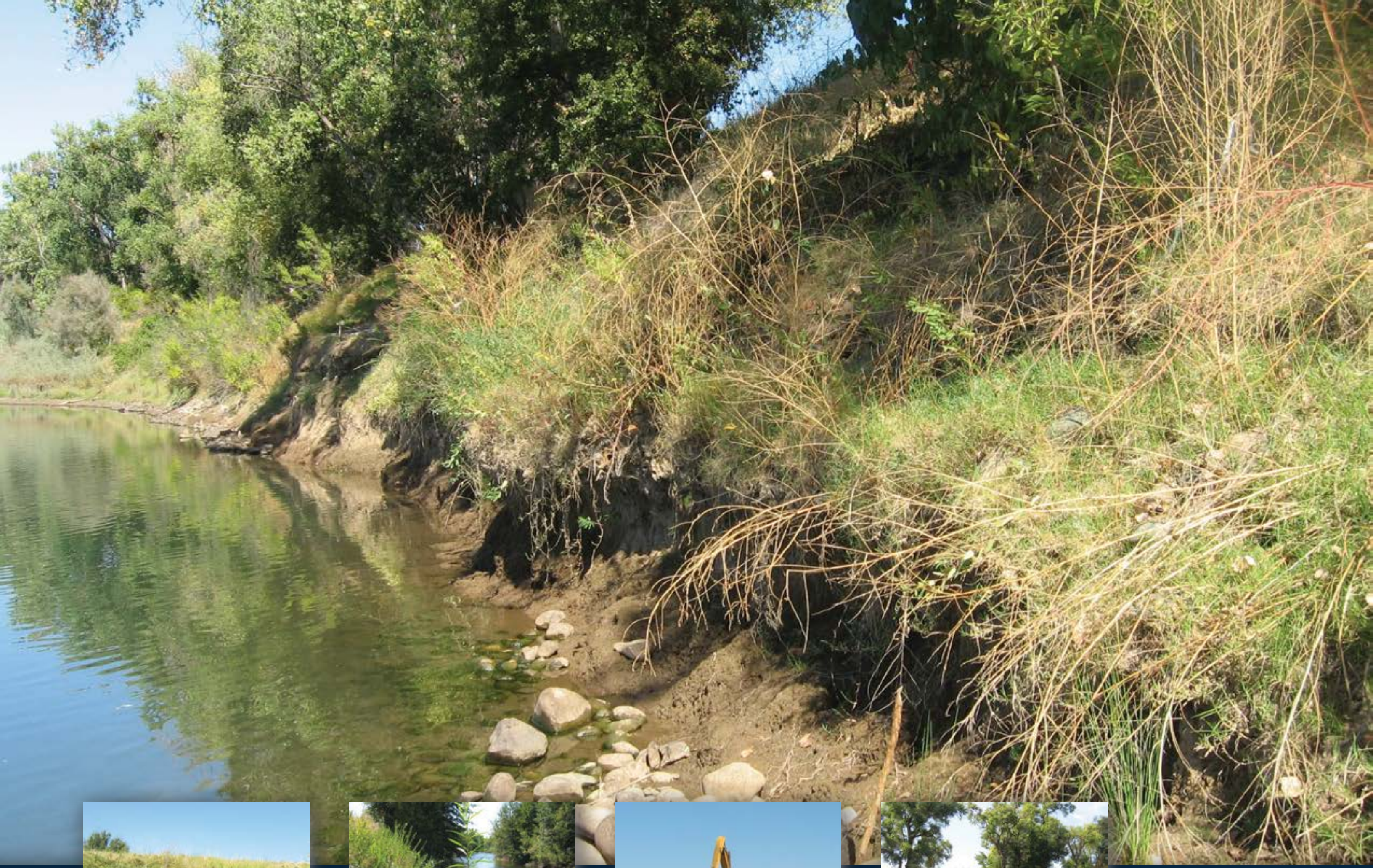

Appendix D- Economics

Sacramento River Bank Protection Project

Sacramento River Basin, California

December 2019

US Army Corps of Engineers
Sacramento District

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PURPOSE

This report describes the assumptions, data, methodologies, and techniques used to perform the economic analysis for the Sacramento River Bank Protection Project (SRBPP) Post-Authorization Change Report (PACR). The results and conclusions of the analysis are also presented in this report.

The majority of the economic analysis was originally completed in a 2011 update for the primary purpose of determining benefit-to-cost ratios to be used for the U.S. Army Corps of Engineers' (USACE) annual program/project economic justification. The 2011 update determined seven economic impact areas were economically feasible: Butte Basin, Natomas, Sacramento, Southport, Yolo, West Sacramento, and Sutter Island. Since then, there has been additional economic analysis to support this Post Change Authorization Report (PACR) and it was determined that only six of the seven previously justified regions and one additional economic impact area, Rio Oso, to be economically justified. The Sutter Island economic impact area was found to be no longer economically justified.

BACKGROUND

The SRBPP is a federal program which recognizes that bank erosion control and stabilization are necessary to ensure the integrity of the Sacramento River Flood Control Project (SRFCP), which includes approximately 1,300 miles of project levees that protect approximately 2.1 million acres of agricultural and urban land uses.

The SRBPP originally consisted of two phases. Phase I was initially authorized by the Flood Control Act of 1960 and consisted of approximately 430,000 feet of levee work; Phase I work has since been completed. Phase II was authorized by the River Basin Monetary Authorization Act of 1974 and consisted of approximately 405,000 feet of levee work and an additional 80,000 feet was authorized by the Water Resources Development Act (WRDA) of 2007 and added to the SRBPP's Phase II work. The economic analysis presented in this report addresses the economic feasibility of potential levee stabilization work authorized under the WRDA of 2007. The USACE Sacramento District identified 106 erosion sites for this analysis; these sites were selected through field observations originally conducted in the year 2007.

For purposes of providing an idea of the geographic scope, Figure 1 on the following page is a map of the SRBPP study area and levees; Figure 2 below displays the 106 erosion sites.

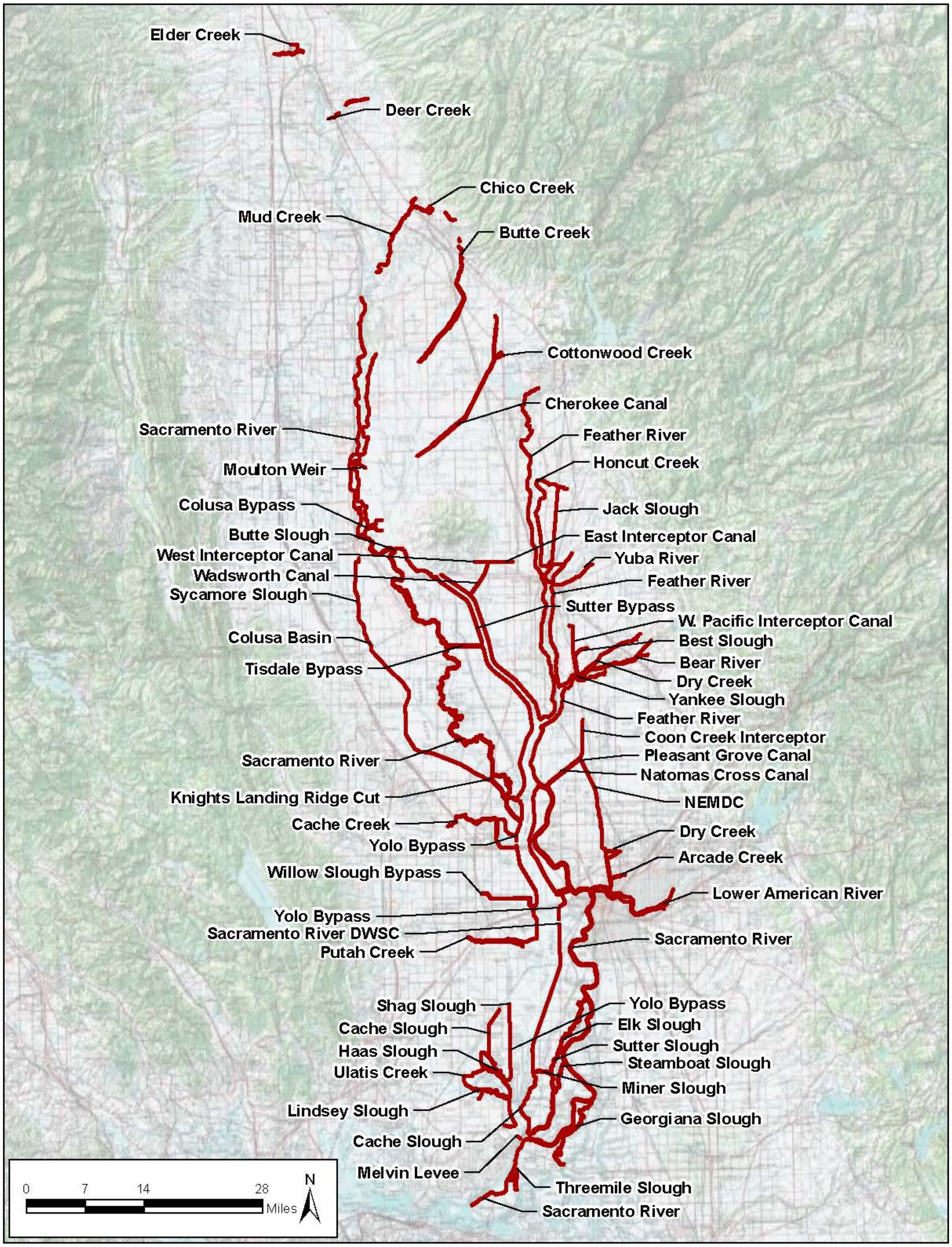

FIGURE 1: GEOGRAPHIC SCOPE OF SRBPP LEVEES.

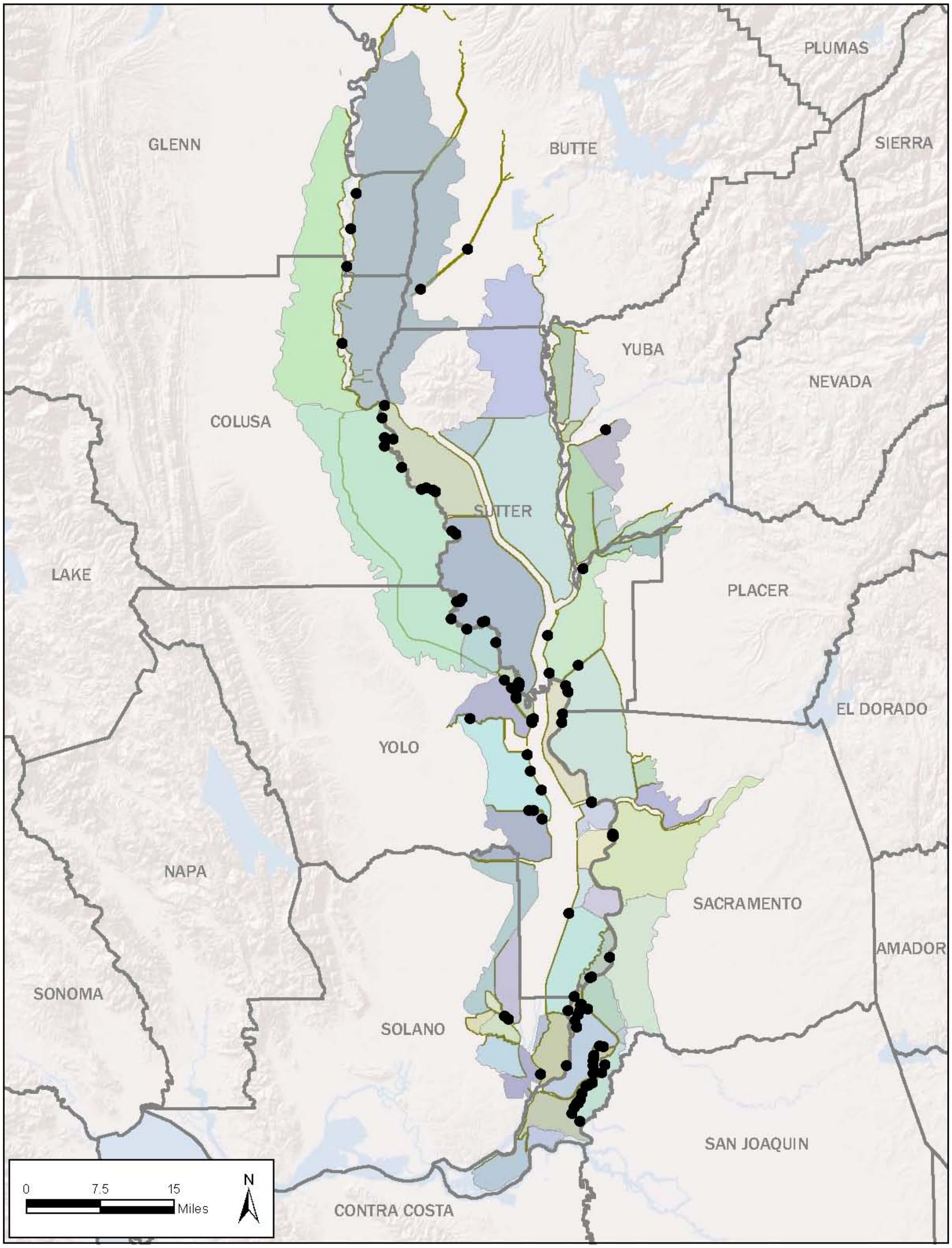

FIGURE 2: GEOGRAPHIC SCOPE AND APPROXIMATE LOCATIONS OF 106 EROSION SITES.

PREVIOUS SRBPP ECONOMIC ANALYSES AND COMPLIANCE WITH CURRENT GUIDANCE

Previous economic analyses for the SRBPP were performed using methods that would not necessarily be relevant or sufficient under current USACE guidance. Some of the past analytical approaches used to economically justify the SRBPP include:

- Determining operation and maintenance (O&M) costs and computing benefits based on a reduction (or savings) in these costs once erosion work was completed

- Estimating benefits based on the reduction of potential inundation losses (damages prevented); damages were calculated based on the potential number of acres inundated throughout the system (assuming levee failures due to erosion) and applying gross losses per acre for rural and urban areas to the estimated number of acres

- Providing qualitative descriptions of the potential accomplishments of the SRBPP, which include protecting a large human population, protecting a significant amount of physical property, and protecting high-value agricultural acreage

- Extrapolating damages/benefits calculated by analyzing only small sections of levee repair and by assuming unusually high without-project damaging flood probabilities (annual exceedance probabilities or AEPs) normally associated with levees requiring immediate emergency repair; high AEPs are not necessarily applicable to the SRBPP levees

The economic analysis presented in this report was performed using current USACE guidance. Defined economic impact areas (rather than one large area as has been used in the past), a current economic inventory, a risk analysis approach (incorporating exceedance probability discharge curves with uncertainty, hydraulic floodplains, geotechnical fragility curves, and economic stage-damage curves), and clear, transparent descriptions of both the assumed without-project and with-project conditions were used in the analysis to estimate project benefits both as an entire system and incrementally by impact area/basin. These are discussed in more detail in the following sections of this report.

CONSISTENCY WITH REGULATIONS AND POLICIES

The economic analysis was performed in accordance with USACE standards, procedures, and guidelines. The *Planning Guidance Notebook* (Engineering Regulation, ER 1105-2-100) serves as the primary source for evaluation methods for flood risk management (FRM) studies and was used as reference for this analysis. Additional guidance for risk analysis was obtained from Engineering Manual (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 July 17, 2017).

PRICE LEVEL, PERIOD OF ANALYSIS, AND DISCOUNT RATE

Monetary values presented in Sections 9-12 are in FY19 price levels. Costs and benefits of the various alternatives were amortized over a 50-year period of analysis using a federal discount rate of 2.875%.

DEFINITION OF ANNUAL EXCEEDANCE PROBABILITY (AEP)

The economic analysis relies heavily on assumed annual exceedance probability (AEP) information derived specifically for the SRBPP or for other ongoing studies in the Sacramento District. The AEP is the probability that flooding will occur in any given year considering the full range of possible annual floods. Within the HEC-FDA model, AEPs are computed by integrating hydrologic/ hydraulic and geotechnical data in the form of exceedance probability-discharge-stage curves and geotechnical fragility curves/target top of levee stages.

SUMMARY OF MAJOR ASSUMPTIONS UNDERLYING THE ECONOMIC ANALYSIS

The major assumptions underlying the economic analysis are summarized below:

- The target annual exceedance probability (AEP) information for the without-project condition was obtained from the contractor-developed report, *Annual Exceedance Probability of Failure and Sensitivity Analysis Due to Bank Erosion* (URS Corporation, February 2011). The primary purpose for developing this information was to be able to estimate without-project damages and benefits for the SRBPP; the URS report was not meant to serve as a detailed, authoritative engineering analysis of conditions at each erosion site. (More details about the AEP analysis and results can be found in the URS-developed report in Enclosure 1.)

- The economic analysis assumed a without-project condition equivalent to Condition A as described in the URS report. Condition A describes the prevailing condition in 2010 of the 106 erosion sites assuming no flood event has occurred and which could potentially lead to worsening of the erosion sites. Existing project performance levels in terms of annual exceedance probabilities (AEP) presented in the contractor-provided report for Condition A were used to simulate the without-project condition in the economic model (HEC-FDA). Annual exceedance probability values presented in the URS report assume failure due to erosion only.

- The URS report also lays out AEP information for several other conditions, all of which make different assumptions. In particular, Condition C is also a without-project condition, but unlike in Condition A, Condition C is a most likely future condition for the year 2025 and assumes that a flood event has occurred causing the erosion sites to worsen. At most erosion sites, estimated

AEP levels associated with Condition C are either 1) the same as those estimated for Condition A (at the same erosion site) or 2) are exceeded by or equal to Condition A's AEP estimate of another erosion site within the same economic impact area. For economic analysis purposes, the existing without-project condition was assumed to be Condition A in terms of hydrology, hydraulics, and geotechnical data inputs into HEC-FDA. Using the AEP information from Condition A allows for a more conservative estimate of damages and benefits than using the AEP information from Condition C. Using the lower AEPs of Condition A translates into lower without-project expected annual damages (EAD) as compared to the other conditions presented in the URS report and therefore has the lowest potential for overstating benefits.

- The with-project condition AEPs were represented in the analysis by the without-project AEPs developed for the 2002 Sacramento and San Joaquin Basins Comprehensive Study for those economic impact areas where more current HEC-FDA input data (exceedance probability-discharge and geotechnical fragility curves) are not available. In areas where there is more current data, these data (and corresponding AEP information) were used in the analysis. The idea behind this assumption is that once erosion sites within an impact area are fixed, the AEP associated with a particular impact area improves to the AEP estimated by either the (without-project) AEP of the Comprehensive Study or the AEP estimate from a more current study.

- The same hydrologic exceedance probability-discharge curves and hydraulic floodplains were used for the without-project and with-project conditions.

- The difference between the without-project and with-project expected damages is directly related to the difference in AEP between the two conditions, which in turn is governed by the difference in levee fragility (geotechnical fragility curves) between the two conditions. For each impact area, the geotechnical levee fragility curves that represent the with-project condition were taken from either the Comprehensive Study without-project analysis or from a more current Corps analysis, depending on the particular study area; these curves, which in this analysis represent the "with-project" levee fragility curves, were then adjusted in HEC-FDA to derive an AEP value that matched the AEP value of Condition A as outlined in the URS report. This process is described in more detail below (*Economic Model and Analytical Approaches/Techniques)*.

- For each economic impact area, expected annual damages were computed in HEC-FDA using exceedance probability-discharge curves, geotechnical fragility curves, and economic stage-damage curves at specific index point locations delineated either for the Comprehensive Study or another more current study and do not necessarily correspond to the exact erosion site location. Index points are used in HEC-FDA for data aggregation purposes and ultimately to quantify risk (consequence and chance of flooding) in an economic impact area.

- Benefit-to-cost ratios are based on the assumption that all known erosion sites within an impact area are repaired.

ECONOMIC IMPACT AREAS

The economic impact areas used for this analysis follow closely those delineated for the 2002 Sacramento and San Joaquin River Basins Comprehensive Study. There were some minor adjustments made that combined certain Comprehensive Study impact areas into one area for the purposes of the SRBPP analysis. For example, in the Comprehensive Study, the Colusa Basin was separated into two areas; for this analysis, the Colusa Basin was considered one impact area. Similarly, the Knights Landing area was delineated into two impact areas in the Comprehensive Study but is only one impact area in this analysis.

Table 1 below displays the economic impact areas the waterways containing erosion sites, and the number of erosion sites associated with each impact area. Twenty four impact areas composed of 106 erosion sites have been identified for this analysis. Of the 106 erosion sites, 101 were included in the previous economic analysis, however, as previously mentioned, only the seven economically feasible impact areas are considered for this update.

Figure 3 displays all of the economic impact areas.

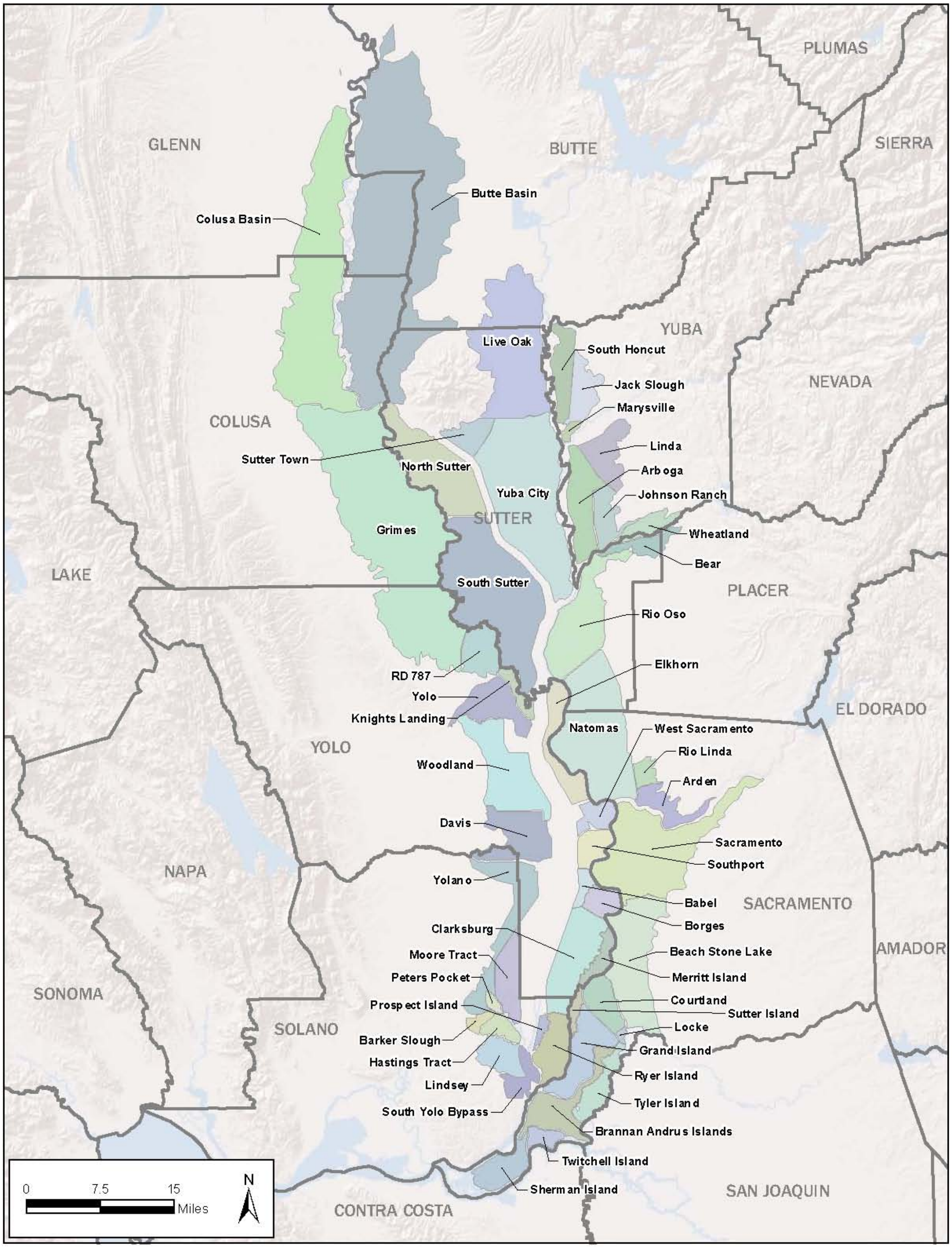

FIGURE 3: MAP OF ECONOMIC IMPACT AREAS.

TABLE 1: ECONOMIC IMPACT AREAS, ASSOCIATED WATERWAYS, AND NUMBER OF EROSION SITES

Economic Impact Area (Number from Comprehensive Study)	Associated Waterways with Erosion Sites[1]	Number of Erosion Sites Identified
Butte Basin (5)	Sacramento River	4
Grimes (10)	Sacramento River	6
South Sutter (11/34)	Sacramento River	10
Knights Landing (13/14)	Knights Landing RC; Yolo Bypass; Sac River	8
Yolo (15)	Cache Creek; Knights Landing Ridge Cut	2
Woodland (16)	Yolo Bypass; Willow Slough	5
Davis (17)	Willow Slough	1
Linda (27)	Yuba River	1
Rio Oso (30)	Bear River; Natomas Cross Canal; Feather	4
North Sutter (32)	Sacramento River	6
Elkhorn (35)	Sacramento River	3
Natomas (36)	Sacramento River	1
Arden/Rio Linda (37)	American River	1
West Sacramento (38)	Sacramento River	2
Southport (39)	Sacramento River	2
Sacramento (40)	Sacramento River	3
Clarksburg (42)	Sutter Slough; Deep Water Ship Channel	3
Merritt Island (46)	Sacramento River	3
Sutter Island (49)	Steamboat Slough; Sutter Slough	4
Grand Island (50)	Steamboat Slough; Sacramento River	4
Tyler Island (53)	Georgiana Slough	17
Brannan Andrus Island (54)	Sacramento River	7
Ryer Island (55)	Steamboat Slough; Cache Slough	2
Hastings Tract (61)	Cache Slough	2

[1] Erosion sites on Cherokee Canal, Deer Creek, and Elder Creek were not analyzed due to insufficient data; in addition, these waterways protect impact areas that contain minimal economic consequences in terms of agricultural and urban damages.

DATA SOURCES AND DEVELOPMENT

The following sections describe the data sources and development used in the economic analysis.

HYDROLOGIC, HYDRAULIC, AND GEOTECHNICAL DATA

For the majority of economic impact areas, the hydrologic/hydraulic/geotechnical HEC-FDA input data (exceedance probability-stage, floodplains, and fragility curves) were developed for the Comprehensive Study and used for the SRBPP analysis. For other impact areas, more current data was obtained from an ongoing Sacramento District study and used in this analysis. Table 2 below shows the source of the HEC-FDA input data used for each of the 24 economic impact areas. Enclosure 2 to this report includes the HEC-FDA input data (exceedance probability-discharge-stage curves and geotechnical fragility curves) used for each impact area.

TABLE 2: SOURCES OF DATA – EXCEEDANCE PROBABILITY-DISCHARGE-STAGE CURVES, FLOODPLAINS, AND FRAGILITY CURVES

Economic Impact Area	Sources of Data					
	Exceedance Probability-Discharge-Stage Curves		Floodplain Depths		Fragility Curves	
	Without-Project	With-Project	Without-Project	With-Project	Without-Project	With-Project
27	2010 Yuba River GRR	2010 Yuba River GRR	2010 Yuba River GRR	2010 Yuba River GRR	Adjusted[2]	2010 Yuba River GRR
36	2010 Natomas PAC	2010 Natomas PAC	2010 Natomas PAC	2010 Natomas PAC	Adjusted[2]	2010 Natomas PAC
37	2008 ARCF GRR[1]	2008 ARCF GRR[1]	2002 Comp Study	2002 Comp Study	Adjusted[2]	2008 ARCF GRR[1]
38	2010 West Sac GRR	2010 West Sac GRR	2010 West Sac GRR	2010 West Sac GRR	Adjusted[2]	2010 West Sac GRR
39	2010 West Sac GRR	2010 West Sac GRR	2010 West Sac GRR	2010 West Sac GRR	Adjusted[2]	2010 West Sac GRR
40	2008 ARCF GRR[1]	2008 ARCF GRR[1]	2002 Comp Study	2002 Comp Study	Adjusted[2]	2008 ARCF GRR[1]
All others	2002 Comp Study	2002 Comp Study	2002 Comp Study	2002 Comp Study	Adjusted[2]	2002 Comp Study

[1]American River Common Features General Reevaluation Report (F3 Milestone)

[2]Without-project fragility curves were derived by adjusting the with-project fragility curves to target the appropriate contractor-developed AEP for Condition A as presented in Enclosure 1 of this report.

AEP INFORMATION FOR THE WITHOUT-PROJECT CONDITION

The AEP information for each erosion site and for various conditions was developed by consultants (URS). The AEP information for Condition A was used in this analysis to represent the without-project (no erosion stabilization work) condition for each site. Table 3 below displays the without-project AEP for each erosion site. More details regarding the development of the AEP information can be found in Enclosure 1.

It also must be noted that the without-project annual exceedance probability, or AEP, information used in this analysis was developed specifically for the purpose of estimating damages and benefits and to determine benefit-to-cost ratios for the USACE's annual economic updates for budgets. The AEP information described in Enclosure 1 was not intended to provide an authoritative, detailed geotechnical engineering analysis of the conditions of the project levees.

TABLE 3: AEP INFORMATION FOR CONDITION A BY EROSION SITE

Annual Exceedance Probability (AEP) in %	Erosion Site and Applicable River Mile
0.5	Deep Water Ship Channel LM 5.0L, 5.01L; Sacramento River RM 35.3R
1	Knights Landing Ridge Cut (KLRC) LM 0.2R; Lower American River RM 7.3R; Sacramento River RM 35.4L, 78.3L; Willow Slough LM 2.2L, 0.6L; Yuba River LM 2.3L
2	Cherokee Canal LM 14.0L; KLRC LM 5.3L; Sacramento River RM 60.1L, 63.0R; Sutter Slough RM 24.7R; Yolo Bypass LM 2.0R
4	Cache Slough RM 15.9L, 22.8R; Cherokee Canal LM 21.9L; Deer Creek LM 2.4L; Elder Creek LM 3.0R, 4.1L; Feather River RM 0.6L, 5.0L; Georgiana Slough RM 2.5L, 3.6L, 4.0L, 4.3L, 4.5L, 4.6L, 6.1L, 6.4L, 6.6L, 6.8L, 8.3L; KLRC LM 3.0L, 3.1L, 4.2L; Natomas Cross Canal LM 3.0R; Sacramento River RM 21.5L, 22.5L, 22.7L, 23.2L, 23.3L, 24.8L, 25.2L, 31.6R, 38.5R, 56.5R, 56.6L, 56.7R, 58.4L, 62.9R, 74.4R, 75.3R, 77.7R, 86.3L, 86.5R, 86.9R, 92.8L, 95.8L, 96.2L, 101.3R, 103.4L, 104.0L, 104.5L, 116.0L, 116.5L, 122.0R, 122.3R, 123.3L, 123.7R, 127.9R, 131.8L, 132.9R, 133.0L, 133.8L, 136.6L, 138.1L, 163.0L, 168.3L, 172.0; Steamboat Slough RM 23.2L, 23.9R, 25.0L, 25.8R, 26.0L; Sutter Slough 26.5L; Willow Slough LM 6.9R; Yolo Bypass LM 0.1R, 2.5R, 2.6R, 3.8R
10	Georgiana Slough RM 0.3L, 1.7L, 9.3L; Steamboat Slough RM 18.8R
20	Bear River RM 0.8L; Elder Creek LM1.4L; Georgiana Slough RM 3.7a/b, 5.3L
50	Cache Creek LM 3.9L; Cache Slough RM 23.6R; Sacramento River RM 99.0L, 152.8L; Steamboat Slough 24.7R

Table 4 displays annual benefits, annual costs, net benefits and benefit-to-cost ratios for all economic impact areas; these results are based on a 2011 economic update and a subsequent PACR related effort. All the benefit and cost information used to determine the benefit-cost ratios was specific to each impact area.

TABLE 4: NET BENEFIT AND BENEFIT-TO-COST ANALYSES BY SUB-BASIN (IMPACT AREA) FOR STUDY AREA: (OCTOBER 2012 PRICE LEVEL, 3.75% DISCOUNT RATE, 50-YEAR PERIOD OF ANALYSIS, IN $1,000S)

Impact Area/Sub-Basin	Annual Benefits	Annual Costs	Net Benefits	Benefit-to-Cost Ratio (BCR)
Butte Basin (5)	4,331	441	3,890	9.8
Grimes (10)	0	586	-586	0.0
South Sutter (11/34)	1,562	2,818	-1,256	0.6
K. Landing (13/14)	0	473	-473	0.0
Yolo (15)	535	103	432	5.2
Woodland (16)	0	229	-229	0.0
Davis (17)	0	23	-23	0.0
Linda (27)	9	137	-128	0.1
Rio Oso (30)	362	314	48	1.2
North Sutter (32)	0	649	-649	0.0
Elkhorn (35)	0	349	-349	0.0
Natomas (36)	17,282	120	17,162	144.0
Arden/Rio Linda (37)	-	-	-	-
West Sac (38)	13,809	73	13,736	189.2
Southport (39)	13,161	443	12,718	29.7
Sacramento (40)	18,321	335	17,986	54.7
Clarksburg (42)	0	463	-463	0.0
Merritt Island (46)	0	380	-380	0.0
Sutter Island (49)	630	613	17	1.0
Grand Island (50)	0	548	-548	0.0
Tyler Island (53)	0	5,963	-5,963	0.0
Brannan Andrus (54)	0	967	-967	0.0
Ryer Island (55)	0	349	-349	0.0
Hastings Tract (61)	14	163	-149	0.1

ECONOMICALLY JUSTIFIED IMPACT AREAS:

Based on the results shown in Table 4, eight of the twenty-four economic impact areas were economically justified: Butte Basin, Natomas, Sacramento, Southport, Yolo, West Sacramento, Rio Oso and Sutter Island. An economic impact area was determined to be economically justified if the benefit-cost ratio was greater than unity. However more recent cost and benefit analysis have shown the Sutter Island economic impact area to be no longer economically justified. As such, the remainder of this economics appendix will focus on the seven remaining economically justified impact areas: Butte Basin, Natomas, Sacramento, Southport, Yolo, West Sacramento, and Rio Oso.

ECONOMIC INVENTORY: COLLECTION OF BASE DATA AND VALUATIONS (STRUCTURES AND CONTENTS)

For each economic impact area, base geographic information system (GIS) inventories with parcel attribute data was obtained from Michael Baker Consultants; this data is based on county assessor data. Building attribute data were used to determine land use and valuation of structure and contents. In those areas where existing data did not exist, field visits were taken to collect the base inventory data using standard USACE practices; for several impact areas, current inventories and valuations were taken from other ongoing District studies and no fieldwork was required.

The following section describes the data collection process in more detail. Fieldwork was used to verify and collect land use and structure characteristics pertinent to the economic analysis. Field sheets containing the base inventory data were used in conjunction with aerial maps to identify properties. Structure characteristics recorded include:

- The number of stories/floors in the building.
- The foundation height of a building, which was estimated by taking the difference between the average ground elevation and the first floor of the structure.
- The specific building use (residential and non-residential occupancy types), including those shown in Table 4 below.
- The building class (a: primary characteristic- steel reinforced frame, b: reinforced concrete frame, c: masonry, d: wood frame, s: pre-fabricated metal frame), which corresponds to the classifications listed in the Marshall and Swift (M&S) Valuation Service handbook. Each of the five classifications corresponds to a grade of construction for use in the structure valuation.
- The construction type (e.g., excellent, very good, good, average, fair, low cost), which addresses the quality of construction and which is also used as input into the structure valuation.
- The structure condition (e.g., new, excellent, very good, good, fair, poor), which 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 (percent good factor) was recorded to account for depreciation, which is also an input into the structure valuation. Table 5 below lists descriptions of the conditions used and the associated percent good factors used in the structure valuations.

TABLE 5: OCCUPANCY TYPES

Occupancy Type	Description
Single-family residential (SFR)	Detached SFR, half-plexes, duplexes, townhomes
Multi-family residential (MFR)	Apartments, townhomes, attached multiple units
Mobile homes (MH)	Mobile homes and parks
Commercial office buildings	Office buildings
Retail	Typical retail stores
Food	Retail stores that sell perishable food items
Restaurants	Restaurants and fast food establishments
Medical	Medical, dental, hospitals, care facilities, veterinary
Shopping centers	Large shopping centers, box stores, shopping malls
Service	Auto repair, service, and maintenance shops
Warehouses	Warehouses, storage, transportation centers
Light industrial	Small tool shops, light manufacturing
Heavy industrial	Heavy manufacturing, large plants
Government	Gov't buildings, county-, city-, state- and federally-owned offices
Schools	Elem., middle, and high schools; colleges; day care/pre-school fac.
Churches	Churches
Recreation	Recreation assembly, clubs, theaters
Farm	Non-res outbuildings, sheds; family farm res.; lt. production fac.

TABLE 6: CONDITION CLASSES AND PERCENT GOOD FACTORS

Condition	Percent Good Factor
New	100%
Excellent	95%
Very Good	90% to 95%
Good	80% to 90%
Fair	70% to 80%
Poor	50% to 70%
Other (abandoned, condemned)	0%

Table 7 below lists the number of structures by impact area and broken down by major damage category (residential, commercial, industrial, and public).

TABLE7: NUMBER OF STRUCTURES BY ECONOMIC IMPACT AREAS AND DAMAGE CATEGORY

	Number of Structures				
Economic Impact Area	**COMMERCIAL**	**INDUSTRIAL**	**RESIDENTIAL**	**PUBLIC**	**TOTAL**
Butte Basin (5)			131		131
Yolo (15)			1		1
Rio Oso (30)			64		64
Natomas (36)	303	156	22,265	85	22,809
West Sacramento (38)/ Southport (39)	485	484	17,419	99	18,487
Sacramento (40)	3,510	1,206	128,015	918	133,649
TOTAL	4,298	1,846	167,895	1,102	175,141

The total value of damageable property (structures and contents) for the seven impact areas included in this analysis is approximately $93.5 billion. Table 8 below displays the total value of damageable property, also by impact area, and broken out by structure value and content value.

TABLE 8: TOTAL VALUE OF DAMAGEABLE PROPERTY BY SEVEN JUSTIFIED ECONOMIC IMPACT AREAS – STRUCTURES & CONTENTS (FY19 PRICE LEVEL, IN $1,000S)

	Value of Damageable Property		
Economic Impact Area	**Structures**	**Contents**	**Total**
Butte Basin (5)	13,665	6,831	20,496
Yolo (15)	21	10	31
Rio Oso (30)	6,950	3,475	10,425
Natomas (36)	6,576,222	3,353,745	9,929,967
West Sacramento (38)/ Southport (39)	3,296,823	2,276,876	5,573,699
Sacramento (40)	52,692,785	25,280,419	77,973,204
TOTAL	62,586,466	30,921,356	93,507,822

Structures values were based on square footage, estimated cost per square foot (from the Marshall & Swift Valuation Handbook), and an estimated percent good factor. Values per square foot were based on occupancy type, building class, and construction type as outlined in Marshall and Swift Valuation Service handbook. Structure values are based on the concept of depreciated replacement value, rather than market value or assessed value. Generally speaking, flooding causes damages primarily to physical improvements to the land, such as structures and contents, and does not necessarily cause damage to the land. Replacement cost of the structure and its contents less depreciation, therefore, is used to determine structure/content values, which then serve as the basis for the NED damage/benefit analysis.

Non-residential content values were based on the results of an expert elicitation that was conducted for the American River Common Features General Reevaluation Report (GRR). An expert elicitation was performed to develop content values and content depth-percent damage curves for specific occupancy types. The results of that expert elicitation were used for the 2009 American River GRR as well as for this study. In total, there were 22 different occupancy types with values ranging from $22 to $235 per square foot with uncertainty.

For SFR 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 percent damages in these generic 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 purposes of reporting total value of damageable property (contents), a content-to-structure value ratio of 50% was used and is consistent with the ratio used in other District studies.

DEPTH-PERCENT DAMAGE CURVES

The depth of flooding is the primary factor in determining potential damages to structures, contents, and automobiles. Damages to structures and contents were determined based on depth of flooding relative to the structure's first floor elevation. To compute these damages, depth damage curves were used. These curves assign loss as a percentage of value for each structure. The deeper the relative depth, the greater the percentage of value damaged. The sources of the functions were different depending on land use. Depth-percent damage functions were used in the HEC-FDA model to estimate the percent of value lost for the various occupancy types listed in Table 5 above.

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 this analysis.

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*.

In 2007, non-residential content depth-percent damage curves were developed based on the previously-mentioned expert elicitation for various occupancy types; these curves were developed specifically for building types in the Sacramento Metropolitan area and were applied to this analysis.

The complete set of depth- percent damage functions with their corresponding uncertainties can be found in Enclosure 3.

AGRICULTURAL CROP DAMAGES

Agricultural damages were computed for the three predominantly agricultural impact areas/sub-basins using the agricultural flood damage estimation model, SCARCE. SCARCE was developed by SPK to estimate crop flood damages and has been approved for use for this study by the FRM-PCX and USACE Headquarters. Table 9 below displays by impact area the single-event agricultural damages for five annual chance events (ACE): 10-, 50-, 100-, 200-, and 500-year. These ACE damages were directly entered into the HEC-FDA model as stage-damage curves in order to compute expected annual agricultural damages and benefits. Enclosure 5 contains additional information on SCARCE.

TABLE 9: AGRICULTURAL DAMAGES BY EVENT AND ECONOMIC IMPACT AREA (FY19 PRICE LEVEL, IN $1,000S)

Economic Impact Area	Damage Consequences Per Annual Chance Event (ACE)				
	10-Year	50-Year	100-Year	200-Year	500-Year
Butte Basin (5)	99,184	130,299	132,616	138,916	150,405
Yolo (15)	0	7,535	7,535	7,535	8,216
Rio Oso (30)	0	0	0	35,233	35,829
TOTAL	99,184	137,834	140,151	181,684	194,450

ECONOMIC UNCERTAINTIES

Uncertainties in key economic variables were considered. Key economic variables, or those which may have a significant impact on expected damages and benefits, include structure/content values, foundation heights/first floor elevations, and percent damages at specific depths of flooding.

Table 10 below lists the uncertainty used for structure and content values. These were taken from other District studies, including the *Natomas Post-Authorization Change Interim Reevaluation Report* (October 2010) and the *Folsom Dam Modification and Folsom Dam Raise Projects, Economic Reevaluation Report* (Feb 2008).

TABLE 10: UNCERTAINTY IN STRUCTURE AND CONTENT VALUES

OCCUPANCTY TYPE	UNCERTAINTY IN VALUE (INPUT TO HEC-FDA)	
	Structures (SD/Mean in Percent)	Contents (SD/Mean in Percent)
Residential (SFR & MFR)	17	--
Mobile Homes	14	--
Office 2-Story	15	14
Office 1-Story	15	16
Retail	13	18
Retail-Furniture	13	20
Auto Dealerships	12	16
Hotel	11	3
Food Stores	11	27
Restaurants	15	3
Restaurants-Fast Food	12	13
Medical	12	46
Shopping Centers	10	23
Large Grocery Stores	11	4
Service (Auto)	15	4
Warehouse	15	31
Light Ind.	16	19
Heavy Ind.	13	31
Government	14	16
Schools	12	33
Religious	12	40
Recreation	13	13
Automobiles	15	N/A

Uncertainty in first floor elevation was assumed to be 0.5 foot; uncertainty in percent damages at specific depths of flooding is presented in Enclosure 3, *Depth-Percent Damage Curves*.

PROJECT COSTS

Table 11 displays the total project costs and average annual costs by sub-basin/impact area. Since construction for each site is expected to be completed in one year or less, interest during construction costs are not included.

TABLE 4: TOTAL PROJECT COSTS & AVERAGE ANNUAL COSTS (FY19 PRICE LEVEL, 2.875% DISCOUNT RATE, 50-YEAR PERIOD OF ANALYSIS, IN $1,000S)

Impact Area (Basin)	Total Project Costs	Average Annual Costs
Butte Basin (5)	14,282	542
Yolo (15)	7,196	273
Rio Oso (30)	9,217	350
Natomas (36)	3,488	132
West Sacramento (38)	2,873	109
Southport (39)	12,320	468
Sacramento (40)	1,653	63
TOTAL	51,029	1,936

ECONOMIC SOFTWARE AND ANALYTICAL APPROACHES/TECHNIQUES

The following sections describe the economic model, analytical approaches, and data application techniques used to perform the economic analysis.

ECONOMIC SOFTWARE: HEC-FDA

The economic software used to perform this economic update is the Hydrologic Engineering Center Flood Damage Analysis (HEC-FDA) program developed by the USACE Hydrologic Engineering Center (HEC) in Davis, California. HEC-FDA was used to model the without-project and with-project conditions in order to compute economic stage-damage curves with uncertainty and expected annual damages (EAD) and benefits (EAB).

INDEX POINT LOCATIONS

HEC-FDA requires the input of engineering data at specified index point locations along a levee reach associated with specific economic impact areas. Index points are used in HEC-FDA to aggregate damages and benefits of an impact area. For the majority of impact areas delineated for this analysis, representative index point locations (and corresponding data) were taken from the Comprehensive Study analysis; for other areas, representative index point locations (and corresponding data) were taken from more current District studies.

APPLICATION OF HYDROLOGIC, HYDRAULIC AND GEOTECHNICAL ENGINEERING DATA IN HEC-FDA

The 2002 Comprehensive Study was the basis for most of the engineering data used in this update. In the majority of impact areas, graphical exceedance probability-stage curves were entered into HEC-FDA along with an equivalent record length, which HEC-FDA used to estimate uncertainty in in-channel stage. Comprehensive Study without-project geotechnical levee fragility curves for each impact area were used to represent the SRBPP with-project condition – or the condition that is trying to be re-attained through the erosion stabilization work. Comprehensive Study hydraulic floodplains (10%, 2%, 1%, 0.5%, and 0.2% ACE events) were also used in this analysis (for the majority of the impact areas).

APPLICATION OF FLOODPLAIN DATA WITHIN HEC-FDA MODEL

Comprehensive Study floodplains (10%, 2%, 1%, 0.5%, and 0.2% ACE events) were provided by the District's GIS section as a GIS database of flood depths at each parcel/structure for each event. Flood depths were provided for the entire study area. Instead of using river station numbers like in a typical HEC-RAS water surface profile (WSP), assignment of water surface elevations by ACE event were completed using grid cell numbers; the grid cell assignments represent actual floodplain water surface elevations by ACE event rather than in-channel water surface elevations. Once the formatted flood plain data were imported into HEC-FDA, a row was inserted at the top of the WSP which included the in-channel stages associated with the index point (for a particular impact area). This step allowed for the linkage between the two-dimensional floodplain data and the in-channel stages within HEC-FDA. Importing formatted floodplain 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.

COMPUTING ECONOMIC STAGE-DAMAGE CURVES IN HEC-FDA

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 hydrologic, hydraulic, and geotechnical engineering data in the HEC-FDA model.

TARGET AEPS TO COMPUTE WITHOUT-PROJECT DAMAGES AND WITH-PROJECT RESIDUAL DAMAGES

The analysis requires the establishment of a without-project condition and a target with-project condition to estimate "pre-repair" damages and "post-repair" residual damages and the benefits of repairing an erosion site. The AEP information from the Comprehensive Study was used to establish the target with-project condition for most of the impact areas; the AEP information from the URS report was used to establish the without-project (pre-erosion repair) condition for all of the impact areas. For those impact areas where there is an ongoing District study with more current data, AEP information from these studies were used in place of the Comprehensive Study information.

It should be noted that the primary purpose of the contractor-developed AEP information was to provide information/data for the economic analysis rather than to provide a detailed assessment of the levee conditions. The contractor-developed AEP information is not intended to be an authoritative analysis of the current geotechnical levee conditions. More detailed geotechnical analyses may be performed for future studies.) The purpose of the current economic analysis is to reasonably estimate benefits of the SRBPP using existing data and information.

TARGET AEPS AND EROSION SITES

"More critical" and "less critical" erosion sites within an impact area were identified based on information provided in the URS report. The AEPs associated with the erosion sites within an impact area were compared to one another. In all cases, an erosion site(s) within an impact area could be identified as having a higher AEP value than the remainder of the erosion sites (for that impact area); these sites were considered the "more critical" sites within the impact area and the AEPs associated with these sites represented the without-project condition (see next section). The "less critical" erosion sites were the remaining sites having a lower AEP value than the "more critical" sites. Initially, the AEP values associated with these sites were used to represent a first with-project condition; ultimately, however, these intermediate with-project conditions were not used in the economic analysis. Instead, the maximum attainable AEP for a particular impact area was represented by the AEP from either the Comprehensive Study analysis or from a District study having a more current analysis. This methodology reflects that even though erosion sites can be repaired to high level of performance, the risk to the impact area may be limited by the performance for other potential failure modes, (e.g.) under seepage, through seepage, instability). The AEP from the Comprehensive Study analysis (or from a District study having a more current analysis) already considers other potential failure modes, and thus represents the maximum attainable AEP for the impact area.

The terms "more critical" and "less critical" do not imply site prioritization or an order of fixes. These terms were used within the context of the economic analysis to compare the magnitude of AEP values of sites within an impact area and to point out that the severity of erosion sites within an impact area, in terms of AEP, are not equal.

ADJUSTING GEOTECHNICAL FRAGILITY CURVES TO ACHIEVE TARGET AEPS AND ESTIMATE BENEFITS

The target without-project AEPs (Condition A from the URS report) were achieved by adjusting the "with-project" geotechnical levee fragility curves, which were actually the without-project levee fragility curves from either the Comprehensive Study or another more current District Study. The fragility curves were adjusted in a methodical manner by first taking the same stages used in the "with-project" levee fragility curves, changing the probabilities of failure (starting from the lower stages), and then computing AEP in HEC-FDA. Although this adjustment technique was methodical, the process can be characterized as inherently trial and error as each step of the adjustment process was repeated until the target without-project AEP was achieved in HEC-FDA. Enclosure 2 shows the geotechnical fragility curves (per impact area) used to represent the two states:

- Without-project condition: no erosion sites are fixed; this is the highest AEP identified in the URS report (Condition A) for an erosion site(s) in an impact area; this is the condition that exists due to a flow event causing an erosion issue.

- With-project condition: assumes the AEP using the information from either the Comprehensive Study or another more current District study; it is assumed that this condition represents the maximum attainable performance level for a particular impact area; this with-project condition is the state that exists prior to any erosion issue and to which an erosion repair is trying to re-attain; benefits are capped by this AEP value.

In some cases, the method of generating target AEPs resulted in AEP values that were equal to or greater (lower performing) for the with-project condition than for the without-project condition. This appears to imply that levee performance in these areas gets worse with repairs to the erosions site. This would not be the case; levee performance would not be degraded by erosion repairs. These anomalous results are an effect of integrating AEP and fragility curve data that came from different sources and were developed using different methods. These anomalous results were not carried forward in the analysis. In impact areas where this occurred, no further analysis was conducted and no benefits were claimed for these basins.

In the future, prior to implementing construction on the additional 80,000 LF addressed in the PACR, new, location-specific fragility curves will be developed using standard methods accepted with the Corps. These fragility curves will be used to (1) verify the cost-benefit analyses reported here and (2) evaluate benefits for the impact areas that were not analyzed because of the anomalous AEP results.

Table 12 below shows the target AEP values for each condition and by impact area.

TABLE 5: ANNUAL EXCEEDANCE PROBABILITY (AEP) VALUES BY IMPACT AREA AND STATE (CONDITION)

Economic Impact Area	AEP Value: Without-Project Condition[1]	AEP Value: Maximum Attainable Based on Available AEP Information[2]
Butte Basin (5)	0.500	0.280
Yolo (15)	0.500	0.074
Rio Oso (30)	0.200	0.086
Natomas (36)	0.010	0.007
West Sac (38)	0.040	0.009
Southport (39)	0.040	0.011
Sacramento (40)	0.040	0.008

[1]AEP information associated with Condition A from URS Report
[2]AEP information taken from the Comprehensive Study, or when available, from a more current District study

ECONOMIC IMPACT AREA GROUPINGS FOR NET BENEFIT AND BENEFIT-TO-COST ANALYSES

For purposes of this report, the net benefit and benefit-to-cost analyses were performed by individual impact area/basin and by groups of impact areas based on the consequences of flooding within a particular impact area. The consequences of flooding criteria used to group the impact areas include the type and amount of damages and the population at risk. Table 13 lists the consequences of flooding, in terms of agricultural and urban damages and population at risk, from a 1% exceedance probability event.

TABLE 6 CONSEQUENCES OF FLOODING FROM A 1% EXCEEDANCE PROBABILITY FLOOD EVENT (FY19 PRICE LEVEL, IN $1,000S)

CONSEQUENCES			
Economic Impact Area	**Agricultural Damages (in $1,000s)**	**Urban Damages (in $1,000s)**	**Population at Risk (Number of People)**
Butte Basin (5)	132,616	0	380
Yolo (15)	7,535	0	3
Rio Oso (30)	0	8,168	186
Natomas (36)		0	100,000
West Sacramento (38)		1,805,996	
Southport (39)		1,413,339	50,515
Sacramento (40)		4,416,165	371,244
TOTAL	140,151	7,643,668	522,328

ENGINEERING PERFORMANCE STATISTICS FOR ECONOMICALLY JUSTIFIED BASINS

The engineering performance statistics for impact areas that are economically justified are presented in Table 14. The section above explains how target "without-project" AEP values were attained using available data and through non-standard techniques. This non-standard approach was used in the absence of more standard engineering data (e.g., without-project geotechnical levee fragility curves) and was believed to be a reasonable approach to measure economic outputs associated with erosion repairs to the levees within each impact area. In addition to the AEP values, Table 14 also displays the long-term risk and assurance results. Long-term risk describes the chance of flooding over a specific time period, for example 30 years; assurance describes the chance of passing a specific exceedance probability event, for example the 1% exceedance probability event, without incurring significant damages.

To reiterate, the analysis estimated benefits using available data and non-standard techniques. In light of this, the engineering performance statistics from HEC-FDA may not be completely representative of a particular impact area, especially in cases where the “without-project” AEP turned out to be greater than the “with-project” AEP. The AEP values used in the analysis are a compilation of existing data, taken from multiple sources, developed using different methods, and used primarily to measure the difference between a “without-project” condition and a “with-project” condition in order to make a reasonable estimate of benefits for each impact area.

In order to resolve those cases where the “with-project” AEP is greater than the “without-project” AEP, more current data/information needs to be provided and a more standard economic risk analysis would have to be performed.

TABLE 7: ENGINEERING PERFORMANCE STATISTICS

Without-Project Condition Performance Statistics										
		Long-Term Risk			Assurance					
EIA	AEP	10	30	50	10%	4%	2%	1%	0.4%	0.2%
Butte Basin	0.500	99%	99%	99%	0%	0%	0%	0%	0%	0%
Yolo	0.500	99%	99%	99%	4%	2%	2%	1%	0%	0%
Rio Oso	0.200	90%	99%	99%	25%	16%	10%	8%	0%	0%
Natomas	0.010	10%	23%	40%	97%	95%	94%	90%	69%	54%
West Sac	0.040	34%	64%	88%	91%	60%	53%	33%	13%	10%
Southport	0.040	34%	65%	87%	87%	74%	72%	68%	65%	65%
Sacramento	0.040	34%	71%	87%	98%	51%	37%	26%	18%	10%
With-Project Condition Performance Statistics										
		Long-Term Risk			Assurance					
EIA	AEP	10	30	50	10%	4%	2%	1%	0.4%	0.2%
Butte Basin	0.280	96%	99%	99%	0%	0%	0%	0%	0%	0%
Yolo	0.074	54%	85%	98%	67%	36%	28%	14%	0%	0%
Rio Oso	0.086	59%	93%	99%	67%	48%	37%	33%	0%	0%
Natomas	0.007	7%	17%	31%	99%	95%	94%	90%	69%	53%
West Sac	0.009	9%	21%	37%	99%	93%	91%	80%	52%	45%
Southport	0.011	11%	25%	44%	96%	92%	92%	90%	89%	89%
Sacramento	0.008	8%	21%	33%	99%	95%	88%	78%	66%	50%

RESULTS: NET BENEFIT AND BENEFIT-TO-COST ANALYSIS

Net benefits and benefit to cost ratios are presented in this section. Table 15, Table 16 and Table 17 summarize the updated annual urban benefits, agricultural benefits and total benefits, respectively. The revised costs are shown again for convenience in Table 19.

Table 15: Total Agricultural and Urban Damages and Benefits – (FY19 Price Level, in $1,000s)

Impact Area/Sub-Basin	Without Project EAD	With Project EAD	Total Benefits	Total Benefits (75% Confidence)
Butte Basin (5)	28,265	23,808	4,457	4,402
Yolo (15)	1,446	71	1,376	1,185
Rio Oso (30)	1,262	784	478	406
Natomas (36)	81,922	58,810	23,113	19,612
West Sacramento (38)	87,419	36,143	51,276	15,662
Southport (39)	76,022	21,620	54,403	14,935
Sacramento (40)	139,998	73,993	66,005	20,790
TOTAL	416,335	215,228	201,107	76,993

Table 20 shows the net benefit and benefit-to-cost ratio. It should be noted that the range in benefits for the urban analysis group is large, which may indicate a high uncertainty with the average annual benefit value for this group. In light of this, the benefit values (for all benefit categories) having a 75% chance of being exceeded were used in the benefit-to-cost ratio calculations.

In addition, when multiple erosion sites are identified within a sub-basin, the assessment assumes that all sites are fixed. If a sub-basin is determined to be economically justified, then it is assumed that all sites are fixed. However, since inventories of erosion sites are completed on an annual basis, the sites identified in one year within one sub-basin may be different from the sites identified in in the next year within the same sub-basin. Still, the assumption is that all sites within a justified sub-basin will be fixed.

TABLE 8: ANNUAL URBAN DAMAGES AND BENEFITS – (FY19 PRICE LEVEL, IN $1,000S)

Impact Area/Sub-Basin	Without Project EAD	With Project EAD	Urban Benefits	Urban Benefits (75% Confidence)
Butte Basin (5)				
Yolo (15)				
Rio Oso (30)	959	506	453	395
Natomas (36)	81,922	58,810	23,113	19,612
West Sac (38)	87,419	36,143	51,276	15,662
Southport (39)	76,022	21,620	54,403	14,935
Sacramento (40)	139,998	73,993	66,005	20,790
TOTAL	386,320	191,072	195,250	71,395

TABLE 9: ANNUAL AGRICULTURAL DAMAGES AND BENEFITS – (FY19 PRICE LEVEL, IN $1,000S)

Impact Area/Sub-Basin	Without Project EAD	With Project EAD	Agricultural Benefits	Agricultural Benefits (75% Confidence)
Butte Basin (5)	28,265	23,808	4,457	4,402
Yolo (15)	1,446	71	1,376	1,185
Rio Oso (30)	303	278	25	11
Natomas (36)				
West Sac (38)				
Southport (39)				
Sacramento (40)				
TOTAL	30,014	24,157	5,858	5,598

TABLE 10: TOTAL AGRICULTURAL AND URBAN DAMAGES AND BENEFITS – (FY19 PRICE LEVEL, IN $1,000S)

Impact Area/Sub-Basin	Without Project EAD	With Project EAD	Total Benefits	Total Benefits (75% Confidence)
Butte Basin (5)	28,265	23,808	4,457	4,402
Yolo (15)	1,446	71	1,376	1,185
Rio Oso (30)	1,262	784	478	406
Natomas (36)	81,922	58,810	23,113	19,612
West Sacramento (38)	87,419	36,143	51,276	15,662
Southport (39)	76,022	21,620	54,403	14,935
Sacramento (40)	139,998	73,993	66,005	20,790
TOTAL	416,335	215,228	201,107	76,993

TABLE 11: COSTS OF FIXING EROSIONS SITES (FY19 PRICE LEVEL, 2.875% DISCOUNT RATE, 50-YEAR PERIOD OF ANALYSIS, IN $1,000S)

Impact Area/Sub-Basin	Total Project Costs	Average Annual Costs
Butte Basin (5)	14,282	542
Yolo (15)	7,196	273
Rio Oso (30)	9,217	350
Natomas (36)	3,488	132
West Sacramento (38)	2,873	109
Southport (39)	12,320	468
Sacramento (40)	1,653	63
TOTAL	51,029	1,936

TABLE 20: ANNUAL BENEFITS, AVERAGE ANNUAL COSTS, NET BENEFITS, & BENEFIT-TO-COST RATIOS FOR ECONOMICALLY FEASIBLE IMPACT AREAS/SUB-BASINS (FY19 PRICE LEVEL, 2.875% DISCOUNT RATE, 50-YEAR PERIOD OF ANALYSIS, IN $1,000S)

Impact Area/Sub-Basin	Annual Benefits (75% Confidence Level)	Average Annual Costs	Net Benefits	Benefit-to-Cost Ratio (BCR)
Butte Basin (5)	4,402	542	3,860	8.1
Yolo (15)	1,185	273	912	4.3
Rio Oso (30)	406	350	57	1.2
Natomas (36)	19,612	132	19,480	148.2
West Sac (38)	15,662	109	15,553	143.7
Southport (39)	14,935	468	14,467	31.9
Sacramento (40)	20,790	63	20,728	331.4
TOTAL	76,993	1,936	75,056	39.8

CONCLUSIONS

Without-project damages are based on AEP information for Condition A as described in Enclosure 1. Although this information is not based on a more traditional geotechnical engineering analysis that would typically describe the conditions of the levees in greater detail, the AEP information is adequate for purposes of making reasonable estimates of project benefits. Still, it is recognized that there is a degree of uncertainty regarding the AEP information used in this analysis, which in turn introduces a degree of uncertainty in the estimates of project benefits.

It is also recognized that a process reliant on trial and error to attain the target without-project AEP values was employed, which indicates that there are multiple ways (i.e., different ways to adjust the geotechnical levee fragility curves) to achieve the target AEPs. This introduces additional uncertainty associated with the project benefits.

In recognition of both the uncertainty in the contractor-developed target AEP values and the uncertainty in the process of achieving these AEPs in HEC-FDA by adjusting levee fragility curves, a range of benefits was reported, and for this analysis, the benefit values having a 75% chance of being exceeded were used to calculate net benefits and benefit-to-cost ratios.

Residual damages and population at risk remain high even after the repairs are made since it was assumed that repairs addressing only erosion issues and no other causes such as under seepage, through seepage, and stability issues would be completed. This limitation is reflected in the amount of benefits being claimed for those impact areas where improvements to specific erosion sites do not necessarily result in a significant reduction in residual risk.

Without-project target AEP values are lower than or equal to the “with-project” AEP values in several impact areas. For these impact areas, benefits were not claimed and is reflected in the benefit-to-cost ratios for that specific impact area. As was mentioned previously, many of the AEP values assumed for this analysis were pulled from the 2002 Comprehensive Study, which may in itself have a certain amount of uncertainty attached to it due to its lack of currency. In light of this, benefits may actually be higher than what is currently being reported.