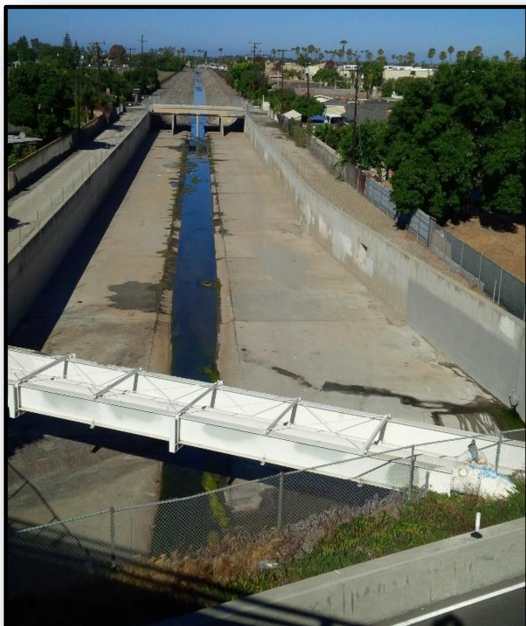
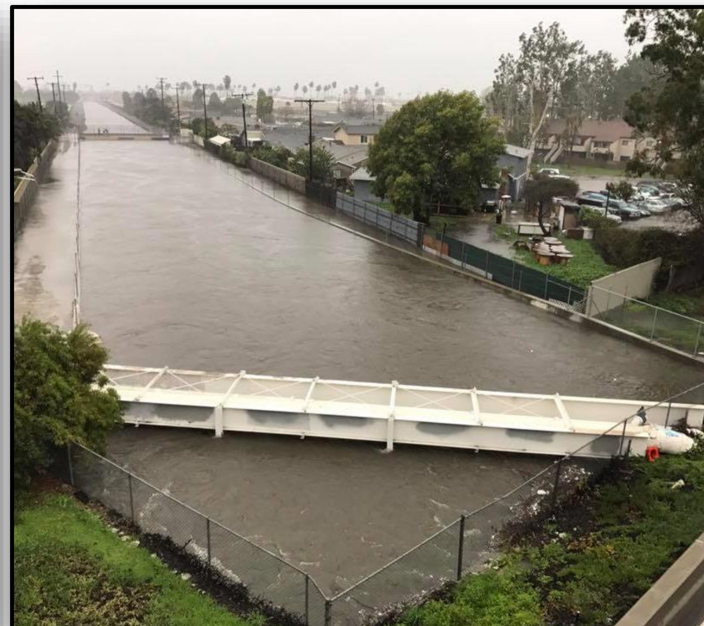
ECONOMIC APPENDIX:

For

WESTMINSTER, EAST GARDEN GROVE, CA

FLOOD RISK MANAGEMENT FEASIBILITY STUDY





December 2019

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Economic Appendix

For

WESTMINSTER, EAST GARDEN GROVE

FLOOD RISK MANAGEMENT STUDY

1. Purpose and Overview

The purpose of this appendix is to present the economic analysis used to evaluate the array of flood risk management alternatives for the Westminster, East Garden Grove, California (CA) Flood Risk Management Feasibility Study and determine the National Economic Development (NED) Plan and Locally Preferred Plan (LPP). Estimates of economic benefits and costs were developed in accordance with engineering regulation (ER) 1105-2-100 *Planning Guidance Notebook*, and the scope and intent of the feasibility study.

Portions of the study area are some of the only areas in Orange County at risk of inundation from a flood event with a one percent annual chance of exceedance (0.01 ACE), corresponding with a one in 100 chance of occurring in a given year. Flood risks within the watershed result from overtopping of the flood conveyance channel systems within the watershed, as well the potential failure of some segments of existing levees along these channels during significant flood events. Under current (without project) conditions, nearly 400,000 people and 44,000 structures are at risk of inundation within the 0.002 ACE (500-year) floodplain; estimated average annual damages within the 0.002 ACE about $72 million, including structure and structure contents, automobile, emergency and other associated costs.

Two alternative scales were evaluated to address flood risks in the study area. Improvements under the Minimum and Maximum Improvement Plans were formed based on strategies that include reducing the impacts of flooding by improving channel conveyance, increasing channel capacity by increasing flood water storage, and improving downstream conveyance to balance improvements to conveyance and capacity upstream. The Minimum Improvement Plan focuses on improving channel conveyance, while the Maximum Improvement Plan focuses on improving channel conveyance and increasing channel capacity. The Minimum Improvement Plan maximizes net benefits and is therefore designated as the NED Plan. The non-Federal Sponsor supports the Maximum Improvement Plan as the LPP. The Recommended Plan is the LPP (Maximum Improvement Plan).

The results of this economic evaluation establish that at the Fiscal Year 2020 (FY20) discount rate of 2.75 percent and FY20 prices, the NED plan has estimated average annual benefits and costs of about $102 million and $24 million, respectively, while the LPP has average annual benefits and costs of about $116 million and $58 million, respectively. The NED Plan has annual net benefits of $78 million, and the LPP has annual net benefits of $58 million. The NED plan has a benefit-cost ratio (BCR) of 4.2 and the LPP has a BCR of 2.0. The NED plan optimizes the scale of channel improvement measures within the flood risk system and is economically justified (average annual benefits exceed average annual costs; BCR greater than 1.0). While the LPP provides a greater level of risk reduction and benefits than the NED Plan, the incremental benefits are less than the incremental costs required to achieve these benefits. However, while the LPP has lower net NED benefits than the NED Plan it is also economically justified and provides regional economic development and other social effects benefits such as reduced risk to life, health and safety.

1.1 Study Authority

The Westminster feasibility study is authorized by the Flood Control Act of 1936 and is being conducted in accordance with the resolution adopted by the House of Representatives Committee on Public Works on May 8, 1964 (Flood Control Act of 1938), which reads:

"Resolved by the Committee on Public Works of the House of Representatives, United States, that the Board of Engineers for Rivers and Harbors is hereby requested to review the reports on (a) San Gabriel River and Tributaries, published as House Document No. 838, 76th Congress, 3d Session; (b) Santa Ana River and Tributaries, published as House Document No. 135, 81st Congress, 1st Session; and (c) the project authorized by the Flood Control Act of 1936 for the protection of the metropolitan area in Orange County, with a view to determining the advisability of modification of the authorized projects in the interest of flood control and related purposes."

1.2 Problems and Opportunities

Risk of property damage and loss of life within the Westminster and East Garden Grove floodplains due to inundation since the 1950s has increased as a result of urbanization and continued development. The increase in the amount of infrastructure and people affected by inundation drives this increase in potential consequences and overall level of risk (which is a function of probability and consequences). Urbanization also changes the impermeable soil area, which can increase the amount of storm runoff by limiting percolation into the ground. During flood events, Pacific Coast Highway (PCH) regularly floods, which exacerbates heavy traffic along a major transportation route.

This study aims to reduce risks to property, infrastructure, and human lives by reducing the probability and severity of inundation in the floodplain area. Additionally, it aims to reduce costly delays to traffic in a densely populated area.

1.3 Methodology

Methodology used in the economic analysis is in accordance with ER 1105-2-100. The analysis also follows ER 1005-2-101 for the incorporation of risk-based analyses. Benefits were computed at Fiscal Year (FY) 2020 price levels for comparison with costs. The analysis uses the current federal discount rate for FY 2020 of 2.75 percent. The period of analysis is 50 years, with a project Base Year of FY 2035.

1.4 Historical Flood Events

Significant flooding occurred in Orange County in 1825, 1862, 1914, 1916, 1938, 1969, 1983, and 1995. Since 2010, the most significant rainfall event occurred in February 2017 and closed portions of Pacific Coast Highway within the study area, but no significant structural damage was reported[1].

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[1] Based upon review of articles from the *Orange County Register* (2017).

2. Study Area

2.1 Location

The Westminster feasibility study floodplain lies in Orange County, California, beginning west of Interstate-5 and continuing west until its confluence with the Pacific Ocean (see Figure 1). The study area is approximately 74 square miles and includes portions of the cities of Garden Grove, Westminster, Fountain Valley, Huntington Beach, Sunset Beach, and Seal Beach that lie within the without-project 0.002 ACE floodplain. The study floodplain is primarily a built-out, urban area, and the majority of the structures in the floodplain are residential. The 0.002 ACE floodplain also contains a significant number of public, industrial, and commercial structures, as well as public wetlands and an ecological reserve. The Westminster floodplain is susceptible to flood risk from the Santa Ana River, which is addressed by the Santa Ana River Mainstem (SARM) Project. This project is designed to reduce flood risk from the Santa Ana River and its tributaries, and reduces the risk of flooding significantly. For future with-project SARM conditions, the annual exceedance probability (AEP) is one percent in the reaches that overlap with the Westminster 0.002 ACE floodplain.

2.2 Floodplain Delineation

Figure 1 displays the 0.002 ACE floodplain and corresponding census tracts. The floodplain extends across 76 portions of, or entire census tracts within Orange County. The .002 ACE flooplain is the most extreme/widespread flooding scenario considered and allows for a more complete description of the potential population and structures at risk than more probable floodplains, e.g., the .01 ACE floodplain.

2.3 Impact Area and Reach Delineation

For the hydraulic and economic analyses, the study area is divided into four channels (C02, C04, C05, C06), and 24 economic impact areas (EIAs). Naming conventions for these impact areas differ from that of the construction reaches (please refer to Appendix A: Hydrology & Hydraulic (H&H) for details regarding bases for delineation of construction reaches). Both impact areas and construction reaches are depicted in Figure 2. In general, EIAs differentiate geographic sections of the floodplain corresponding with the source of flooding (i.e., channel), bank of channel (left bank vs. right bank), channel characteristics (e.g., leveed vs. un-leveed), and channel capacity/probability of flooding.

As displayed in Figure 2, impact areas C04_4b and C05_5, overlap within the floodplain, indicating that the overlap area is subject to flooding from both channels. The methodology used to account for this overlap, and the impact it has on economic damages is discussed in Section 3.

The channels within the study area vary by reach in construction material and geometry. Improvements to the channels have been ongoing since they were originally built in the 1950s and 1960s. The following types of channels are found throughout the Westminster channel system:

1. Concrete rectangular channels – vertical channel walls with concrete lined sides and bottom
2. Riprap-lined trapezoidal channels – sloped channel walls that are lined with riprap and have a soft bottom
3. Concrete-lined trapezoidal channels – sloped channels that are lined with concrete and have a concrete bottom
4. Enclosed culverts – rectangular or box conduits that are not exposed at the surface
5. Leveed channels – earthen berms are located along channels in the flattest downstream extents of the watershed
6. Steel sheet pile channels – rectangular channels composed of vertical sheet pile walls with a soft bottom.

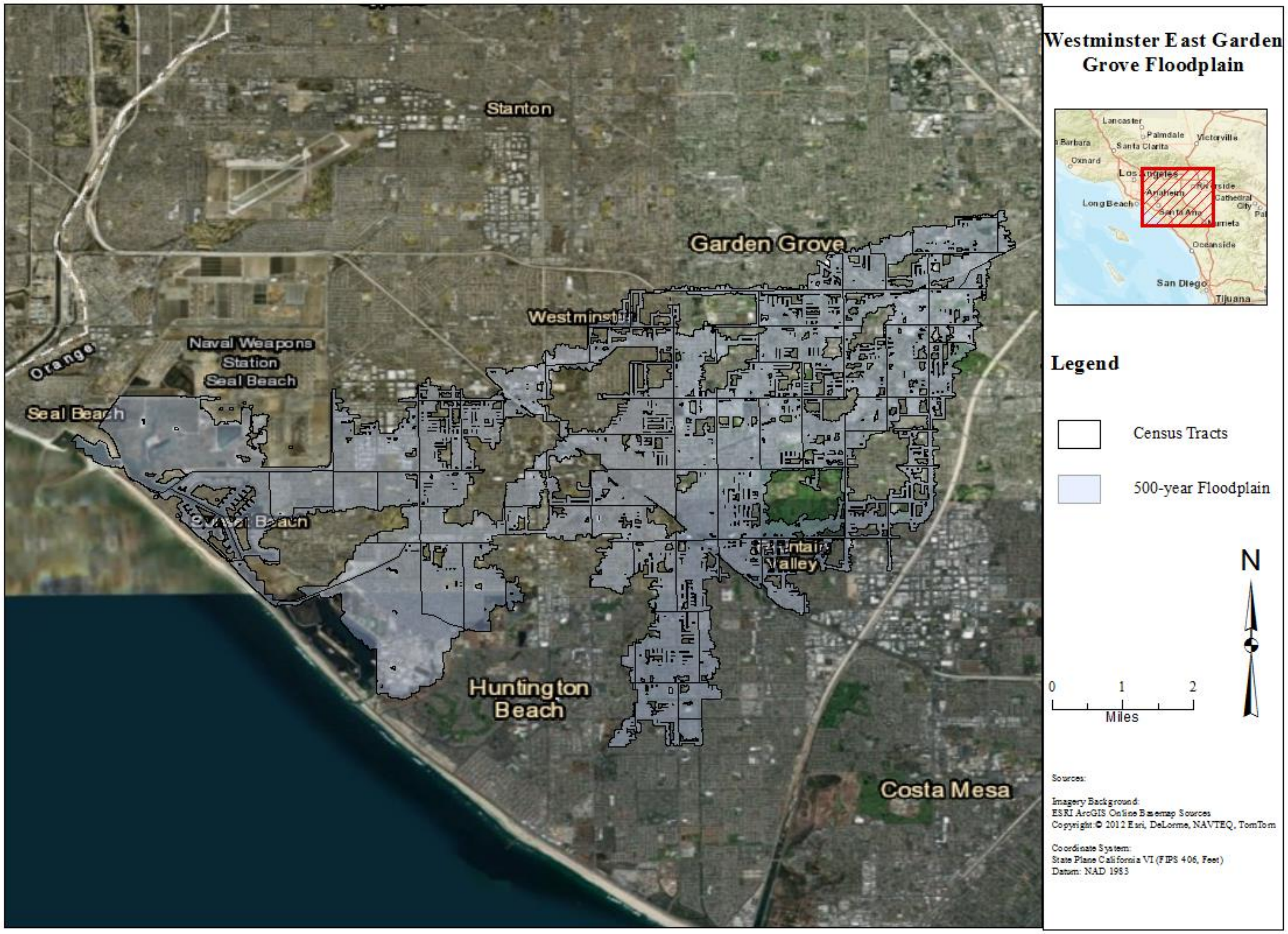

Figure 1. Westminster 500-year Floodplain

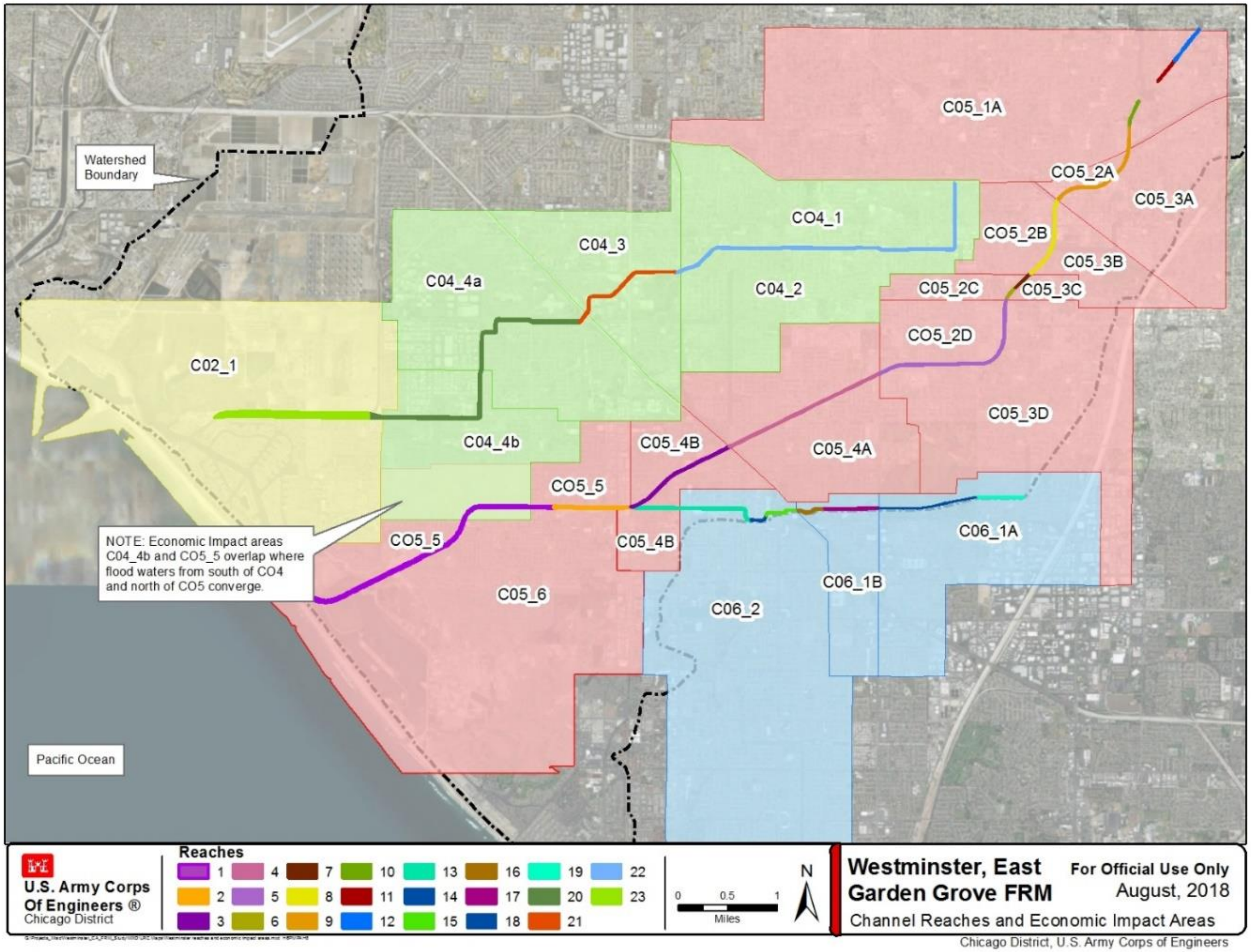

Figure 2. Westminster Watershed Impact Areas

2.4 Socio-Economics

This section presents the socio-economic characteristics of the population within the floodplain. This data helps inform the potential impact a flood event could have on the surrounding population, and highlights the geographic location of economically vulnerable populations. Data is shown for the 0.002 ACE floodplain, and was taken from the American Community Survey (ACS) 2016 estimates on factfinder.census.gov. Because data is available at the census-tract level, estimates were calculated using entire census tracts when a portion of the census tract lies within the floodplain. Therefore, the population estimates may overestimate population at risk, although not to a significant degree since there are not significant differences in the floodplain and census tract boundaries.

2.4.1 Population

Figure 3 displays population density by census tract. Lighter pink areas denote a lower population density while dark red census tracts denote a higher population density. The highest population density by census tract within the floodplain corresponds with channel C05, east of Interstate (I)-405 and west of I-5.

Table 1 presents the population count by flood channel, and the total floodplain. There are 29 census tracts in C02/04 impact areas and 63 census tracts in C05/06 impact areas. Since a portion of these EIAs overlap, some census tracts are included in both C02/04 and C05/06. The total population at risk of inundation in the 0.002 ACE floodplain is nearly 400,000, and the population above 65 years of age at risk in a flood event is nearly 60,000.

Table 1. Population by Census Tract (2016)

Location	Census Tract Count*	Population Count‡	Population above 65 years
C02-04	29	142,805	23,961
C05-06	63	341,869	47,270
Floodplain Total	76	397,393	57,315

U.S. Census American Community Survey (2016)
**Some census Tracts are contained in both C02/C04 and C05/C06, so the sum of the channel counts does not equal the total count*
‡Population count includes population for entire census tracts, rather than only the portion that lies in the floodplain

Table 2 displays the historical population of Orange County, which contains the entire study area. Population growth over the last decade shows a general declining trend. Population growth is estimated to remain very low or stagnant in the study area over the life of the project, largely due to the densely populated and built-out nature of the floodplain area. It is estimated that the future with-project population will be similar to the future without-project population, since the floodplain lacks room for development, and current zoning laws don’t allow for high-density construction.

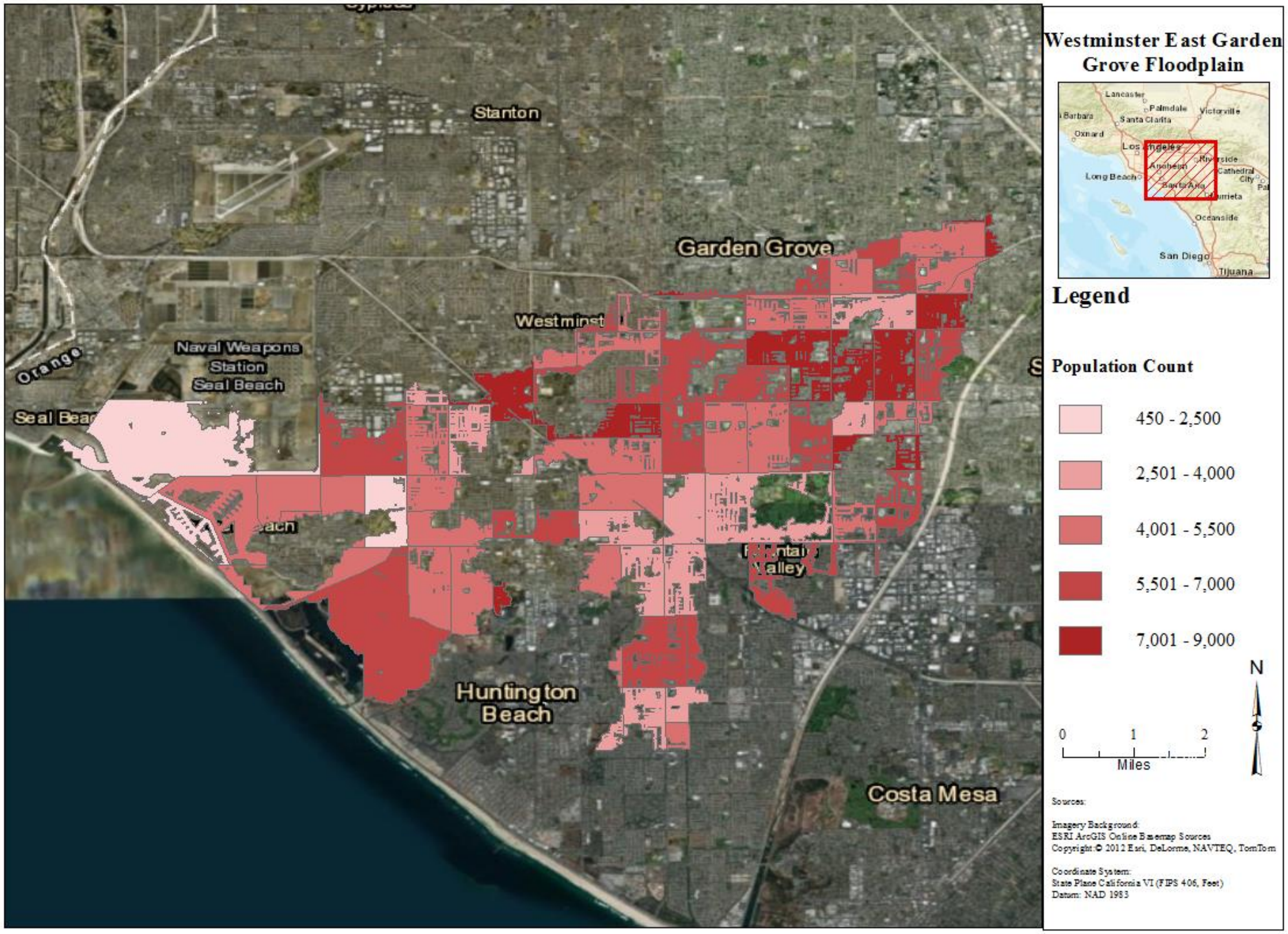

Figure 3. Floodplain Population

Table 2. Historical and Future Population Orange County

Year	Population Orange County	Geometric Rate of Growth
2010	3,017,116	-
2011	3,053,465	1.20%
2012	3,085,386	1.05%
2013	3,113,649	0.92%
2014	3,136,750	0.74%
2015	3,160,576	0.76%
2016	3,177,703	0.54%
2017	3,190,400	0.40%
2018	3,203,148	0.27%
2019	3,211,648	0.13%
2020	3,215,860	0.00%

Note: 2010-2017 figures shown are taken from American Community Survey annual estimate; 2018-2020 are projected figures (U.S. Census Bureau, 2017).

2.4.2 Demographics

Poverty, financial, and housing unit characteristics help identify the vulnerability of the population in the event of a 0.002 ACE flood. The tables and figures below describe these characteristics, and include census data for the poverty count, the number of individuals who speak a language other than English, the relationship between average household size and income, and the relationship between median home value and income. All data was taken from 2016 ACS estimates found on census.gov, at the census-tract level. Statistics for census tracts where a portion of the tract lies within the floodplain are included in the tables below.

Table 3. Demographics by Study Location

Location	Poverty Count	Percent of Population below poverty line	Speaks a language other than English	Percent of Population that speaks another language
C02-04	22,026	15.4	70,648	50.4
C05-06	47,270	15.5	191,127	55.9
Floodplain Total*ᵻ	61,499	15.5	213,654	53.8

U.S. Census American Community Survey (2016)
**Some census Tracts are contained in both C02/C04 and C05/C06, so the sum of the channel counts does not equal the total count*
ᵻPopulation count includes population for the entire census tract, rather than only the portion that lies in the floodplain

Table 3 shows that over 61,000 people, or 15.5 percent of the population in the floodplain is below the poverty line. This estimate is higher than both the state poverty rate of 14.3 percent, and the national poverty level of 12.7 percent, according to 2016 census bureau data. The percent of the population in the floodplain that speaks a language other than English is 53.8 percent, while the national estimate is 19.7 percent.

The areas of the floodplain with the highest concentration of poverty can be seen in Figure 4, which shows income level by census tract, and household size. The figure shows that higher income areas tend to be closer to the coast, while lower income levels are found in census tracts located a few miles inland. Additionally, average household size tends to be higher in census tracts where the median income is lower, while household size is smaller in higher-income census tracts. The portion of the floodplain in lighter shades of blue is therefore more economically vulnerable in event of a flood, and damages to homes and property in this area would be significantly impactful.

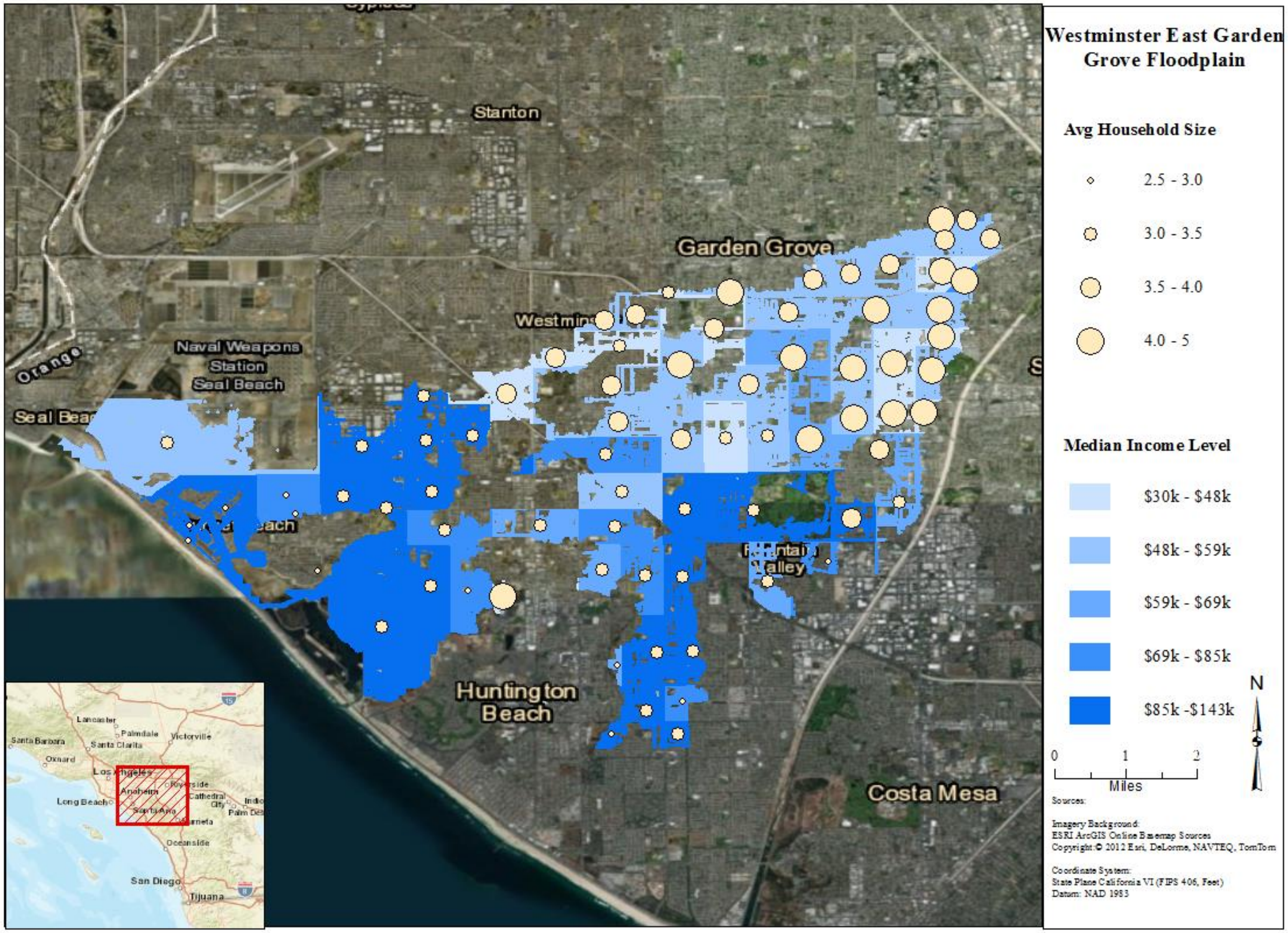

Figure 4. Household Size and Income

Table 4 shows income and housing statistics for the floodplain, by study area. The median income in C02/04 is significantly higher than in C05/06. The maximum median income in a census tract in the floodplain is $140,242 while the minimum is $30,670. The census tract with the lowest income is located in impact area C04_3, just east of I-405 in the city of Westminster. The census tract with the highest median income is located in impact area C05_6, near PCH in Huntington Beach. The lowest median home value in a census tract is $91,500, located in west Santa Ana, and the highest median home value for a census tract is $1.2 million, located in Sunset Beach.

Table 4. Income and Household Characteristics

Location	Median Income, $	Median Home Value, $	Home Value to Income Ratio	Average Household Size	Percent Owner Occupied	Percent Renter Occupied
C02-04	76,961	524,800	6.8	3.4	55.7	44.3
C05-06	60,179	495,800	8.2	3.6	54.9	45.1
Floodplain Total*	61,679	503,650	8.2	3.5	54.6	45.4

U.S. Census American Community Survey (2016)
**Some census Tracts are contained in both C02/C04 and C05/C06; entire census tracts with a portion in the floodplain are included in statistics*

The median home value to income ratio is 6.8 in C02/04 and 8.2 in C05/06. Since the national average home value to income ratio is 3.31, overall mortgage debt is likely higher in the 0.002 ACE floodplain than average mortgage debt nationally. Approximately 45 percent of housing units in the floodplain are occupied by renters, while about 55 percent are occupied by owners. The average household size in a census tract is 3.5.

2.4.3 Structures and Land Use

The study floodplain is primarily a built-out, urban area, and the majority of the structures in the floodplain are residential. The 0.002 ACE floodplain also contains a significant number of public, industrial, and commercial structures, as well as public wetlands and an ecological reserve.

Figure 5 displays structures by use and includes residential, commercial, industrial and public structures. The figure shows that the number of residential structures in the floodplain is higher than commercial, industrial, or public structures.

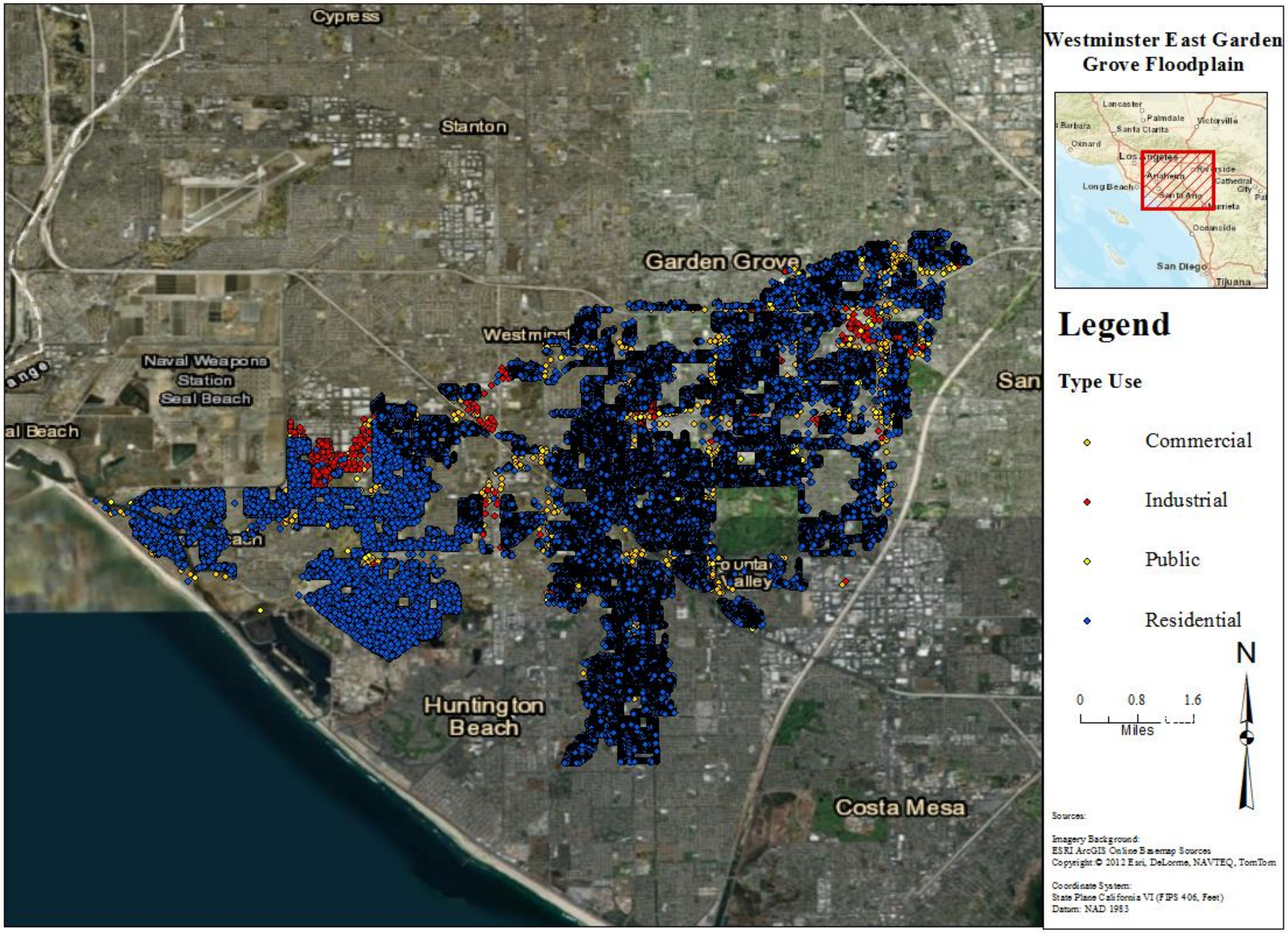

Figure 5. Structure Inventory by Use

Table 5 shows the structure count by zoned land use and channel. There are approximately 43,653 structures in the 0.002 ACE floodplain. Residential development in the floodplain is most common, with over 95 percent of the structures in the study being residential. About 84 percent of the residential structures in the floodplain are single family structures, 10 percent are multi-family structures, and 6 percent are mobile home units. Nearly 4 percent of all structures are either commercial or industrial.

Table 5. Number of Structures by Use and Impact Area

Zoned Land Use	C02	C04	C05	C06	Total by Use
Residential	2,982	10,382	20,554	7,941	41,859
Single Family Residential	2,264	8,864	16,861	7,324	35,313
Multi-Family Residential	235	1,053	2,156	585	4,029
Mobile Home	483	465	1,537	32	2,517
Commercial	46	292	539	139	1,016
Industrial	11	288	296	25	620
Public	11	36	98	13	158
Total by Channel	3,050	10,998	21,487	8,118	43,653

Note: Multiple structures are contained in both C02/C04 and C05/C06; these structures were analyzed under both reach conditions

Channel C05 has the highest number of total structures, and contains nearly 50 percent of residential structures in the floodplain. The methodology used to develop the structure inventory and structure and content values is detailed in Section 3.

Major commercial structures in the floodplain include the Bella Terra Mall in Huntington Beach, in C04_4a, and major industrial structures in the floodplain include portions of Boeing Co. Campus in Huntington Beach, also located in C04_4a. The majority of retail structures are located in C05/06, west of the 405. Public structures in the floodplain include schools, hospitals, churches, and city buildings. The majority of residential structures are single family residential, and much of the floodplain is zoned for low to medium density development.

Table 6 displays depreciated structure and content values by land use for C02/04 and C05/06. Residential structures account for 79 and 88 percent of combined structure and structure content value in C02/04 and C05/06, respectively. Industrial structures account for about seven percent and six percent of combined structure and structure content value in C02/04 and C05/06, respectively. Industrial structures account for about 10 percent and 3 percent of combined structure and structure content value in C02/04 and C05/06, respectively. Public structures comprise the remainder of structure and structure content value in the study area.

Table 6 Structure and Content Value by Land Use, FY 2020 Price Level ($000's)

Land Use Type	Structure Value	Content Value	Total Value	% of Channel Total
C02/04	**2,256,547**	**1,225,459**	**3,482,006**	**100**
Residential	1,841,405	920,703	2,762,108	79
Commercial	152,482	80,021	232,502	7
Industrial	167,744	184,508	352,252	10
Public	94,916	40,227	135,143	4
C05/06	**4,618,174**	**2,428,566**	**7,046,740**	**100**
Residential	4,151,537	2,075,769	6,227,306	88
Commercial	263,290	170,926	434,217	6
Industrial	103,946	132,951	236,897	3
Public	99,401	48,920	148,321	2
Floodplain Total	6,874,721	3,654,025	10,528,746	

Table 7 displays depreciated structure and structure content values by Economic Impact Area (EIA), in FY 2020 price levels. Total structure value in the floodplain area is $6.9 billion, and total structure content value is $3.7 billion. In C02/04, EIA C04_4b accounts for the largest portion of depreciated structure and content value (about 24%). C06_2 accounts for 20 percent of total depreciated structure and content value in C05/06, the largest portion of any of the impact areas in these channels. C05_4a and C05_6 also account for a significant share of structure and content value in C05/06.

Table 7. Structure and Content Values, FY 2020 PL ($000's)

Impact Area	Structure Value	Content Value	Total Value	% of Channel Total
C02/04	**2,256,547**	**1,225,459**	**3,482,006**	**100**
C02_1	446,388	230,021	676,409	19
C04_1	289,664	149,432	439,096	13
C04_2	477,594	241,294	718,888	21
C04_3	183,714	144,651	328,365	9
C04_4a	316,444	171,597	488,042	14
C04_4b	542,742	288,464	831,206	24
C05/06	**4,618,174**	**2,428,566**	**7,046,740**	**100**
C05_1A	455,135	245,806	700,941	10
C05_2A	17,518	9,261	26,779	0
C05_2B	129,279	67,717	196,997	3
C05_2C	83,038	41,721	124,760	2
C05_2D	185,471	97,209	282,679	4
C05_3A	67,719	40,386	108,104	2
C05_3B	103,849	58,865	162,715	2
C05_3C	30,364	20,974	51,338	1
C05_3D	477,614	284,695	762,310	11
C05_4A	737,947	373,588	1,111,535	16
C05_4B	240,576	124,319	364,894	5
C05_5	268,986	144,648	413,634	6
C05_6	613,609	313,248	926,856	13
C06_1A	188,225	89,491	277,716	4
C06_1B	103,512	52,791	156,303	2
C06_2	915,332	463,848	1,379,180	20
Total	6,874,721	3,654,025	10,528,746	

3. Methodology

This section details the methodology used to develop the Hydrologic Engineering Center - Flood Damage Analysis (HEC-FDA), addresses uncertainties, and describes how the structure inventory and structure values were developed.

3.1 HEC-FDA Analysis

The random and unpredictable nature of flood events means that future damage is unknown, and is best represented by a range of possible damage values and their likelihood in a probability distribution. The metric of interest in computing equivalent annual benefits is the expected annual damage (EAD) value, because it captures the mean of the probability distribution of annual damage. The USACE Hydrologic Engineering Center developed a software, HEC-FDA 1.4.2 (USACE certified), which uses Monte Carlo simulation to obtain a random sample of the contributing relationships and compute stage-damage functions, exceedance probability-discharge curves, and conditional stage-discharge relationships, in order to generate the EAD estimates. In other words, knowledge uncertainties are incorporated into EAD estimates using Monte Carlo simulation. Each iteration of a Monte Carlo simulation randomly samples the uncertainty distributions, and the resulting values are used to transform the flow and stage distributions to a damage distribution and integrate it in order to compute the EAD. Thousands of iterations of this process are used to infer the EAD distribution. The EAD is therefore the probability weighted average of all possible peak annual damages, where damage is a continuous random variable.[2]

In order to compute the EAD values, HEC-FDA requires the following data:

1. **Structure Inventory Data –** This includes a structure identification number, a use category (industrial, commercial, single family residence, etc.), stream location identified by cross sectional or grid data, ground or first floor elevation, and depreciated structure and content value. This data was compiled using ArcGIS 10.3.1 and Microsoft Excel, and imported into the HEC-FDA program.
2. **Hydrologic and Hydraulic Data** – This data includes water surface profiles, exceedance probability discharge relationships, stage/discharge relationships, and levee fragility curves. Water surface profiles were developed in HEC-RAS by hydraulic engineers, transformed into an HEC-FDA compatible format using GEO-FDA software and imported into the HEC-FDA program.
3. **Depth/Damage Functions for Structures and Structure Contents –** Depth-damage relationships for non-residential structures were obtained from the Sacramento District's expert elicitation report, *Technical Report: Content Valuation and Depth-Damage Curves for Non-residential Structures*. Depth-damage relationships for residential structures were obtained from EGM 04-01.
4. **Risk and Uncertainty Parameters –** Uncertainty parameters discussed in section 3.2 of this report were also entered into HEC-FDA.

Discharge-exceedance probability, stage-discharge, and damage-stage functions derived at a damage reach index location are used to compute the damage-exceedance probability function. Monte Carlo simulation is a computationally efficient method of obtaining the damage-exceedance probability function due to uncertainty in input parameters. This numerical integration process requires all these relationships, and risk and uncertainty parameters to be input into HEC-FDA. Expected annual damage values are obtained from the cumulative distribution function produced in successive iterations of the Monte Carlo process.

3.2 Primary Sources of Uncertainty

There are many sources of uncertainty when estimating flood risk. These uncertainties are accounted for in the HEC-FDA portion of the analysis. The primary sources of uncertainty present in the calculation of economic damages include: storm water discharge, water surface elevations, levee performance, structure elevations, structure and structure content values, and depth-damage relationships.

1. **Levels of Storm Water Discharge –** The amount of rainfall from storm events with equal probabilities can vary by location throughout the watershed. Variability in storm intensity, elapsed time during rainfall, ground permeability, soil, ambient temperature, and other physical factors can also cause variation in the location and timing of rainwater entering the channel. This variation causes uncertainty in the level of storm water discharge at any location along the river.

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[2] This process is described in more detail in the HEC-FDA User's Manual Version 1.4.1 available at http://www.hec.usace.army.mil/software/hec-fda/documentation/CPD-72_V1.4.1.pdf

In addition to natural variation arising from physical factors, there is uncertainty in the modeling of water discharges for a storm event due to limited historical meteorological and stream gauge data. This data can often be incomplete or limited in sample size (length of record for time-series data). Discharge-probability distributions in this study were computed using the graphical method and were based on a period of record length of 30 years. HEC-FDA calculates 95 percent confidence intervals for storm discharges that are used in economic computations.

2. **Water Surface Elevation –** The shape of the riverbed, water temperature, location and amount of debris, and obstructions in the channel can affect the water surface elevation for a specific location along the river. When the water surface elevation exceeds the top of the levee elevation, water flows onto the floodplain. Thus uncertainty affects water surface elevations in the floodplain and in the channel. To address this uncertainty, a standard deviation with standard normal distributions, developed by USACE engineering staff, were input into HEC-FDA for water surface elevations. For the without project condition, a standard deviation of 1.0 feet, held constant at the 0.2 ACE was used; a standard deviation of 0.75 feet was used for both the minimum and maximum project alternatives, becoming constant at the 0.1 ACE and 0.02 ACE, respectively, reflecting the extent of channel improvements under each alternative.

3. **Levee Performance –** There is uncertainty about how an existing levee will perform under certain water surface elevations, how interior water-control facilities will perform, and the thoroughness of closures or openings in an existing levee. For this analysis, geotechnical failure functions were assigned to impact areas C02_1, C05_5, and C05_6, which have existing levees. For all other impact areas, top of bank elevations were entered, and it is assumed that the there is no breach prior to overtopping. The potential for levee breaches prior to overtopping increases the probability of damages and therefore the overall expected annual damage estimates.

4. **Structure Elevations –** Structure elevation is key in determining the depth of flooding inside of a structure during a flood event. First floor structure elevation is the aggregate of topographical elevation and foundation height. Both of these elevations are prone to uncertainty; topographical elevation uncertainty stems from the level of detail of the survey used to develop the data, while foundation height uncertainty is caused by assigning a standard foundation height by structure type based on sample statistics, rather than surveying each individual structure. Structures were sampled and surveyed by strata, as outlined in Section 3.4. Structure elevations were determined by taking the sum of the foundation height and corresponding topographical elevation data based on structure location. Statistical uncertainty was determined by referencing the standard deviation estimates contained in USACE Engineering Manual 1110-2-1619, which presents standard deviation of error estimates for various measurement methods, based on Institute for Water Resources (IWR) research. Ground elevations were derived using topographical data, and based on the engineering manual cited above, standard deviations of error ranging from 0.60 to three feet were assigned. First floor elevations were estimated during field surveys. Since additional stairs are typically required when a structure's doorway is six or more inches above the ground or last stair, it was assumed that : (1) ninety-eight percent of the data would be accurate within 0.50 feet, and (2) a standard deviation of error in the first floor elevation estimate would be no greater than 0.25 feet. Thus, standard deviation of error estimates between 0.85 and 3.25 feet were assigned to the joint ground and first floor elevation data. It is assumed that joint distribution error and corresponding probability distribution functions are normally distributed with a mean error of zero.

5. **Depreciated Structure and Content Replacement Values –** The depreciated replacement values for structures and contents are used to determine economic damages in the floodplain and are a function of structure type, condition, and size. Since surveying every structure in the floodplain was not feasible for this study, uncertainty arises in these values. A combination of stratified sampling, assessor data, and Google Earth Pro was used to determine the condition and square footage of the

structure, as outlined in Section 3.3. *Marshall & Swift* multiplier values per square foot and uncertainties for structure condition and corresponding estimates of depreciation were used to calculate the structure and content value for each structure. Errors for structure value estimates are assumed to be normally distributed with a mean error of zero, and standard deviations range from 10 to 15 percent of mean structure value. Structure content values are estimated as a percentage of the structure value, based on structure type and the depth-damage function.

6. **Depth-Damage Relationships** – Depth-damage functions are used to calculate the percent damage a structure will incur at a specific water elevation in a flood event. This is another calculation that is subject to variation between structure and flood event. The methodology used to construct depth-damage relationships for non-residential structures was developed by an expert-opinion elicitation process, conducted by USACE Sacramento District and published in *Technical Report: Content Valuation and Depth Damage Curves for Nonresidential Structures, May 2007.* This report provides non-residential depth-damage curves for structure contents by structure type, as well as content-to-structure value ratios and associated standard errors. The use of these curves developed by the Sacramento District is appropriate for the Westminster study, since damage to non-residential structures in Sacramento is similar to damage that would be incurred by a similar amount of flooding in the Westminster study area. This is due to the fact that floodwaters rapidly inundate highly urbanized areas with minimal warning in both geographic locations. Non-residential depth-damage functions and structure-content ratios used from the referenced report are provided in Addendum A.

   Depth-damage functions and associated standard errors for residential structures and their contents were developed by the Institute for Water Resources (IWR) and published in *Economic Guidance Memorandum 04-01: Generic Depth-Damage Relationships for Residential Structures with Basements, October 2003.*The depth-damage functions and standard error estimates are based upon previous damages that occurred during flood events in the United States.

   Depth damage functions for other damage categories are described in the discussion of damages by category in the following sections.

3.3 Engineering Inputs

3.3.1 Hydraulic and Hydrologic Inputs

Hydraulic and Hydrologic (H&H) inputs including water surface profiles and corresponding relationships were used to compute expected annual damages through Monte Carlo sampling of discharge-exceedance probability relationships, stage-discharge relationships, and stage-damage relationships and their uncertainties. Uncertainty parameters for the exceedance-probability relationship and stage-discharge relationship were developed by H&H engineers. For the exceedance-probability relationship, uncertainty is based on an Equivalent Record Length (N) of a 30 year gage record for all project conditions and reaches. For the stage-discharge relationship, uncertainty is as follows:

<u>Without / Existing Project Condition</u>
Normal Distribution with a standard deviation of 1 foot, becoming constant at the 5 year profile.

<u>Minimum Channel Improvements Plan</u>
Normal Distribution with a standard deviation of 0.75 feet, becoming constant at the 10 year profile.

<u>Maximum Channel Improvements Plan</u>
Normal Distribution with a standard deviation of 0.75 feet, becoming constant at the 50 year profile.

These values are based on how river stages within the channel react to various flows and is not expected to change during the period of analysis. Additional detail regarding the estimation of these parameters can be found in the H&H Appendix.

3.3.2 Geotechnical Inputs

Levee fragility curves were developed by geotechnical engineers to address potential levee failure in the leveed impact areas including C02_1, C05_5, and C06_6. In these areas, in addition to overtopping, levees could potentially fail, increasing flow outside of the channel and damage to structures. Under the without-project condition, there is a 15 percent chance of levee failure at the probable no-failure point (PNP), and an 85 percent chance of levee failure at the probable failure point (PFP) elevation for all three leveed reaches. Geotechnical functions for leveed reaches were input into FDA using corresponding PNP and PFP elevations. PNP, PFP, and top of bank elevations for each leveed reach are shown in the table below.

Table 8 Geotechnical Functions[3]

Impact Area	Probable No-Failure Point Elevation (PNP)	Probability of failure at PNP	Probable Failure Point Elevation (PFP)	Probability of failure at PFP	Levee Crest (or top of bank)	Probability of Failure at crest
C05_6	6.19	0.15	11.72	0.85	12.9	1
C05_5	8.31	0.15	12.09	0.85	12.9	1
C02_1	10.29	0.15	10.33	0.85	10.335	1

3.4 Damages to Structures and Structure Contents

Residential, commercial, industrial, and public structures in the floodplain are at risk of being damaged when flood events occur that exceed the system capacity. To estimate the economic losses resulting from these damages, an inventory of structures within the floodplain was developed. Depreciated replacement costs of these structures and their contents were then calculated and flood damages for varying probabilistic events were estimated. The structure inventory for this study was developed using the inventory for the 2017 *Santa Ana River Mainstem Economic Reevaulation Report* (USACE 2017) (hereafter 2017 ERR), which has a 0.002 ACE floodplain that fully encompasses the Westminster 0.002 ACE floodplain. The following section describes the development of the structure inventory in detail.

3.4.1 Structure Inventory

Structure inventory for the feasibility study was developed using existing structure inventory from the Santa Ana River Mainstem floodplain, which contains the Westminster floodplain. This structure inventory was last updated in 2017 and is comprised of a) previously existing structures that were included in the 2013 *Santa Ana River Mainstem Economic Reevaluation Report (*USACE 2013) (hereafter

[3] Note - Fragility curve for C02_01 adjusted to reflect stages/probabilities corresponding with most likely failure point upstream of index cross section.

2013 ERR) and b) structures that were identified as newly constructed since 2013 using a combination of tax assessor data and Google Earth Pro historical imagery, which were added to the 2017 ERR.

The price level for structures included in the 2013 ERR were updated to October 2016 price levels through updated *Marshall & Swift* multipliers for each occupancy time. A sample review of structures from the 2013 ERR database was performed using Google Earth to verify that there was minimal change in structure use or condition from 2013 to 2016. Therefore, the methodology used to update price levels is considered appropriate. Any error arising from this methodology would be trivial, due to the minimal variation in percent changes between *Marshall & Swift* occupancy categories and the large number of structures in the inventory. Structures originally included in the 2013 ERR were evaluated using data collected during field surveys conducted in 2012. Structures were identified as lying in the floodplain using geo-referenced parcel tax assessor data in ArcGIS.[4] This data included geographic coordinates, the zoned type-use of each parcel (residential, commercial, industrial, public, or agricultural), street address, structure square footage, and other parcel characteristics. The geographic spread and large number of structures in the floodplain made a survey of 100 percent of the structures impractical. Instead, a sample of structures in the floodplain was randomly selected and subsequently stratified by study area location, reported land use, home value, industrial zone or year of construction[5]. The allocation of parcels between strata was based on optimal and proportional allocation methods.[6] Parcels were randomly selected within strata using a uniform random number generator. The uncertainty parameters for first floor elevation and structure and content values differ between structures that were sampled and structures that weren't sampled in the random selection and subsequent survey. For example, the standard deviation for the first floor elevation of a single family residential structure that was sampled is 0.85 feet, while the standard deviation for the first floor elevation for same type of structure that wasn't surveyed is 1.1 feet. Correspondingly, the coefficient of variation for the structure value and structure content value for sampled and non-sampled structures varies by structure type. Uncertainty parameters for all structure types, both sampled and non-sampled, are normally distributed with a mean error of zero.

In order to add structures built between 2013 and 2017 to the structure inventory, tax assessor data was obtained from the Orange County Flood Control District. This data included parcel numbers but lacked structure-specific data (square footage, year built, etc.) for buildings constructed since 2013. In order to obtain square footage and building classification for valuation purposes, data was imported into Google Earth Pro, and new structures were identified by comparing historical images from April 2013 and February 2016 (dates are based on available Google Earth images at the time of analysis). New and previously existing structures were exported from ArcGIS to Google Earth Pro, and satellite imagery was used to verify the location, and classify the type and condition of the new structure. Square footage was estimated by exporting the parcel data from ArcGIS 10.3.1 to Google Earth Pro, and using the

[4] Portions of parcels intersecting the floodplain were included in the analysis.

[5] Study area location refers to the floodplain areas discussed throughout the report (i.e. lower Santa Ana, upper Santa Ana River, Oak Street drain, Santiago Creek, etc.). Reported land use refers to the land use reported in the tax assessor records (i.e. Single Family Residency, Multifamily Residence, Industrial, Commercial, etc.). Home value refers to the value of residential parcels reported in the 2010 census data. Year of construction refers to the year of the building's construction, sometimes reported in the tax assessor records. Industrial zone refers to general geographic zones where industrial structures are clustered. Whether home value, year of construction, or industrial zone were used to stratify the parcel data depends up on the parcels' reported land use and data availability.

[6] Residential structures were assigned to optimally allocated strata (using the optimal allocation sampling method), based on home value data found in the tract level census data, when accurate year of construction data did not exist. All other strata were proportionally allocated (using the proportional allocation method) with respect to land use, with some manual adjustment to the proportions when previous survey results suggested a higher allocation would increase statistical efficiency.

measurement tool and aerial photographs to estimate approximate square footage of the structure.[7] Additionally, based upon typical structure characteristics identified in the 2013 survey and Google Earth, all structures built between 2013 and 2017 were assumed to have a foundation height of 0.5 feet for single and multi-family residences and three feet for mobile homes, and were assumed to be single story[8]. Thus square footage is an approximation of actual square footage, but is conservative, and any bias present in square footage measurements would bias the damage estimates downward. Ground elevation was added to foundation heights to estimate the first floor stage for each structure in the floodplain. In order to extract Westminster data from the SARM structure inventory, structures were georeferenced, then extracted from within the Westminster 0.002 ACE floodplain using ArcGIS 10.3.1. For structures with high structure values (structures larger than 10,000 square feet), values were updated to reflect their specific category type and square footage, rather than the type and square footage assigned during the stratified sampling and assignment process outlined above. Structure inventory data was projected into CCS83, Zone VI (US Feet), which corresponds with the projection of hydraulic inputs.

The structure inventory, as well as water surface profiles developed by H&H Engineers, were then imported into Hydrologic Engineering Center's HEC-GeoFDA software (Version 1.0), which is used to combine geographically-referenced engineering and economic data into a format that can be imported into HEC-FDA. GeoFDA was used to assign a ground elevation and an impact area in C02/04 or C05/06. Structures were then imported into HEC-FDA for analysis. As shown above in Figure 2, there is a small portion of economic impact areas C04_4b and C05_5/C05_6 that overlap. There are 855 structures included in both C04_4b and C05_5/C05_6. In order to prevent overestimation of damages, damages to structures in the overlapping floodplain area were assigned to the C04 floodplain, as the primary source of flooding to these structures.

3.4.2 Structures Built After 1991

According to the Water Resources Development Act of 1990 (WRDA90) Section 308, new or improved structures built within the 100-year (0.01 ACE) floodplain after July 1, 1991 with first floor elevations lower than the 100-year flood elevation, should be excluded from the structures used to calculate NED benefits for flood damage reduction projects. To ensure this study is compliant with Section 308, the Federal Emergency Management Agency's (FEMA's) 100-year floodplain from Flood Insurance Rate Map (FIRM) data was gathered from ArcGIS online and analyzed in ArcMap 10.3.1. Of the three structures in the Westminster floodplain that were built since 2013, none are located within the FEMA 100-year floodplain. For the portion of the structure inventory that was developed prior to 2013, it was determined that the majority of the structures were constructed prior to 1990, and that any remaining structures posed trivial risk to the study's overall findings. This factor, combined with the frequency of missing date of construction data in the tax assessor records, was reason to make no further attempt in identifying or structures built between 1991 and 2013.

3.5 Other Damages Categories

In addition to damages to structures and their contents, various other damages are incurred in a flood event, including post-flood cleanup costs, damages to vehicles, other public assistance. This section

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[7] It was assumed that each 1,000 square ft. of multi-family residence was one unit. Thus to determine the number of units in a multi-family residence, the total square footage was divided by 1,000. Only one structure per MFR is included in the structure count in Table 4, although each structure represents more than one unit.

[8] For structures surveyed in Google Earth Pro that were assumed to be single story, only the first floor square footage is used to calculate damages.

explains these categories in more detail and justifies them as flood damage reduction categories that should be included in the calculation of with-project benefits.

3.5.1 Cleanup Costs

ER 1105-2-100 provides for emergency expenses, which include hazardous and toxic waste cleanup, to be included in damages estimates for flood events. Structures that are inundated in a flood event require post-flood cleanup in order to remove floodwater, sediment, debris, mold, mildew, and toxins. These cleanup costs are considered a damage category in the calculation of with-project benefits and can vary based on depth of flooding. A depth-damage curve is used to estimate the cost incurred for a given level of inundation in a structure. Depth-damage functions for cleanup costs come from USACE Sacramento District's *Technical Report: Content Valuation and Depth Damage Curves for Nonresidential Structures, May 2007*.

Based on research and analysis conducted by both USACE Sacramento and New Orleans Districts, a maximum value of ten dollars per square foot for each structure is used for cleanup costs. The maximum value is applied for flood depths greater than or equal to 3 feet, while flood depths less than 3 feet are assigned a portion of the maximum value. The maximum per square foot cost includes clean-up costs associated with mold and mildew abatement, including costs of paid professional firms to apply fans and chemicals to eliminate mold and prevent mold in inundated areas.

3.5.2 Vehicle Damages

Due to the high number of residential structures in the floodplain, this economic analysis accounts for vehicle damages for single family, multi-family and mobile home residential structures. Damages to autos in commercial, industrial, and public parking lots are not included in the analysis. Automobile damages are calculated as a function of the number of vehicles per residence, estimated average value per vehicle, estimated percentage of vehicles removed from the floodplain in an evacuation, and the depth of flooding above the ground elevation.

Assuming that each single family residence and each 1,000 square feet of multi-family residence comprises one household, 2.4 vehicles were assigned to each household. This is the mean number of vehicles per household based on county-level census data. Consistent with guidance in EGM 09-04, it is estimated that for any given flood event with a warning time of less than six hours, fifty percent of the vehicles will be removed from the floodplain.

Depreciated replacement values for vehicles are based on average private-seller used auto prices in the study area. Weighted averages of used auto prices from autotrader.com and craigslist.com within a ten mile radius of a central zip code in the floodplain were used. The average cost per vehicle was valued at $15,395. Adjusting for the average of 2.4 vehicles per household and number of vehicles removed in a flood event, the average auto replacement cost is $18,474. Standard errors associated with weighted average vehicle values were computed and input into FDA. An automobile depth-damage function was used to determine the percentage of damage to the vehicle in a flood event. Depth damage functions for this study were taken from EGM 09-04. Damages for autos begin once flood depth reaches 0.5 feet and reach 100 percent damage at a flood depth of 9 feet. It is assumed that the elevation of vehicles parked at residential structures is equal to the ground elevation of the corresponding residential structure, since an attached garage or carport would likely have the same elevation as the rest of the structure.

3.5.3 Other Emergency Costs

Other emergency costs incurred in flood events come from FEMA's Individuals and Households Program (IHP) and include the following: Public Assistance (PA) to aid in debris removal, emergency protective measures, repair roads, bridges, water facilities, public buildings and utilities, and public parks and recreation facilities; and Other Needs Assistance (ONA), which includes aid to replace essential household items, and moving, storage, medical, dental, and funeral expenses. This analysis uses housing assistance and other needs assistance to calculate the public assistance to HA and ONA ratio in terms of dollars per claim, but housing assistance is not included as an emergency cost.

For emergency costs in this report, historical FEMA claims data from 1998 to 2016 was used to determine average amounts per claim made for public and other needs assistance. The average PA is $7,934 and the average ONA is $826, with a combined PA/ONA of $8,761.

Similar to automobile and cleanup costs, other emergency costs are assigned a depth-damage function that associates a specific depth of flooding to a percentage of the emergency costs in the HEC-FDA program. Fifty percent of the emergency costs are incurred when the flood depth reaches 0.5 feet, while flood depths one foot or greater incur 100 percent of the emergency damage cost. This is based on the assumption that households must incur a depth of flooding greater than zero to be eligible to file a claim. Thus structures which are inundated one foot or more above the first floor elevation would incur public and other needs assistance related costs as reflected in the historical FEMA claims data.

3.6 Traffic Delay Analysis

In addition to causing physical damages, flood events also cause increased traffic delays when major roads and highways become inundated. These delays include the opportunity cost of time for motorists and increased vehicle operating costs, and count as a justifiable damage category.

Initial modeling of traffic delays has been conducted using the Dynamic Urban Systems for Transportation (DynusT) model provided by Metropia (contractor). This model utilizes route, capacity, and usage data from the Southern California Association of Governments (SCAG) Transportation Program. However, this modeling effort and subsequent reviews were not complete at the time of submittal of this Final Feasibility Report. Significant model review comments indicated further efforts to verify the model calculations and outputs would be required prior to the model's approval for use in Agency decision making. Therefore, the without project damages/costs and benefits of alternatives do not include traffic delay impacts. Should DynustT be approved for use prior to or during the pre-construction engineering and design phase for the project, it may be used to inform economic updates for the recommended plan.

Based upon the preliminary traffic analysis that has been completed, the traffic delay impacts would be substantial for major flood events, but given the low probability of such events, the impact to overall estimates of without project damages and with project benefits is expected to be relatively minor (less than 10%). Regardless, in addition to the national economic development impacts associated with traffic delays, there are also other social effects impacts, including life and safety impacts associated with lack of access and delays for police, fire, and ambulance vehicles. Risks associated with these impacts, as well as the reduction in such risks that can be realized with proposed alternatives, are an important consideration in assessing overall project benefits and federal interest.

3.7 Advanced Bridge Replacement

In accordance with the IWR-88-2, this analysis includes advanced bridge replacement benefits. Bridges replaced during project construction extend the life of current bridges for stream and river crossings, thus providing economic benefit. This economic benefit can be claimed to partially offset the cost of the bridge replacement. Benefits are calculated using the additional useful life that is extended by the bridge replacement. Based upon feedback obtained from Orange County and USACE engineering staff, the assumed service life of each structure was assumed to be 75 years, which is the assumed functional life of the bridges and crossings from the time of construction. Most of the bridges are assumed to be at or near the end of their functional life or will be by the Base Year. The extension of structure life used was 50 years for structures with an age greater than 75 years by the Base Year, based on the period of analysis for the project. The extended life of the structure for structures less than 75 years old was 50 less the remaining life of the structure. For example, for a structure that is 50 years old, the remaining useful life of the structure would be 25 years. This number would then be subtracted from 50, in order to get 25 years as the extension of the structure life with implementation of the project. The capital recovery factor was calculated based on the current discount rate of 2.75% for the 50 year period of analysis, and was then used to calculate the annual cost of the new structure over 50 years. The present value in year one of the benefits for the extended life of the structure was then calculated, and multiplied by the capital recovery factor to obtain the average annual benefits for each crossing replacement.

A detailed table showing bridge/crossing locations, corresponding reaches, and costs and expected average annual benefits realized by the advanced replacement of each bridge/crossing is shown in Addendum A of this appendix.

3.8 National Flood Insurance Program Operating Costs

EGM 06-04 provides guidance on including the reduction in flood insurance program operating costs as a benefit to the project, as a result of fewer structures being within the 100-year floodplain. The benefit in flood insurance operating costs is calculated by multiplying the number of structures in the floodplain under each project condition by the average price of operating costs per policy, and subtracting the product from the without project condition. This methodology assumes that each structure in the 100-year floodplain represents one household that carries a flood insurance policy. The price per policy was taken from EGM 06-04, which represents an estimated average cost per policy for administration of the National Flood Insurance Program. The most recent flood insurance policy costs, which are used in this analysis, were given in EGM 06-04 *National Flood Insurance Program Operating Costs, Fiscal Year 2006.* This benefit category was evaluated, in addition to the reduction in without project damages shown on Tables 12 and 13, below, and accounts for a very small portion of overall project benefits for project alternatives.

3.9 Other Social Effects

In accordance with ER 1105-2-101, life loss is categorized as an OSE (Other Social Effects) category. A life safety analysis includes the estimation of the population at risk and associated statistical estimates for life loss. For this analysis, life loss was calculated using Hydrologic Engineering Center – Flood Impact Analysis (HEC-FIA) version 3.0. This software uses Monte Carlo simulation to estimate the number of individuals at risk of life loss by probabilistic event for nighttime and daytime, and for populations over and under the age of 65.

The latest version of the National Structure Inventory (NSI) and associated population parameters were used for the life loss analysis. This data was loaded into HEC-FIA, along with terrain, arrival time and depth grids, and impact area data. Structure inventory was calculated to make sure no structures were located within channels or harbors. Uncertainty parameters and depth-damage functions were unchanged from the defaults that automatically populate for the NSI data.

Warning relative to start time was set at 30 minutes prior to inundation arrival time, with a likely offset of 15 minutes. This warning time was established by Orange County Public Works given existing engineering data and modeling and historical observations. It should be noted that warning relative to start time has a significant impact on the life loss results; for example, increasing the warning time to 1 hour prior to inundation would decrease life loss statistics substantially. Calculations were computed with uncertainty. Tables 9 and 10 display life loss by channel for 0.01 and 0.002 ACE events.

Table 9. Aggregate Life Loss 0.01 ACE – Without Project Conditions

	Life Loss Day Under 65	Life Loss Day Over 65	Life Loss Night Under 65	Life Loss Night Over 65
Channel				
C02/04	31	3	7	1
C05/06	214	60	393	68
Total	245	63	400	69

Figures shown represent number of individuals at risk.

Table 10. Aggregate Life Loss 0.002 ACE – Without Project Conditions

	Life Loss Day Under 65	Life Loss Day Over 65	Life Loss Night Under 65	Life Loss Night Over 65
Channel				
C02/04	101	22	153	24
C05/06	320	92	548	103
Total	421	114	701	127

Figures shown represent number of individuals at risk.

Table 9 shows that nighttime life loss for individuals under and over the age of 65 totals 400 and 69, respectively, under the without project conditions for the 0.01 ACE. Similarly, life loss figures displayed in Table 10 show that nighttime life loss for individuals under and over 65 years of age totals 701 and 127, respectively, for the without project condition for the .002 ACE.

As noted, these life loss results are very sensitive to warning time assumptions, and would be minimal if the assumed warning time were increased to one hour or more. It should also be noted that there is no specific information available on historical life loss associated with flooding of the Westminster channels to support these projections and it is possible that these estimates may be overestimated. However, there has also been a lack of major flood events in the study area to substantiate that these estimates overstate potential life loss.

Additional other social effects include health and safety-related issues caused by floodwaters, emotional and psychological impacts of flood-related losses, and disruption to daily life, including education and work activities, that occur as the result of a flood. In addition, as noted in Section 3.6, inundation of the dense transportation network within the floodplain also results in risks to life and safety due to impacts to accessibility and delays for emergency and other vehicles. These impacts are not quantified in this report, but are worth bearing in mind when assessing the overall impact of a flood event.

4. Without Project Damages

This section describes the analysis of damages that are expected to occur in the absence of a Federal project to address flood risks in the study area. These damages include those to structure and structure contents, transportation delay costs, and other damages, which include cleanup costs, vehicle damages, and emergency costs.

HEC-FDA software was used to calculate economic damages for the study. Expected and equivalent annual flood damages are the basis for calculating with-project benefits, and are crucial to the evaluation of the project. Expected annual damages are equal to the mean of all possible values of damage that are derived through Monte Carlo sampling of discharge-exceedance probability relationships, stage-discharge relationships, and stage-damage relationships and their uncertainties. Uncertainty parameters for the exceedance-probability relationship and stage-discharge relationship were developed by H&H engineers. For the exceedance-probability relationship, uncertainty is based on an Equivalent Record Length (N) of 30 year gage record (the period of historical measurement of the velocity of channel flows in cubic feet per second) for all project conditions and reaches. For the stage-discharge relationship, uncertainty is as follows:

<u>Without / Existing Project Condition</u>
Normal Distribution with a standard deviation of 1 foot, becoming constant at the 5 year profile

<u>Minimum Channel Improvements Plan</u>
Normal Distribution with a standard deviation of 0.75 feet, becoming constant at the 10 year profile

<u>Maximum Channel Improvements Plan</u>
Normal Distribution with a standard deviation of 0.75 feet, becoming constant at the 50 year profile.

These values are based on how river stages within the channel react to various flows and are not expected to change during the period of analysis. Additional detail regarding the estimation of these parameters can be found in the H&H Appendix.

Equivalent annual damages are equal to expected annual damages that have been discounted to present values and annualized. Equivalent annual damages are normally calculated for the base and future years, and interpolated for in-between years. Since hydrologic conditions were modeled to be the same in the base and future years, equivalent annual damages and expected annual damages are the same values in this analysis. This section presents expected annual damages, and as the result of time-dependent variance in hydrologic, hydraulic, and economic data, the values in this section are estimates only.

4.1 Without Project Expected Annual Damage Estimates

Expected annual damage is the mean damage for the damage reach, obtained by integrating the damage exceedance probability curve. Structure and structure contents include the cost of the damage to the physical structure and the contents inside it, based on a depth-percent damaged relationship as previously described. Structure and structure contents include damages to residential, public, commercial, and industrial structures. Other related flood damages include damages to residential vehicles, emergency, and cleanup costs. Values were calculated in fiscal year (FY) 2017 price levels and indexed to FY 2020 price levels for comparison with costs later in the report. Values were indexed using *Marshall & Swift* Valuation Service construction cost indices (Western region), which results in a multiplier of 1.086 to update prices to FY 2020 levels. Table 11 displays expected annual damages by reach and use type.

Table 11. Without-Project Expected Annual Damages for Structure and Structure Contents, FY 2020 PL ($000's)

Reach	Residential	Commercial	Industrial	Public	Total
C02_1	1,485	39	15	76	1,615
C04_1	0	0	0	0	0
C04_2	0	0	0	0	0
C04_3	2	1	4	0	7
C04_4a	74	2	17	0	93
C04_4b	225	36	206	336	803
C05_1A	86	5	1	1	92
C05_2A	30	12	31	0	73
C05_2B	132	40	43	7	221
C05_2C	21	0	0	0	21
C05_2D	422	1	14	0	436
C05_3A	147	32	64	11	253
C05_3B	53	12	6	0	70
C05_3C	0	0	0	0	0
C05_3D	448	46	3	124	622
C05_4A	7,626	442	25	37	8,131
C05_4B	60	26	0	0	86
C05_5	2,793	84	40	0	2,917
C05_6	36,402	368	1,165	0	37,934
C06_1A	104	0	0	0	104
C06_1B	18	1	0	0	19
C06_2	2	0	0	0	2
Total	50,133	1,145	1,630	591	53,500

Under the existing condition of the floodplain, annual damages for structures and contents total more than $53.5 million. Damages to residential structures account for about 94 percent of without-project damages. Commercial and industrial damages combined account for 5 percent of without-project damages, and public structures also make up nearly 1 percent of without-project damages. EIA C05_6 contains 71 percent of structural damages, while C05_4A and h C05_5 account for 15 and 5 percent of damages, respectively. Combined, these three impact areas account for nearly 92 percent of without project structure and content damages.

Table 12 shows additional without-project damages for ‘Other’ flood damage categories evaluated within HEF-FDA (except traffic impacts), which include clean-up costs, other emergency costs as defined above, and damages to residential vehicles.

Table 12. Without-Project Other Flood Damage Categories Summary FY 2020 PL ($000's)

Reach	Clean-up	Emergency	Vehicle	Total
C02_1	175	427	305	907
C04_1	0	0	0	0
C04_2	0	0	0	0
C04_3	1	0	0	1
C04_4a	9	8	4	20
C04_4b	57	83	57	196
C05_1A	13	23	19	55
C05_2A	9	5	4	18
C05_2B	22	16	6	44
C05_2C	2	3	1	6
C05_2D	40	370	256	667
C05_3A	29	20	11	60
C05_3B	7	6	2	16
C05_3C	0	0	0	0
C05_3D	87	157	143	387
C05_4A	968	1,085	1,170	3,224
C05_4B	12	10	24	46
C05_5	375	342	327	1,044
C05_6	3,671	4,512	3,329	11,512
C06_1A	6	11	2	19
C06_1B	2	3	2	7
C06_2	0	0	0	1
Total	5,485	7,081	5,665	18,230

Emergency costs account for 39 percent of other damages, while clean-up and auto damages each account for about 30 and 31 percent of other damages, respectively. C05_6 accounts for 63 percent of other damages, while C05_4a accounts for 18 percent.

Tables 13 and 14 show equivalent annual damages by use, aggregated by channel. As noted earlier, damages to structures in the overlapping floodplain area between C04 and C05 were based upon damages attributable to C04 as the primary source of flooding to these structures. Hence, the damages shown for C05 do not include damages to structures in the overlapping floodplain area. Accordingly, overall expected damages may be underestimated to a small degree, to the extent that concurrent flooding from the C05 channel would result in additional damages to these structures. Given the small number (855) of structures in this overlap area relative to the overall number of structures in the C05/C06 floodplain, this impact would be negligible.

Table 13. Without-Project Expected Annual Damages by Use, FY 2020 Price Level ($000's)

Channel	Residential	Commercial	Industrial	Public	Total
C02-C04	1,787	78	240	412	2,518
Reach C02	1,485	39	15	76	1,615
All Reaches C04	302	39	226	336	902
C05-C06	48,346	1,067	1,390	180	50,983
All Reaches C05	48,221	1,066	1,390	180	50,858
All Reaches C06	124	1	0	0	125
Total	50,133	1,145	1,630	591	53,500

Table 13 shows that C05/C06 account for over 95 percent of residential structure damage. This includes damages to single family and multi-family residences, and damage to mobile homes. Expected annual structure and structure content damages total more than $53 million.

Table 14 shows that emergency costs account for the largest portion of ‘other’ flood damages, followed by clean-up and vehicle damages. Total expected annual ‘other’ flood damages are estimated to be more than $18 million under the without project condition in the study area.

Table 14. Without-Project Expected Annual Damages by Use, FY 2020 Price Level ($000's)

Channel	Clean-up	Emergency	Vehicle	Total
C02-C04	241	518	366	1,125
Reach C02	175	427	305	907
All Reaches C04	66	91	61	218
C05-C06	5,243	6,563	5,298	17,105
All Reaches C05	5,235	6,549	5,293	17,077
All Reaches C06	9	14	5	28
Total	5,485	7,081	5,665	18,230

Table 15 shows total without-project expected annual damages by floodplain channel.

Table 15. Without-Project Expected Annual Damages by Channel FY 2020 Price Level ($000's)

Reach	Structure and Structure Contents	Other Related Flood Damage Categories	Total Without Project Damages
Reaches C02-C04	2,518	1,125	3,643
Reach C02	1,615	907	2,522
All Reaches C04	902	218	1,120
Reaches C05-C06	50,983	17,105	68,088
All Reaches C05	50,858	17,077	67,935
All Reaches C06	125	28	153
Total	53,500	18,230	71,730

Table 15 shows that under without project conditions, expected annual flood damages total nearly $72 million. More than $53 million of this sum is comprised of damages to structures and their contents and over $18 million is attributed to ‘other’ flood damages including emergency, cleanup, and damages to vehicles.

Without-project expected annual damages computed for this analysis are significantly higher than past analyses completed for earlier iterations of the feasibility study. This is primarily attributable to the following: updated hydraulic and hydrologic data, the development of a new and larger floodplain (particularly the inclusion of C02), the inclusion of levee fragility curves, changes to the FDA software, and updated price levels. Updated hydraulic and hydrologic data resulted in discharge flows and stages that are higher for more frequent events in all channels. Because economic damages are computed based on stage-discharge and stage-damage relationships, it is expected for damages to be higher, particularly for lower frequency events, considering the updated data. As part of the updated H&H data, the floodplain was also expanded to included areas that weren't previously included in the analysis. The number of structures and the absolute value of damages to structures is also expected to be higher as a result. Previous analyses also did not include geotechnical functions for leveed reaches. Since including probabilistic values and stages for levee failure increases uncertainty, it is expected that damages will be significantly increased in leveed reaches (C05_5, C05_6, and C02_1), which is the case in this analysis. Additionally, this study uses FDA 1.4.2 to calculate expected damages. Changes to the FDA software since previous studies were conducted allow for wider confidence intervals at the upper end of the exceedance probability curve, which more accurately captures uncertainty, but also leads to larger damage estimates than previous versions of the software. Lastly, this study uses a structure inventory that uses FY 2017 price levels, and then indexes those to FY 2020 values. This change in price level should also be taken into account when comparing values to previous analyses.

4.2 Without-Project Performance

Without-project performance statistics help inform the risk of a flood event of a specific frequency. Three components are indicators of project performance: the annual exceedance probability (AEP) is the likelihood flooding occurs in any given year; the long-term risk is the probability that flooding occurs in a period of 10, 30, or 50 years; and the assurance is the probability that flooding doesn't occur, conditional on a flood event of 0.02, 0.01, and 0.002 frequency occurring. The table below shows these statistics by reach for the without-project condition.

Table 16. Without-Project Condition Project Performance (%)

Reach	AEP[1]	Long-Term Risk[2]			Assurance[3]		
		10 year	30 year	50 year	2.00%	1.00%	0.20%
Reaches C02-C04							
C02_1	6.37	48.20	86.10	96.30	48.43	44.88	43.95
C04_1	0.01	0.12	0.37	0.62	99.96	99.95	99.94
C04_2	0.01	0.11	0.34	0.56	99.98	99.97	99.97
C04_3	0.03	0.32	0.95	1.58	99.00	99.00	99.00
C04_4a	9.34	62.49	94.72	99.26	36.98	34.38	20.60
C04_4b	3.03	26.48	60.26	78.52	74.91	73.99	66.36
Reaches C05-C06							
C05_1a	0.86	8.23	22.71	34.90	97.02	96.77	96.26
C05_2a	9.01	61.12	94.12	99.00	68.24	66.98	62.43
C05_2b	16.94	84.38	99.00	99.00	19.89	17.35	11.02
C05_2c	4.28	35.42	73.07	88.77	62.28	57.65	44.20
C05_2d	25.53	94.75	99.00	99.00	4.11	2.96	1.40
C05_3a	6.91	51.11	88.31	97.21	74.64	73.78	67.98
C05_3b	14.36	78.78	99.04	99.00	28.49	24.90	21.74
C05_3c	0.01	0.12	0.36	0.60	99.00	99.00	99.00
C05_3d	1.82	16.83	42.46	60.19	90.88	90.14	88.42
C05_4a	10.08	65.45	95.87	99.00	72.92	71.01	65.48
C05_4b	0.38	3.70	10.70	17.19	98.32	98.26	98.07
C05_5	60.57	99.00	99.00	99.00	24.34	23.92	23.23
C05_6	72.46	99.00	99.00	99.00	16.49	16.11	15.49
C06_1a	99.00	99.00	99.00	99.00	0.01	0.01	0.01
C06_1b	0.35	3.46	10.02	16.13	95.15	92.14	87.38
C06_2	0.02	0.18	0.54	0.90	99.95	99.95	99.94

[1]*Probability that flooding will occur in any given year*
[2]*Probability the target stage is exceeded during the period of time listed below*
[3]*Probability that no flooding occurs, given that a flood event of the frequency listed below has occurred*

Table 16 shows that there is more than a 60 percent chance that a flood will occur in any given year in reaches C05_5, C05_6, and C06_1a. Correspondingly, in these reaches the assurance is low; there is only a 1 percent chance that no flooding occurs, given the occurrence of a 0.002 ACE in reach C06_1a. For reaches C05_5 and C06_6, the corresponding probabilities are about 23 percent and 15 percent, respectively. In all three of these reaches, there is a 99 percent chance flooding will occur within 10, 30, or 50 years. Since C05_5 and C05_6 contain more than 25 percent of the structures in channel C05 and have a high probability of flooding, the without-project condition poses significant risks. This is reflected in the high equivalent annual damages estimates for C05, shown above.

5. With-Project Benefits

Hydrologic and hydraulic data were developed for a 'maximum' channel improvement alternative and a 'minimum' channel improvement alternative. Minimum channel improvements include improvements in impact areas C05_2D, C05_3D, C05_4A, C05_4B, C05_5, C05_6, all impact areas in C06 and C02, and all impact areas in C04, except C04_3. Maximum channel improvements include improvements in all reaches, except for C05_1A. Improvements under the Minimum and Maximum Improvement Plans were formed based on strategies that include reducing the impacts of flooding by improving channel conveyance, increasing channel capacity by increasing flood water storage, and improving downstream conveyance to balance improvements to conveyance and capacity upstream. The Minimum Improvement

Plan focuses on improving channel conveyance, while the Maximum Improvement Plan focuses on improving channel conveyance and increasing channel capacity. Additional details on the plan formulation strategy can be found in Appendix H. This section explains the results of the Minimum and Maximum Plan with-project conditions, and provides the basis for formulation of the NED plan.

With-project benefits are defined as the difference between without-project damages and with-project damages computed in HEC-FDA, and are the benefits achieved by taking action as opposed to the study area remaining in its current state. Benefits by channel are shown in the tables below.

5.1 Minimum and Maximum Improvement Plan Expected Annual Benefit Summaries

Table 17. With-Project Minimum Improvement Plan Expected Annual Benefits, FY 2020 Price Level ($000's)

Reach	Structure and Structure Contents	Other Related Flood Damage Categories	Bridge Benefits	Flood Insurance Benefits	Total With-Project Benefits
Reaches C02-C04	2,161	912	0	73	3,146
C02	1,260	694	0	41	1,994
C04	901	218	-	32	1,152
Reaches C05-C06	50,253	16,801	2,469	663	70,186
C05	50,223	16,791	2,469	641	70,124
C06	30	10	-	23	63
Total	52,414	17,713	2,469	737	73,332

** Figures may not sum to total due to rounding*

With-project average annual benefits for the Minimum Improvement Plan total over $73 million. The majority of this is attributed to structure and structure content benefits, which total over $52 million. These are the estimated damages to structures avoided if the Minimum Improvement Plan measures are built in the specified channels. The benefits for clean-up, emergency, relocation, and auto categories total nearly $18 million. Advanced bridge replacement benefits, which are the benefits gained by extending the functional life of bridges in certain channels, are just about $2.5 million. Flood insurance benefits, which represents the reduction in policy operating costs due to flood reduction, is approximately $737 thousand.

Table 18. With-Project Maximum Improvement Expected Annual Benefits, FY 2020 Price Level ($000's)

Reach	Structure and Structure Contents	Other Related Flood Damage Categories	Bridge Benefits	Flood Insurance Benefits	Total With-Project Benefits
Reaches C02-C04	2,517	1,125	3,208	103	6,952
C02	1,615	907	0	39	2,561
C04	902	218	3,208	64	4,392
Reaches C05-C06	50,981	17,105	9,540	817	78,442
C05	50,857	17,077	6,502	779	75,215
C06	124	28	3,037	38	3,227
Total	53,498	18,230	12,747	919	85,395

** Figures may not sum to total due to rounding*

Table 18 shows estimated with-project benefits when all of the Maximum Improvement Plan measures are in place. Structure and structure contents account about 63 percent of total annual benefits, at over $53 million. Other flood benefits account for over $18 million, bridge benefits account for nearly $13 million, and flood insurance benefits account for about $1 million of total benefits. Total with-project benefits under the Maximum Improvement Plan exceed $85 million, which is approximately $12 million more than total with-project benefits for Minimum Improvement Plan measures. Implementing the Maximum

Improvement Plan would nearly eliminate without-project damages, with only minimal residual damages. Additionally, since the Maximum Improvement Plan requires a significant number of bridge replacements and modifications, there are substantial benefits associated with advanced bridge replacement.

5.2 Expected Annual Damages by Annual Chance of Exceedance Event

In addition to knowing a range of possible values of damage reduced, it is also helpful to see damages by flood event. Table 19 below compares expected annual damages for without, Minimum, and Maximum Improvement Plan conditions, by percent annual chance event and impact area, for the 0.1, 0.02, 0.01, and 0.002 annual chance events. Note that under Minimum Improvement Plan conditions, some of the reaches have no proposed improvements but do realize economic benefits from a reduction in flood damages. This is due to increased conveyance capacity downstream of these areas of the channel, as a result of riprap trapezoidal channels being replaced with concrete lined trapezoidal and concrete lined rectangular channels in downstream reaches.

Table 19. Expected Annual Damages by Flood Event, FY 2020 Price Levels ($000) [1]

	0.1 ACE			0.02 ACE			0.01 ACE			0.002 ACE		
Location	Without	Max	Min	Without	Max	Min	Without	Max	Min	Without	Max	Min
C02-C04	0	0	0	104,039	0	0	147,666	0	0	182,567	0	75,558
C02_1	0	0	0	69,711	0	0	82,871	0	0	93,399	0	75,341
C04_1	0	0	0	0	0	0	0	0	0	0	0	0
C04_2	0	0	0	0	0	0	0	0	0	0	0	0
C04_3	0	0	0	0	0	0	0	0	0	0	0	0
C04_4a	0	0	0	3,148	0	0	4,201	0	0	5,044	0	217
C04_4b	0	0	0	31,179	0	0	60,593	0	0	84,124	0	0
C05-06	292,379	0	1,569	638,362	0	13,255	738,778	41	23,459	878,398	406	49,792
C05_1A	0	0	0	0	0	0	0	0	0	15,631	0	0
C05_2A	0	0	0	1,980	0	1,068	2,262	0	1,419	2,488	209	1,699
C05_2B	837	0	408	5,170	0	2,830	6,502	0	5,205	7,567	0	7,105
C05_2C	0	0	0	1,019	0	0	1,622	0	369	2,105	0	1,554
C05_2D	4,240	0	833	10,818	0	4,499	14,499	0	6,895	17,444	0	10,843
C05_3A	0	0	0	10,856	0	3,372	12,991	0	6,248	14,699	0	8,548
C05_3B	281	0	0	1,851	0	985	2,250	0	1,930	2,569	0	2,685
C05_3C	0	0	0	0	0	0	0	0	0	0	0	0
C05_3D	0	0	0	0	0	0	50,975	0	0	100,488	0	0
C05_4A	2,342	0	0	212,763	0	0	239,065	0	0	260,107	0	13,428
C05_4B	0	0	0	0	0	0	0	0	0	30,649	0	0
C05_5	17,808	0	0	25,697	0	0	26,683	0	0	27,473	0	0
C05_6	266,483	0	0	367,648	0	0	380,294	0	0	390,117	0	0
C06_1A	388	0	328	560	0	501	1,634	0	1,394	2,564	0	2,439
C06_1B	0	0	0	0	0	0	0	41	0	4,497	197	1,490
C06_2	0	0	0	0	0	0	0	0	0	0	0	0
Total	292,379	0	1,569	742,401	0	13,255	886,444	41	23,459	1,060,965	406	125,349

The 0.002 ACE, or the 500-year event, is the lowest probability event analyzed, and would cause the highest expected economic damages in the floodplain, while the 0.1 ACE, or 10-year event, is a higher probability event and would result in the lowest expected economic damages for the events displayed above. For the 0.002 annual chance event, estimated without project damages are more than $1.06 billion dollars. This decreases to $406,000 for the Maximum Improvement Plan and $125 million for the Minimum Improvement Plan. For the 0.1 annual chance event, expected damages are $292 million under without project conditions, and are virtually eliminated under Maximum Improvement Plan conditions and total about $1.6 million under Minimum Improvement Plan conditions.

5.3 With-Project Performance

The project performance statistics for Maximum Improvement Plan conditions and Minimum Improvement Plan project conditions are displayed below.

Table 20. With-Project Maximum Improvement Project Performance (%)

		Long-Term Risk[2]			Assurance[3]		
Reach	AEP[1]	10 year	30 year	50 year	2.00%	1.00%	0.20%
Reaches C02-C04							
C02_1	0.02	0.22	0.66	1.10	99.99	99.94	99.82
C04_1	0.01	0.10	0.30	0.50	100.00	100.00	100.00
C04_2	0.01	0.10	0.30	0.50	100.00	100.00	100.00
C04_3	0.01	0.10	0.31	0.52	100.00	100.00	100.00
C04_4a	0.02	0.20	0.61	1.01	100.00	99.97	99.82
C04_4b	0.08	0.81	2.40	3.97	99.98	99.47	98.59
Reaches C05-C06							
C05_1a	0.02	0.24	0.72	1.20	99.97	99.97	99.92
C05_2a	0.50	4.90	14.00	22.23	99.84	98.51	94.53
C05_2b	0.45	4.37	12.54	20.01	99.94	98.47	93.53
C05_2c	0.03	0.27	0.82	1.36	100.00	99.96	99.75
C05_2d	0.04	0.35	1.06	1.76	100.00	99.99	99.62
C05_3a	0.36	3.53	10.23	16.47	99.95	99.30	95.49
C05_3b	0.41	4.06	11.68	18.70	99.93	98.59	94.08
C05_3c	0.10	0.96	2.85	4.70	100.00	99.81	98.82
C05_3d	0.01	0.10	0.31	0.51	100.00	100.00	100.00
C05_4a	0.06	0.61	1.80	2.99	99.99	99.79	99.22
C05_4b	0.02	0.16	0.48	0.80	100.00	99.96	99.90
C05_5	0.02	0.18	0.54	0.89	99.99	99.95	99.88
C05_6	0.01	0.13	0.38	0.64	100.00	99.99	99.96
C06_1a	99.90	100.00	100.00	100.00	0.00	0.00	0.00
C06_1b	1.64	15.27	39.17	56.33	95.84	88.54	77.71
C06_2	0.01	0.10	0.30	0.50	100.00	100.00	99.98

[1]*Probability that flooding will occur in any given year*
[2]*Probability the target stage is exceeded during the period of time listed below*
[3]*Probability that no flooding occurs, given that a flood event of the frequency listed below has occurred*

Table 20 shows that in C05_5, the annual exceedance probability (AEP) decreases from over 60 percent under the without-project condition to less than 1 percent under the with-project condition for the Maximum Improvement Plan. The Maximum Improvement Plan also result in an increase in the probability that no flooding occurs in specific channels, when there is a flood event. For example, in C05_6, the assurance increases from 16 percent under the without project condition to over 99 percent under the Maximum Improvement Plan condition for the 0.01 ACE. The Maximum Improvement Plan measures significantly decrease the probability of flooding in these impact areas.

Table 21. With-Project Minimum Improvement Project Performance (%)

Reach	AEP[1]	Long-Term Risk[2]			Assurance[3]		
		10 year	30 year	50 year	2.00%	1.00%	0.20%
Reaches C02-C04							
C02_1	0.94	8.97	24.58	37.51	89.24	87.72	87.23
C04_1	0.01	0.10	0.30	0.50	99.00	99.00	99.00
C04_2	0.01	0.10	0.30	0.50	99.00	99.00	99.00
C04_3	0.01	0.11	0.33	0.55	99.00	99.00	99.00
C04_4a	0.41	4.05	11.68	18.69	96.33	91.98	81.89
C04_4b	0.05	0.52	1.55	2.56	99.39	98.58	96.55
Reaches C05-C06							
C05_1a	0.03	0.32	0.95	1.57	99.00	99.00	99.00
C05_2a	5.05	40.45	78.89	92.51	74.44	72.87	69.59
C05_2b	10.62	67.47	99.00	99.00	18.74	15.34	7.18
C05_2c	1.39	13.06	34.29	50.34	81.57	74.93	56.01
C05_2d	14.01	77.89	98.92	99.00	2.20	1.45	0.14
C05_3a	3.08	26.86	60.88	79.07	82.92	81.79	79.33
C05_3b	8.80	60.18	99.00	99.00	28.40	23.18	11.79
C05_3c	0.01	0.10	0.31	0.51	99.00	99.00	99.00
C05_3d	0.02	0.17	0.52	0.87	99.00	99.00	99.75
C05_4a	0.23	2.27	6.67	10.86	99.00	99.00	99.00
C05_4b	0.01	0.10	0.30	0.50	99.00	99.00	99.00
C05_5	0.01	0.10	99.00	99.00	99.99	99.99	99.98
C05_6	0.01	0.10	0.30	99.00	99.99	99.99	99.98
C06_1a	99.00	99.00	99.00	99.00	0.01	0.01	0.01
C06_1b	0.29	2.87	8.35	13.53	99.00	99.00	91.50
C06_2	0.01	0.11	0.32	0.53	99.00	99.00	99.00

[1]*Probability that flooding will occur in any given year*
[2]*Probability the target stage is exceeded during the period of time listed below*
[3]*Probability that no flooding occurs, given that a flood event of the frequency listed below has occurred*

Table 21 displays project performance under Minimum Improvement Plan conditions. In C02_1, the probability that flooding will occur in any given year decreases from about 6 percent under the without-project condition to less than 1 percent under the Minimum Improvement Plan. The probability no flooding will occur given that a 0.002 annual chance event occurs increases from 44 percent under the without-project condition to over 87 percent with the Minimum Improvement Plan for C02_1. The two tables above show that Maximum Improvement Plan provides a higher level of risk reduction to some areas, particularly C02_1, C05_2b and C05_2d, than Minimum Improvement Plan. One EIA that still shows a high probability of channel exceedance under both the Minimum and Maximum Improvement Plans is C06_1a. This portion of the C06 channel is unimproved in the both the existing condition and for both the Minimum and Maximum Improvement Plans, and the flooding in this area is relatively minor.

6. Costs

Costs for Minimum and Maximum Improvement Plan measures are used to calculate net benefits and the benefit-cost ratio, in order to formulate the NED plan. Project first costs include construction costs by reach, environmental mitigation costs, contingency costs, preconstruction engineering and design (PED) and supervision and administration (S&A) costs, and lands, easements, rights of way and relocations (LERRDs), which includes real estate costs and costs for replacing bridges and crossings in the project area. Table 22 shows project first costs by channel for Minimum and Maximum Improvement Plan measures.

Table 22. Project First Costs by Plan, FY 2020 Price Levels ($000)

Project Component	Plan: Minimum Improvement	Plan: Maximum Improvement	% of Construction Cost by Component - Min Plan	% of Construction Cost by Component - Max Plan
C02-C04	83,992	445,741	17%	36%
Reach C02	37,582	99,314	8%	8%
Reach C04	46,409	346,427	10%	28%
C05-C06	348,767	726,107	72%	59%
Reach C05	328,879	595,606	68%	49%
Reach C06	19,888	130,501	4%	11%
Non Reach-Specific	51,097	52,749	11%	4%
Widen Warner Ave	36,888	36,888	8%	3%
Remove Tide Gates	3,791	3,791	1%	0%
Mitigation	7,813	7,813	2%	1%
Real Estate	2,605	4,257	1%	0%
Total First Costs[1]	483,856	1,224,598	100%	100%

[1] *Construction costs include bridge replacement costs by reach; annual O&M costs not included*

Table 22 shows that channels C05 and C06 together comprise the majority of first costs for the Maximum and Minimum Plans. The total first cost for Minimum Improvement Plan is about $484 million, and the total first cost for Maximum Improvement Plan is more than $1.225 billion.

Table 23 shows total annual costs, including annualized investment cost and OMRR&R costs, for the Minimum and Maximum Improvement Plans under the current federal 2.75 percent discount rate.

Table 23. Alternative Plan Average Annual Costs in FY 2020 Price Levels ($000)

Cost Category	Plan: Minimum Plan, 2.75%	Plan: Maximum Plan, 2.75%
Construction Costs[1]	414,590	860,532
LERRDs	69,266	364,065
Total First Costs	483,856	1,224,598
Interest During Construction	169,181	343,293
Gross Investment	653,037	1,567,891
Interest and Amortization	24,189	58,076
OMRR&R	-70	135
Total Annual Costs[2]	24,119	58,211

[1] Includes PED, S&A, and contingency costs

[2] Negative OMRR&R costs represents a reduction in such costs relative to without project conditions.

In Table 23, gross investment costs include the project first cost and interest during construction (for details on cost inputs, refer to Appendix C). Annual costs are computed by amortizing first costs over the 50-year period of analysis, using an interest rate of 2.75 percent, and then adding annual operation, maintenance, repair, rehabilitation, and replacement (OMRR&R) costs. IDC was calculated for LERRDs and Construction Costs by calculating the future value of the stream of first cost payments, calculated at an annual discount rate of 2.75 percent for the period of construction corresponding to the construction increment (see construction schedule in Section 7), and subtracting first costs. OMRR&R costs represent the net increase or decrease in such costs accounting for the OMRR&R requirements with the channel improvements relative to current conditions. There are some reaches where there is anticipated to be a reduction in channel OMRR&R requirements and costs, which is why the net OMRR&R costs for the

Minimum Improvement Plan are slightly negative. The overall impacts on OMRR&R with either the Minimum or Maximum Improvement Plan are expected to be negligible.

The table shows that total first costs are about $484 million for the Minimum Improvement Plan, and exceed $1.225 billion for the Maximum Improvement Plan. Accordingly, interest during construction is significantly higher for the Maximum Improvement Plan. Average annual costs including OMRR&R for the Minimum Improvement Plan are over $24 million, and over $58 million for the Maximum Improvement Plan.

7. Benefit-Cost Analysis

7.1 Benefit-Cost for Minimum and Maximum Improvement Plans

An incremental construction schedule to compute net benefits and the benefit-cost ratio for the Minimum and Maximum Improvement Plans. The following figure displays the construction schedule, by increment.

Table 24. Construction Increment Table

Construction Increment	Construction Duration	Construction Start	Construction End
Inc 1	4	2021	2024
Inc 2	3	2025	2027
Inc 3	3	2028	2030
Inc 4	3	2031	2033
Inc 5	2	2034	2035
Total	15	2021	2035

Under the construction schedule, different portions for each of these channels are completed at different times under the Minimum and Maximum Improvement plans.

For each construction increment, benefits and construction costs realized before the base year of 2035 were compounded to the base year, accounting for "pre-project" benefits. Interest during construction was calculated for the duration of the construction period of each increment. For the Minimum Improvement Plan, most of the project is assumed to be completed within the first increment (roughly $383 million, or 79%), with most of the remaining features completed within the second increment (roughly $77 million, or 16%). The remainder of the Minimum Improvement Plan would be completed in the third increment. For the Maximum Improvement Plan, roughly 40% (or about $494 million) of the project would be completed in the first increment, about 32% (or roughly $395 million) in the second increment, and about 19% (or about $239 million) in the third increment, with the remainder completed in the last increments. Note that these are planning level schedule assumptions that could vary substantially during project implementation.

Annual benefits and OMRR&R costs for a 50-year period were discounted back to the base year. The sum of these benefits and costs is shown in Table 25. Benefits for each construction increment are calculated for the year immediately preceding the last year of construction since the majority of benefits will be realized incrementally, prior to the entire project being completed.

Using these construction schedules, the costs and benefits for the Minimum and Maximum Improvement Plans were analyzed. Costs and benefits are shown in Table 25 at 2.75 percent, taking into account the incremental construction schedule displayed in Table 24.

Table 25. Benefit-Cost Analysis, FY 2020 Price Level, 2.75% ($000)

	Minimum Plan	Maximum Plan
Average Annual Costs	$24,119	$58,211
Annual Benefits	$101,743	$116,255
Net Annual Benefits	$77,624	$58,044
Benefit to Cost Ratio	4.2	2.0

Note: Cost and benefits are displayed in FY2020 price levels and discounted at 2.75% over a 50 year period of analysis, with a base year of 2035

At the 2.75 percent discount rate, equivalent annual benefits and costs for the Minimum Improvement plan are $102 million and $24 million, respectively, and the equivalent annual benefits and costs for the Maximum Improvement Plan are $116 million and $58 million, respectively. The Minimum Improvement Plan has annual net benefits of $78 million, and the Maximum Improvement Plan has annual net benefits of $58 million. These values include benefits compounded to the base year, and interest during construction. The Minimum Improvement Plan has a BCR of 4.2 and the Maximum Improvement Plan has a BCR of 2.0 at the 2.75 percent rate. Both plans are economically justified, and the Minimum Improvement Plan maximizes net benefits.

7.2 Probability of Economic Justification

The following table shows the probabilities that expected annual benefits will exceed the given values for the 25th, 50th and 75 percentiles. The table also shows average annual costs to indicate whether the Minimum and Maximum Improvement Plans would be economically justified given the estimated benefits for each of these percentiles.

Table 26. Probabilistic Results – EAD Reduced and Economic Justification, 2.75% ($000)

	Equivalent Annual	Prob EAD Reduced Exceeds Value		
MINIMUM IMPROVEMENT PLAN	**Value**	**75%**	**50%**	**25%**
Struct/Cont & Other Benefits	$97,230	$7,558	$40,280	$133,018
FIA Benefits	$97,230	$7,558	$40,280	$133,018
Advanced Bridge Replacement Benefits	$3,506	$3,506	$3,506	$3,506
Total EAD Reduced	$101,743	$12,071	$44,793	$137,531
Average Annual Costs	$24,119	$24,119	$24,119	$24,119
Net Benefits	$77,624	-$12,048	$20,674	$113,412
BCR	4.2	0.5	1.9	5.7
MAXIMUM IMPROVEMENT PLAN				
Struct/Cont & Other Benefits	$99,166	$7,860	$40,923	$134,146
FIA Benefits	$1,225	$1,225	$1,225	$1,225
Advanced Bridge Replacement Benefits	$15,864	$15,864	$15,864	$15,864
Total EAD Reduced	$116,255	$24,949	$58,012	$151,235
Average Annual Costs	$58,211	$58,211	$58,211	$58,211
Net Benefits	$58,044	-$33,262	-$199	$93,024
BCR	2.0	0.4	1.0	2.6

Table 26 shows that there is between a 50% and 75% probability that the Minimum Improvement Plan is economically justified. For the Maximum Improvement Plan, the probability that the plan is economically justified is approximately 50%.

7.3 National Economic Development Plan Identification

In order to identify the National Economic Development (NED) Plan, the benefits and costs for the C02/C04 channel system were analyzed separately from those for the C05/C06 system since these two systems are considered to be separable elements. An evaluation was conducted of the benefits and costs for both the Minimum Improvement Plan and Maximum Improvement Plan features for each system to identify which plan maximizes net NED benefits. The following table shows the results of the benefit/cost analysis for the two channel systems.

Table 27. Benefit/Cost Analysis by Channel System ($1,000s)

MIN Plan @ 2.75%	C02/C04	C05/C06	Total
Total First Cost	$83,992	$399,864	$483,856
Avg. Annual Cost	$3,875	$20,244	$24,119
Avg. Annual Benefits	$4,307	$97,437	$101,743
Net Benefits	$432	$77,192	$77,624
BCR	1.11	4.81	4.22
MAX Plan @ 2.75%	**C02/C04**	**C05/C06**	**Total**
Total First Cost	$445,741	$778,856	$1,224,598
Avg. Annual Cost	$20,786	$37,425	$58,211
Avg. Annual Benefits	$8,974	$107,281	$116,255
Net Benefits	-$11,812	$69,856	$58,044
BCR	0.43	2.87	2.00

As shown in the above table, improvements on both the C02/C04 system and C05/C06 system are economically justified under the Minimum Improvement Plan. For the Maximum Improvement Plan, improvements are economically justified for the C05/C06 system, but not the C02/C04 system. Further, the net benefits are higher for both the C02/C04 and C05/C06 systems under the Minimum Improvement Plan than the Maximum Improvement Plan. Therefore, the NED Plan is comprised of the Minimum Improvement Plan features for both systems.

Although the C02/C04 system under the Maximum Improvement Plan is not economically justified, the overall plan that includes features for both systems is economically justified.

7.4 Reduction in Life Loss

The following tables show the expected reduction in life loss for the Minimum and Maximum Improvement Plans.

Table 28. Aggregate Life Loss 0.01 ACE

	Life Loss Day Under 65			Life Loss Day Over 65			Life Loss Night Under 65			Life Loss Night Over 65		
Channel	Without	Max	Min	Without	Max	Min	Without	Max	Min	Without	Max	Min
C02/04	31	0	1	3	0	0	7	0	2	1	0	0
C05/06	214	0	22	60	0	6	393	0	35	68	0	6
Total	245	0	23	63	0	6	400	0	37	69	0	6

Note: Without denotes existing project conditions, and Max and Min represent Maximum and Minimum channel improvements.

Figures shown represent number of individuals at risk.

Table 29. Aggregate Life Loss 0.002 ACE

	Life Loss Day Under 65			Life Loss Day Over 65			Life Loss Night Under 65			Life Loss Night Over 65		
Channel	Without	Max	Min	Without	Max	Min	Without	Max	Min	Without	Max	Min
C02/04	101	0	2	22	0	0	153	0	0	24	0	0
C05/06	320	0	66	92	0	15	548	0	109	103	0	20
Total	421	0	68	114	0	15	701	0	109	127	0	20

Note: Without denotes existing project conditions, and Max and Min represent Maximum and Minimum channel improvements.

Figures shown represent number of individuals at risk.

Table 28 shows that for the .01 ACE, nighttime life loss for individuals under the age of 65 decreases from 400 under the without project condition to 37 under the Minimum Improvement Plan, and is near zero under Maximum Improvement Plan. Corresponding nighttime life loss for individuals over the age of 65 decreases from 69 under the without project condition to 6 under the Minimum Improvement Plan and is near zero under the Maximum Improvement Plan.

Similarly, life loss figures displayed in Table 29 for the .002 ACE show that nighttime life loss for individuals under 65 years of age is 701 for the without project condition, which decreases to 109 under the Minimum Improvement Plan, and is near zero under Maximum Improvement Plan. Corresponding nighttime life loss for individuals over the age of 65 decreases from 127 under without project conditions to 20 under the Minimum Improvement Plan, and is near zero under the Maximum Improvement Plan.

As noted in Section 3.9, these life loss results are very sensitive to warning time assumptions, and both without project and with project life loss would be minimal if the assumed warning time were increased to one hour or more. It is therefore possible these results may overstate actual life loss for these scenarios.

8. Recommended Plan

The non-Federal Sponsor has identified the Maximum Improvement Plan as the Locally Preferred Plan (LPP). The Recommended Plan is the Locally Preferred Plan.

8.1 Summary of NED Benefits & Costs

The equivalent annual benefits and costs for the LPP total approximately $116 million and $58 million respectively. The net benefits for the LPP total approximately $58 million, and the benefit/cost ratio is estimated at 2.0.

Table 30. Recommended Plan - Benefit/Cost Summary

Recommended Plan Benefit/Cost Summary	
Construction Cost	$852,719
Environmental Mitigation	$7,813
LERRD	$364,065
Total First Cost	$1,224,598
IDC	$343,293
Investment Cost	$1,567,891
Annualized Investment Cost	$58,076
OMRR&R	$135
Total Annual Cost	$58,211
Equivalent Annual Benefits	$116,255
Net Benefits	$58,044
Benefit/Cost Ratio	2.00

8.2 Summary of Other Social Effects for Recommended Plan (LPP)

The Recommended Plan is anticipated to have positive other social effects (OSE) related benefits, most significantly related to life and safety. The plan would reduce the probability and severity of flooding within the floodplain, thereby reducing life, safety and health risks to floodplain residents and those traveling through the floodplain.

The expected annual life loss for the .01 and .002 ACE events under without project conditions were projected to be as high as 469 and 828, respectively (under a nighttime flooding scenario). Under the Recommended Plan, the probability of life loss is anticipated to be nearly eliminated. Additional other social effects include reduction in health and safety-related impacts caused by floodwaters, avoidance of emotional and psychological impacts of flood-related losses, and disruption to daily life, including education and work activities, that occur as the result of a flood.

8.3 Regional Economic Development Benefits for Recommended Plan (LPP)

8.3.1 Purpose

The regional economic development (RED) account registers changes in the distribution of regional economic activity that result from each alternative plan. Evaluations of regional effects are to be carried out using nationally consistent projections of income, employment, output and population. The RED account displays information not analyzed in other accounts in the feasibility report that could have a material bearing on the decision-making process.

The RED account is born out of the difference in perspectives between the Federal government and local communities directly impacted by water resource planning. The Federal objective in water resource planning is contributing to national economic development and the Federal perspective is the nation as a whole. Local communities and regions directly impacted by water resource planning may consider impacts at the state, regional, or local level a more relevant measure. From the Federal perspective transferring employment opportunities and resources from one region of the nation to another to construct a water resource project does not in itself constitute national economic development and therefore regional economic impacts may not be fully captured in the NED account. However, from a regional or local perspective the transfer of employment opportunities and resources to construct a project in that region, as opposed to some other region of the United States, can be a significant benefit to the local economy in terms of supporting local employment, labor income and revenues. This is why the different perspectives between the Federal government and local communities impacted by water resource projects are addressed in different accounts. The Federal perspective is addressed principally in the NED account while the regional or local perspective is addressed principally in the RED account.

8.3.2 Process

To perform an economic analysis from the regional perspective (RED account), several impacts from constructing, operating and maintaining the water resource project are analyzed. Economic impacts are the estimated change in economic activity (output, labor income, value added, and employment) associated with the new or already occurring economic stimulus to an economy. Impacts are evaluated for a particular geographic location (impact area) in which the economic stimulus (spending) occurs. These impacts are termed direct, indirect, and induced effects.

i) Direct effects represent that proportion of the project expenditure in each industry that flows to material and service providers within the project's impact area (county or multi-county region). Direct effects are immediate effects associated with the change in total sales for a particular industry. Direct effects for employment and labor income represent the jobs and labor income associated with directly stimulated industry or activity.

ii) Indirect Effects are changes in inter-industry purchases in response to new demand from the directly affected industries. In other words the supply of materials and services to meet the needs of the directly affected industries.

iii) Induced effect occurs from household expenditures or consumer spending associated with workers' earnings from both direct and indirect labor income. This includes increased spending on local goods and services such as restaurants, grocery stores, hotels, and gas stations due to the direct and indirect effects of the project.

An example of the economic impacts from spending to construct a project is shown in Figure 6. First the direct effects from hiring a construction firm to complete the project are experienced, then that firm purchases supplies and services from other firms to complete the project causing indirect effects. Finally, both direct and indirect effects contribute to induced spending at local retailers, restaurants, convenience stores, etc. This leads local retailers, restaurants, convenience stores, and so on to purchase more goods and services and perhaps hire additional workers. At the same time all this cycling of dollars also leads to increased tax revenue. This cycle continues until the additional dollars are no longer in circulation in the regional economy due to leakages. Leakages occur when goods and services with value added outside of the region are purchased (e.g. purchased clothing that was manufactured in Asia or consulting services from a firm located and engaged in business activity primarily outside the region). The graphic below illustrates the concepts of direct, indirect, and induced effects

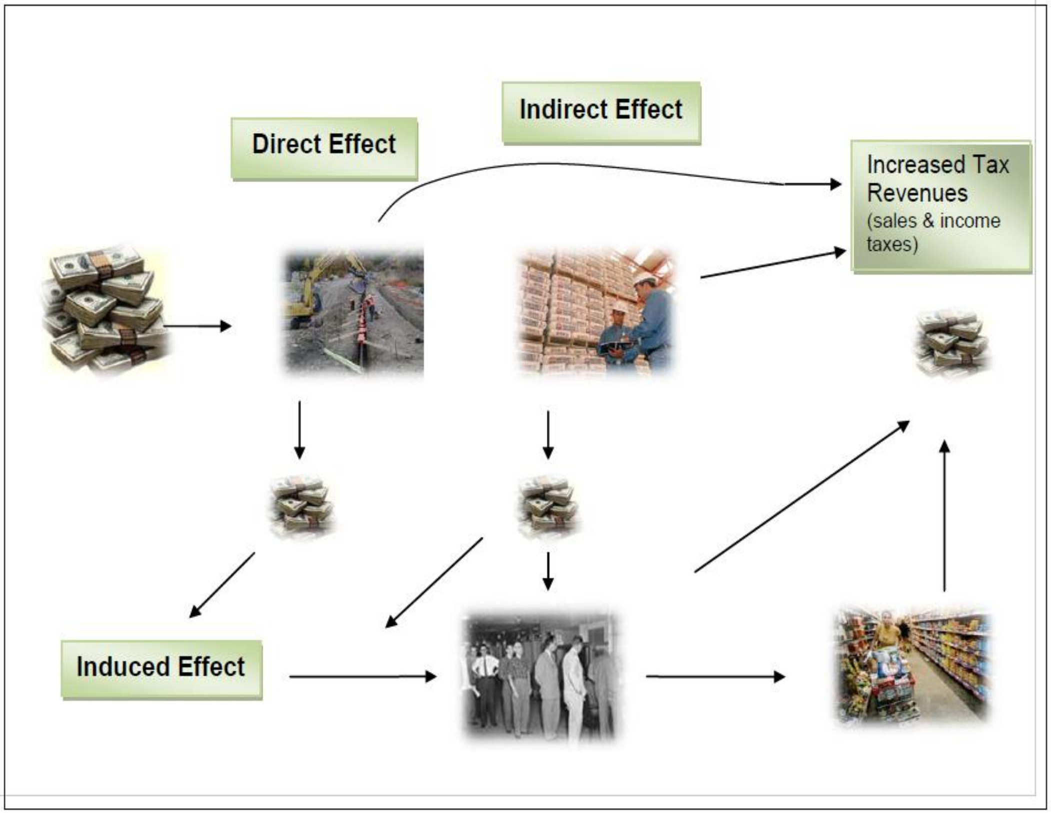

Figure 6. Regional Economic Development Impacts Diagram

The direct, indirect, and induced effects are estimated through multipliers, which can be thought of, figuratively, as money multiplying throughout the regional economy. A portion of the money spent on construction equipment and labor (direct effect) is re-spent on construction supplies (indirect effect) and a portion of the money from both is re-spent on local restaurants and gas stations (induced effect). Economists have used regression analysis on historical spending data to estimate how much spending and re-spending varies when there is an economic stimulus to the region through various construction projects. This produces the "multipliers" that are applied to the initial construction spending (i.e. cost of constructing the project) to estimate the direct, indirect, and induced effects of the project studied in this feasibility report.

8.3.3 RED Analysis and Results

The RECONS (Regional ECONomic System) model was used to estimate the direct, indirect, and induced effects of the Recommended Plan based on project first cost estimates. This model was developed by USACE and certified (reviewed and approved for Agency-wide use) to provide estimates of regional and national job creation, and retention and other economic measures such as income, value added, and sales. This model generates regional construction multipliers based on the USACE business lines (navigation, flood mitigation, water storage & supply, etc.). Each business line is subdivided into numerous work activities, which improves the accuracy of the estimates for regional and national job creation, and retention and other economic measures such as income, value added, and sales. For the RED analysis for project expenditures, the business line selected was Flood Risk Management and the work activity selected was Construction of Earthen and Concrete Channels and Canals. Table 28 shows that the total first cost of the Recommended Plan is approximately $1.225 billion.

RED analysis results for the impact of project expenditures are presented for the region, state, and nation. The region (local impact area) consists of the southern California region of the Los Angeles, Long Beach & Anaheim Metropolitan Statistical Area. This means regional impacts that have been measured accrue within the metropolitan region but not specifically in the Study Area. The state-level impacts are for California and the national impacts are for the contiguous United States.

Direct impacts (effects) to employment and income are due to the demand for goods and services. These contribute to additional output, additional demand for jobs, and increased value-added to goods and services within region, the state of California, and the nation. The direct impacts from construction expenditures for the Recommended Plan are expected to support about 3,800 full-time equivalent (FTE) jobs over the period of construction within the region. The project is projected to support an additional 3,200 FTE jobs during construction through the indirect and induced effects that support or compliment that construction effort, for a total of about 7,000 FTE jobs. The regional capture rate, which is the region's direct output as a share of total spending, is high, as reflected in the regional outputs relative to the national outputs. This is logical since much of the labor, equipment and materials comes from within the region.

Overall, construction of the Recommended Plan is projected to lead to about $767 million in gross regional product (GRP) and support about 7,000 additional FTE jobs within the region during construction. The impact to the state would be of a somewhat greater magnitude. Approximately $970 million in GRP and about 8,600 FTE jobs would be supported state-wide over the period of construction.

Table 31. Recommended Plan – Regional Economic Development Summary

Impacts		Regional	State	National
Total Spending ($000)		$1,224,598	$1,224,598	$1,224,598
Direct Impact				
	Output ($000)	$1,017,781	$1,172,089	$1,200,114
	Jobs	3,800	4,400	4,700
	Labor Income ($000)	$310,905	$362,186	$376,069
	GRP ($000)	$435,105	$522,359	$539,373
Total Impact				
	Output ($000)	$1,575,836	$1,949,692	$2,603,802
	Jobs	7,000	8,600	11,900
	Labor Income ($000)	$508,202	$629,733	$810,150
	GRP ($000)	$767,172	$970,098	$1,279,930

The projected construction schedule shows that about 40% of project construction should occur within the first 4-year increment, with about another 32% occurring over the subsequent 3-year period. This indicates that during the first four years, the average annual impact within the region would include approximately $77 million in GRP and 700 FTE jobs. During the subsequent 3-year period, the average annual impact within the region would include approximately $83 million in GRP and about 749 FTE jobs.

9. Conclusion

The purpose of the economic evaluation is to evaluate flood risk within the Westminster Watershed. Under the without project condition, it is estimated that nearly 400,000 people and 44,000 structures are at risk of inundation. It is estimated that average annual damages would nearly $72 million, including structure and structure content, vehicle, emergency and cleanup damages.

This study assessed Minimum and Maximum channel improvement plans in the study area and determined that the Minimum Improvement Plan had greater net benefits. The study also assessed the separable benefits and costs for the Minimum and Maximum Improvement Plans for the C02/C04 and C05/C06 systems. This analysis showed that the Minimum Improvement Plan maximized net benefits throughout both systems and has been identified as the NED Plan. The non-Federal Sponsor has identified the Maximum Improvement Plan features in both systems as the Locally Preferred Plan. The NED Plan has an estimated $102 million in average annual benefits and the LPP would result in average annual benefits of $116 million.

The study finds that at the 2.75 percent discount rate, the NED plan has annual net benefits of $78 million and a BCR of 4.2, and the Recommended Plan (LPP) has annual net benefits of $58 million, and a BCR of 2.0. The LPP does not maximize annual net benefits, but is economically justified.

The Recommended Plan would also provide life and safety benefits, especially for low probability flood events. Additional other social effects benefits include reduction in health and safety-related impacts caused by floodwaters, avoidance of emotional and psychological impacts of flood-related losses, and disruption to daily life, including education and work activities, that occur as the result of a flood.

With an estimated project cost of $1.225 billion, the Recommended Plan will generate significant RED benefits to the Los Angeles/Orange County, California region. These benefits include supporting nearly 7,000 full time equivalent jobs over the construction period, as well as generating over $767 million in gross regional product.

10.Addendum A - Additional Tables

Table A1. Content to Structure Value Ratios by Use

The table below shows the mean content/structure value ratios used to estimate content values for non-residential structures for this study. The coefficient of variation values were also applied in the HEC-FDA model to account for uncertainty in the CSVRs. The Use Categories are identified with an initial letter designating Commercial (C), Industrial (I) and Public (P). For purposes of estimating the value of property at risk, residential structures were assumed to have a CSVR of 50%. However, for single and multi/family residential structures, content values were imported into HEC-FDA at a CSVR of 100% as required to use the IWR Depth Damage functions which calculate content damages as a percent of structure value.

Use Category	Content to Structure Ratio					
	n	Mean	Standard Deviation	Coefficient of Variation	Min	Max
Commercial						
C-AUTO1	21	62%	0.07	12%	0.52	0.79
C-DEAL1	29	69%	0.15	22%	0.47	1.22
C-FOOD1	320	42%	0.07	16%	0.25	0.61
C-FOOD2	20	43%	0.06	14%	0.24	0.53
C-FURN1	20	55%	0.14	26%	0.32	0.87
C-FURN2	1	36%	-	-	0.36	0.36
C-GROC1	33	106%	0.18	16%	0.78	1.53
C-HOS1	1	92%	-	-	0.92	0.92
C-HOS2	23	87%	0.37	42%	0.53	1.94
C-HOTEL2	15	69%	0.13	19%	0.53	0.95
C-MED1	242	148%	0.25	17%	0.84	2.03
C-MED2	85	121%	0.30	24%	0.74	2.03
C-OFF1	825	34%	0.09	27%	0.17	0.80
C-OFF2	772	28%	0.09	31%	0.13	0.63
C-REST1	393	134%	0.35	26%	0.00	2.83
C-REST2	93	118%	0.29	25%	0.00	1.92
C-RESTFF1	136	42%	0.08	20%	0.28	0.76
C-RET1	1374	51%	0.13	25%	0.00	1.30
C-RET2	225	47%	0.13	27%	0.13	1.04
C-SERV1	593	193%	0.46	24%	0.00	4.71
C-SERV2	10	193%	0.29	15%	1.53	2.52
C-SHOP1	63	67%	0.11	17%	0.54	1.00
C-SHOP2	17	54%	0.01	3%	0.51	0.57
Industrial						
I-HV1	95	31%	0.09	30%	0.16	0.69
I-HV2	22	20%	0.04	22%	0.14	0.31
I-LT1	568	188%	0.55	29%	0.91	4.09
I-LT2	70	126%	0.47	37%	0.00	2.61
I-WH1	1168	89%	0.25	28%	0.00	2.36
I-WH2	34	85%	0.27	31%	0.04	1.29
Public						
P-CH1	356	20%	0.05	23%	0.08	0.39
P-CH2	99	17%	0.05	28%	0.10	0.32
P-GOV1	161	35%	0.08	24%	0.22	0.60
P-GOV2	162	26%	0.07	28%	0.14	0.60
P-REC1	149	132%	3.56	269%	0.36	2.56
P-REC2	48	58%	0.15	26%	0.31	0.91
P-SCH1	267	38%	0.11	29%	0.00	1.75
P-SCH2	52	32%	0.09	29%	0.00	0.52

Table A2. Depth/Damage Functions

Category	Occupancy	Struct/Cont	Depth										
			-8	-1	0	1	2	3	4	6	8	12	15
Commercial	C-AUTO1	S	0	0.0	7.0	16.3	24.7	27.7	29.6	39.8	43.3	47.3	49.9
Commercial	C-AUTO1	C	0	0.0	0.0	34.9	78.4	90.4	100.0	100.0	100.0	100.0	100.0
Commercial	C-RET1	S	0	0.0	7.0	16.3	24.7	27.7	29.6	39.8	43.3	47.3	49.9
Commercial	C-RET1	C	0	0.0	0.0	22.8	49.5	64.7	90.2	100.0	100.0	100.0	100.0
Commercial	C-RET2	S	0	0.0	2.5	5.0	10.1	15.3	17.1	21.5	22.8	43.3	49.1
Commercial	C-RET2	C	0	0.0	0.0	19.1	31.5	35.7	45.1	50.0	50.0	72.3	100.0
Commercial	C-DEAL1	S	0	0.0	7.0	16.3	24.7	27.7	29.6	39.8	43.3	47.3	49.9
Commercial	C-DEAL1	C	0	5.3	5.8	25.3	52.1	72.0	96.2	100.0	100.0	100.0	100.0
Commercial	C-GROC1	S	0	0.0	7.0	16.3	24.7	27.7	29.6	39.8	43.3	47.3	49.9
Commercial	C-GROC1	C	0	0.0	0.0	32.0	69.8	88.6	100.0	100.0	100.0	100.0	100.0
Commercial	C-HOS1	S	0	0.0	7.0	16.3	24.7	27.7	29.6	39.8	43.3	47.3	49.9
Commercial	C-HOS1	C	0	0.0	0.0	33.5	72.8	88.7	100.0	100.0	100.0	100.0	100.0
Commercial	C-HOS2	S	0	0.0	2.5	5.0	10.1	15.3	17.1	21.5	22.8	43.3	49.1
Commercial	C-HOS2	C	0	0.0	0.0	28.1	46.3	48.9	50.0	50.0	50.0	72.3	100.0
Commercial	C-HOTEL2	S	0	0.0	2.5	5.0	10.1	15.3	17.1	21.5	22.8	43.3	49.1
Commercial	C-HOTEL2	C	0	0.0	0.0	24.8	49.1	49.8	50.0	50.0	50.0	72.3	100.0
Commercial	C-FOOD1	S	0	0.0	7.0	16.3	24.7	27.7	29.6	39.8	43.3	47.3	49.9
Commercial	C-FOOD1	C	0	0.0	0.0	29.3	72.2	96.2	100.0	100.0	100.0	100.0	100.0
Commercial	C-FOOD2	S	0	0.0	2.5	5.0	10.1	15.3	17.1	21.5	22.8	43.3	49.1
Commercial	C-FOOD2	C	0	0.0	0.0	24.6	45.8	49.8	50.0	50.0	50.0	72.3	100.0
Commercial	C-RESTFF1	S	0	0.0	7.0	16.3	24.7	27.7	29.6	39.8	43.3	47.3	49.9
Commercial	C-RESTFF1	C	0	0.0	0.0	23.3	59.4	90.2	100.0	100.0	100.0	100.0	100.0
Commercial	C-RESTFF2	S	0	0.0	2.5	5.0	10.1	15.3	17.1	21.5	22.8	43.3	49.1
Commercial	C-RESTFF2	C	0	0.0	0.0	19.6	37.7	49.7	50.0	50.0	50.0	72.3	100.0
Commercial	C-MED1	S	0	0.0	7.0	16.3	24.7	27.7	29.6	39.8	43.3	47.3	49.9
Commercial	C-MED1	C	0	0.0	0.0	33.5	72.8	88.7	100.0	100.0	100.0	100.0	100.0
Commercial	C-MED2	S	0	0.0	2.5	5.0	10.1	15.3	17.1	21.5	22.8	43.3	49.1
Commercial	C-MED2	C	0	0.0	0.0	28.1	46.3	48.9	50.0	50.0	50.0	72.3	100.0
Commercial	C-OFF1	S	0	0.0	7.0	16.3	24.7	27.7	29.6	39.8	43.3	47.3	49.9
Commercial	C-OFF1	C	0	0.0	0.0	34.9	78.4	90.4	100.0	100.0	100.0	100.0	100.0
Commercial	C-OFF2	S	0	0.0	2.5	5.0	10.1	15.3	17.1	21.5	22.8	43.3	49.1
Commercial	C-OFF2	C	0	0.0	0.0	29.3	49.8	49.8	50.0	50.0	50.0	72.3	100.0
Commercial	C-SHOP1	S	0	0.0	7.0	16.3	24.7	27.7	29.6	39.8	43.3	47.3	49.9
Commercial	C-SHOP1	C	0	0.0	0.0	32.8	58.5	71.9	97.2	100.0	100.0	100.0	100.0
Commercial	C-SHOP2	S	0	0.0	2.5	5.0	10.1	15.3	17.1	21.5	22.8	43.3	49.1
Commercial	C-SHOP2	C	0	0.0	0.0	27.5	37.2	39.6	48.6	50.0	50.0	72.3	100.0
Commercial	C-REST1	S	0	0.0	7.0	16.3	24.7	27.7	29.6	39.8	43.3	47.3	49.9
Commercial	C-REST1	C	0	0.0	0.0	29.6	77.3	96.1	100.0	100.0	100.0	100.0	100.0
Commercial	C-REST2	S	0	0.0	2.5	5.0	10.1	15.3	17.1	21.5	22.8	43.3	49.1
Commercial	C-REST2	C	0	0.0	0.0	24.8	49.1	49.8	50.0	50.0	50.0	72.3	100.0
Commercial	C-SERV1	S	0	0.0	7.0	16.3	24.7	27.7	29.6	39.8	43.3	47.3	49.9
Commercial	C-SERV1	C	0	9.1	9.9	23.2	42.8	67.4	100.0	100.0	100.0	100.0	100.0
Commercial	C-SERV2	S	0	0.0	2.5	5.0	10.1	15.3	17.1	21.5	22.8	43.3	49.1
Commercial	C-SERV2	C	0	7.6	8.3	19.5	27.2	37.1	50.0	50.0	50.0	72.3	100.0

Table A2 Cont. Depth/Damage Functions

Category	Occupancy	Struct/Cont	Depth										
			-8	-1	0	1	2	3	4	6	8	12	15
Industrial	I-LT1	S	0	0.0	7.0	16.3	24.7	27.7	29.6	39.8	43.3	47.3	49.9
Industrial	I-LT1	C	0	0.0	0.0	35.2	64.2	74.8	91.8	100.0	100.0	100.0	100.0
Industrial	I-LT2	S	0	0.0	2.5	5.0	10.1	15.3	17.1	21.5	22.8	43.3	49.1
Industrial	I-LT2	C	0	0.0	0.0	29.6	40.8	41.2	45.9	50.0	50.0	72.3	100.0
Industrial	I-HV1	S	0	0.0	7.0	16.3	24.7	27.7	29.6	39.8	43.3	47.3	49.9
Industrial	I-HV1	C	0	0.0	0.0	16.1	41.0	56.4	85.4	97.1	98.1	100.0	100.0
Industrial	I-WH1	S	0	0.0	7.0	16.3	24.7	27.7	29.6	39.8	43.3	47.3	49.9
Industrial	I-WH1	C	0	0.0	0.0	23.4	54.9	69.0	84.2	100.0	100.0	100.0	100.0
Industrial	I-WH2	S	0	0.0	2.5	5.0	10.1	15.3	17.1	21.5	22.8	43.3	49.1
Industrial	I-WH2	C	0	0.0	0.0	19.6	34.8	38.0	42.1	50.0	50.0	72.3	100.0
Public	P-CH1	S	0	0.0	7.0	16.3	24.7	27.7	29.6	39.8	43.3	47.3	49.9
Public	P-CH1	C	0	0.0	0.0	32.9	74.8	85.5	98.8	98.8	98.8	99.3	100.0
Public	P-CH2	S	0	0.0	2.5	5.0	10.1	15.3	17.1	21.5	22.8	43.3	49.1
Public	P-CH2	C	0	0.0	0.0	27.6	47.1	47.1	49.4	49.4	50.0	72.3	100.0
Public	P-REC1	S	0	0.0	7.0	16.3	24.7	27.7	29.6	39.8	43.3	47.3	49.9
Public	P-REC1	C	0	0.0	0.0	37.8	74.6	94.7	98.0	100.0	100.0	100.0	100.0
Public	P-REC2	S	0	0.0	2.5	5.0	10.1	15.3	17.1	21.5	22.8	43.3	49.1
Public	P-REC2	C	0	0.0	0.0	31.7	47.1	49.0	49.0	50.0	50.0	72.3	100.0
Public	P-SCH1	S	0	0.0	7.0	16.3	24.7	27.7	29.6	39.8	43.3	47.3	49.9
Public	P-SCH1	C	0	0.0	0.0	21.9	47.3	66.7	76.1	100.0	100.0	100.0	100.0
Public	P-SCH2	S	0	0.0	2.5	5.0	10.1	15.3	17.1	21.5	22.8	43.3	49.1
Public	P-SCH2	C	0	0.0	0.0	18.4	30.1	36.8	38.0	50.0	50.0	72.3	100.0
Public	P-GOV1	S	0	0.0	7.0	16.3	24.7	27.7	29.6	39.8	43.3	47.3	49.9
Public	P-GOV1	C	0	0.0	0.0	34.9	78.4	90.4	100.0	100.0	100.0	100.0	100.0
Public	P-GOV2	S	0	0.0	2.5	5.0	10.1	15.3	17.1	21.5	22.8	43.3	49.1
Public	P-GOV2	C	0	0.0	0.0	30.1	49.9	49.9	50.0	50.0	50.0	71.2	100.0
Residential	SFR1	S	0	2.5	13.4	23.3	32.1	40.1	47.1	58.6	67.2	77.2	80.2
Residential	SFR1	C	0	2.4	8.1	13.3	17.9	22.0	25.7	31.5	35.7	39.7	40.0
Residential	SFR2	S	0	3.0	9.3	15.2	20.9	26.3	31.4	40.7	48.8	61.4	67.7
Residential	SFR2	C	0	1.0	5.0	8.7	12.2	15.5	18.5	23.9	28.4	34.7	36.9
Residential	MFR1	S	0	2.5	13.4	23.3	32.1	40.1	47.1	58.6	67.2	77.2	80.2
Residential	MFR1	C	0	2.4	8.1	13.3	17.9	22.0	25.7	31.5	35.7	39.7	40.0
Residential	MFR2	S	0	3.0	9.3	15.2	20.9	26.3	31.4	40.7	48.8	61.4	67.7
Residential	MFR2	C	0	1.0	5.0	8.7	12.2	15.5	18.5	23.9	28.4	34.7	36.9
Residential	MH1	S	0	6.4	9.9	44.7	45.7	45.9	50.0	65.6	66.0	66.0	66.0
Residential	MH1	C	0	0.0	0.0	38.3	56.4	68.6	79.9	89.7	89.7	89.7	89.7
Auto	AUTO		0	0.0	0.0	23.6	42.2	58.5	72.4	92.2	99.2	100.0	100.0
Cleanup	CLN	S	0	0.0	0.0	37.0	55.0	100.0	100.0	100.0	100.0	100.0	100.0
Emergency	EMG	S	0	0.0	0.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Table A3 – Advanced Bridge Replacement Benefits

Advanced Bridge Replacement Benefits									rate	0.0275	FY20 PL
CHANNEL	REACH	BRIDGE	CROSSING COST	Extension of Structure Life Through Project Duration	Capital Recovery Factor (For 50 Years)	Annual Cost of New Structure (Over 50 Years)	Present Worth Annuity for Extended Life of Structure	Benefits in Last Year of Structure Life	Single Payment PW for Remaining Life of Structure	Present Worth in Year 1	Average Annual Benefit
C04	R01	Warner Ave. Bridge	$ 36,888,219	50	0.03704	$ 1,366,373.55	27.00	$ 36,888,200	1.000	$ 36,888,200	$ 1,366,400
C05	R01	Edward st.	$ 5,969,677	50	0.03704	$ 221,122.31	27.00	$ 5,969,700	1.000	$ 5,969,700	$ 221,100
C05	R01	Springdale St.	$ 14,565,050	50	0.03704	$ 539,502.85	27.00	$ 14,565,100	1.000	$ 14,565,100	$ 539,500
C05	R01	Tide Gate Crossing	$ 4,203,186	50	0.03704	$ 155,689.87	27.00	$ 4,203,200	1.000	$ 4,203,200	$ 155,700
C05	R01	Oil Field Bridge	$ 5,034,463	50	0.03704	$ 186,481.15	27.00	$ 5,034,500	1.000	$ 5,034,500	$ 186,500
C05	**R01 Total**		**$ 66,660,595**								**$ 2,469,200**
C05	R03	Beach/Heil	$ 11,016,806	50	0.03704	$ 408,072.63	27.00	$ 11,016,800	1.000	$ 11,016,800	$ 408,100
C05	R03	Pedestrian Bridge	$ 1,401,719	50	0.03704	$ 51,920.97	27.00	$ 1,401,700	1.000	$ 1,401,700	$ 51,900
C05	**R03 Total**		**$ 12,418,526**								**$ 460,000**
C05	R04	Bushard st.	$ 3,960,351	50	0.03704	$ 146,695.02	27.00	$ 3,960,400	1.000	$ 3,960,400	$ 146,700
C05	R04	Pedestrian Bridge	$ 1,934,373	50	0.03704	$ 71,650.94	27.00	$ 1,934,400	1.000	$ 1,934,400	$ 71,700
C05	R04	Magnolia/Edinger	$ 6,717,639	46	0.03704	$ 248,827.53	25.92	$ 6,450,500	0.897	$ 5,787,200	$ 214,400
C05	**R04 Total**		**$ 12,612,362**								**$ 432,800**
C05	R05	Bolsa st.	$ 5,521,166	50	0.03704	$ 204,509.06	27.00	$ 5,521,200	1.000	$ 5,521,200	$ 204,500
C05	R05	Euclid st.	$ 6,235,010	50	0.03704	$ 230,950.49	27.00	$ 6,235,000	1.000	$ 6,235,000	$ 231,000
C05	R05	Deming	$ 3,176,309	50	0.03704	$ 117,653.41	27.00	$ 3,176,300	1.000	$ 3,176,300	$ 117,700
C05	R05	Ward St.	$ 3,176,309	50	0.03704	$ 117,653.41	27.00	$ 3,176,300	1.000	$ 3,176,300	$ 117,700
C05	R05	Pedestrian Bridge	$ 1,934,373	50	0.03704	$ 71,650.94	27.00	$ 1,934,400	1.000	$ 1,934,400	$ 71,700
C05	R05	McFadden / Brookhurs	$ 11,128,100	50	0.03704	$ 412,195.07	27.00	$ 11,128,100	1.000	$ 11,128,100	$ 412,200
C05	**R05 Total**		**$ 31,171,267**								**$ 1,154,800**
C05	R06	Fifth st.	$ 3,176,309	50	0.03704	$ 117,653.41	27.00	$ 3,176,300	1.000	$ 3,176,300	$ 117,700
C05	**R06 Total**		**$ 3,176,309**								**$ 117,700**
C05	R07	Hazard/ New Hope	$ 6,611,886	50	0.03704	$ 244,910.32	27.00	$ 6,611,900	1.000	$ 6,611,900	$ 244,900
C05	**R07 Total**		**$ 6,611,886**								**$ 244,900**
C05	R08	Westminster Ave	$ 4,742,268	50	0.03704	$ 175,657.96	27.00	$ 4,742,300	1.000	$ 4,742,300	$ 175,700
C05	R08	Morningside Ave	$ 3,176,309	50	0.03704	$ 117,653.41	27.00	$ 3,176,300	1.000	$ 3,176,300	$ 117,700
C05	R08	W. Fay Circle	$ 3,176,309	50	0.03704	$ 117,653.41	27.00	$ 3,176,300	1.000	$ 3,176,300	$ 117,700
C05	**R08 Total**		**$ 11,094,886**								**$ 411,100**
C05	R09	Pearce st	$ 2,103,451	50	0.03704	$ 77,913.75	27.00	$ 2,103,500	1.000	$ 2,103,500	$ 77,900
C05	R09	Trask	$ 3,176,309	50	0.03704	$ 117,653.41	27.00	$ 3,176,300	1.000	$ 3,176,300	$ 117,700
C05	R09	Pedestrian Bridge	$ 3,882,763	50	0.03704	$ 143,821.10	27.00	$ 3,882,800	1.000	$ 3,882,800	$ 143,800
C05	R09	Harbor Blvd	$ 4,170,478	50	0.03704	$ 154,478.34	27.00	$ 4,170,500	1.000	$ 4,170,500	$ 154,500
C05	R09	OCTD Yard	$ 25,336,066	38	0.03704	$ 938,471.17	23.39	$ 21,953,800	0.722	$ 15,853,600	$ 587,200
C05	**R09 Total**		**$ 38,669,067**								**$ 1,081,100**
C05	R10	D/S Aspenwood	$ 3,528,361	50	0.03704	$ 130,693.73	27.00	$ 3,528,400	1.000	$ 3,528,400	$ 130,700
C05	**R10 Total**		**$ 3,528,361**			$ -		$ -		$ -	**$ 130,700**
C06	R13	Newland	$ 2,982,298	50	0.03704	$ 110,467.05	27.00	$ 2,982,300	1.000	$ 2,982,300	$ 110,500
C06	R13	Beach Blvd #3	$ 3,896,561	50	0.03704	$ 144,332.21	27.00	$ 3,896,600	1.000	$ 3,896,600	$ 144,300
C06	**R13 Total**		**$ 6,878,859**			$ -		$ -		$ -	**$ 254,800**
C06	R15	Magnolia	$ 75,117,252	50	0.03704	$ 2,782,412.10	27.00	$ 75,117,300	1.000	$ 75,117,300	$ 2,782,400
C06	**R15 Total**		**$ 75,117,252**								**$ 2,782,400**
C04	R20	Edwards Street	$ 13,220,906	41	0.03704	$ 489,714.52	24.41	$ 11,952,400	0.783	$ 9,363,100	$ 346,800
C04	R20	Bolsa Avenue	$ 4,889,093	41	0.03704	$ 181,096.51	24.41	$ 4,420,000	0.783	$ 3,462,500	$ 128,300
C04	R20	McFadden Avenue	$ 12,669,647	50	0.03704	$ 469,295.38	27.00	$ 12,669,600	1.000	$ 12,669,600	$ 469,300
C04	**R20 Total**		**$ 30,779,647**								**$ 944,400**
C04	R22	Woodbury Road	$ 1,985,658	50	0.03704	$ 73,550.59	27.00	$ 1,985,700	1.000	$ 1,985,700	$ 73,600
C04	R22	Teal Drive	$ 1,985,658	50	0.03704	$ 73,550.59	27.00	$ 1,985,700	1.000	$ 1,985,700	$ 73,600
C04	R22	Mallard Avenue	$ 1,985,658	50	0.03704	$ 73,550.59	27.00	$ 1,985,700	1.000	$ 1,985,700	$ 73,600
C04	R22	Blake Street	$ 1,985,658	50	0.03704	$ 73,550.59	27.00	$ 1,985,700	1.000	$ 1,985,700	$ 73,600
C04	R22	Ranney Avenue	$ 1,985,658	50	0.03704	$ 73,550.59	27.00	$ 1,985,700	1.000	$ 1,985,700	$ 73,600
C04	R22	Westmister Avenue	$ 10,196,601	50	0.03704	$ 377,691.48	27.00	$ 10,196,600	1.000	$ 10,196,600	$ 377,700
C04	R22	Ward St.	$ 4,201,573	50	0.03704	$ 155,630.14	27.00	$ 4,201,600	1.000	$ 4,201,600	$ 155,600
C04	R22	Brookhurst Street	$ 5,521,166	50	0.03704	$ 204,509.06	27.00	$ 5,521,200	1.000	$ 5,521,200	$ 204,500
C04	R22	Magnolia Street	$ 6,303,837	50	0.03704	$ 233,499.93	27.00	$ 6,303,800	1.000	$ 6,303,800	$ 233,500
C04	R22	Newland Street	$ 3,176,309	50	0.03704	$ 117,653.41	27.00	$ 3,176,300	1.000	$ 3,176,300	$ 117,700
C04	R22	Pedestrian Bridge	$ 1,934,373	50	0.03704	$ 71,650.94	27.00	$ 1,934,400	1.000	$ 1,934,400	$ 71,700
C04	R22	Beach Blvd/W. Hazard	$ 19,827,111	50	0.03704	$ 734,414.42	27.00	$ 19,827,100	1.000	$ 19,827,100	$ 734,400
C04	**R22 Total**		**$ 61,089,259**								**$ 2,263,100**
TOTAL ALL REACHES			**$ 359,808,275**								**$12,747,000**