US Army Corps of Engineers®

CHICAGO DISTRICT

MCCOOK LEVEE

MCCOOK, IL

Appendix C: Economic Analysis

March 2018

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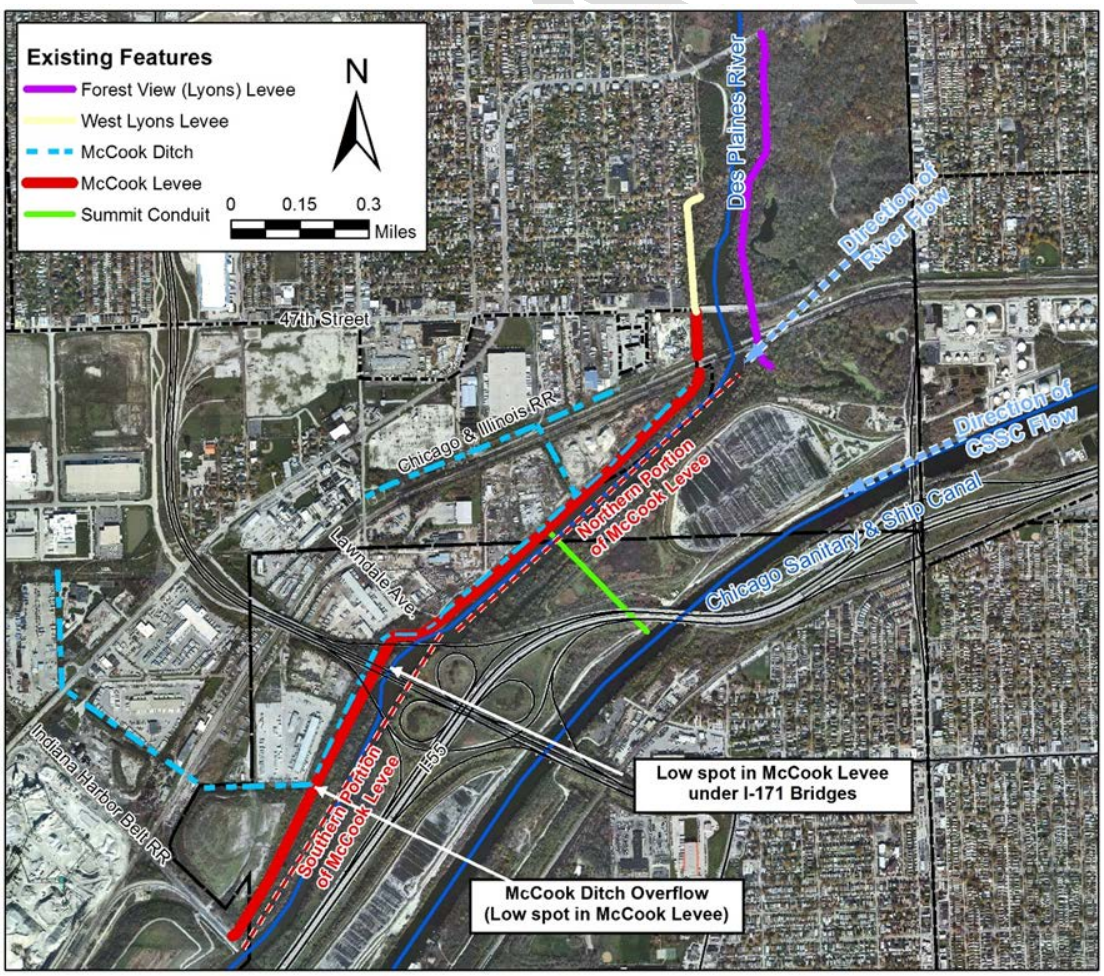
1 Introduction

The analyses described in this appendix build upon that which was developed for the McCook, IL Section 205 Federal Interest Determination (FID) submitted by the Chicago District (LRC) to the Great Lakes and Ohio River Division (LRD) on August 2015. This feasibility phase of the study process is to further refine, compare, and evaluate the potential project alternatives. The final step of this study phase is to determine the National Economic Development (NED) plan. The economic analyses is a critical input in the development of the final recommendation, but not the sole determining factor. For further information regarding alternative development and plan selection, see the Main Report.

1.1 Project Area

The project area consists of the existing McCook and West Lyons Levees located in (McCook, IL), and nearby structures that are at risk of flooding if the levees fail or are overtopped. These leveed areas are in the 'Goose Lake — Des Plaines River' subwatershed (HUC 071200040706). Figure 1 highlights the location of all of major hydraulic features within the project area. These features are described in greater detail in the Main Report.

Figure 1. Project Area



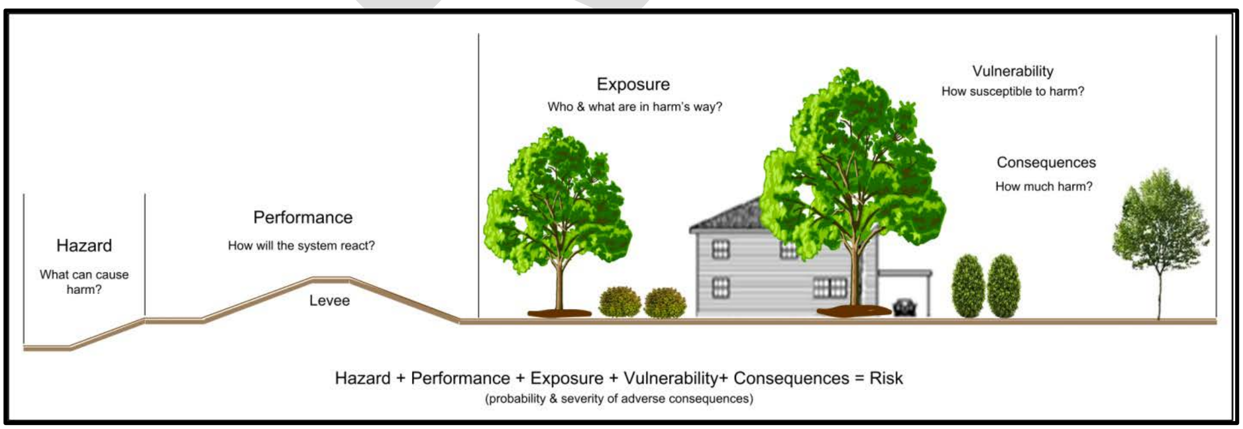
The economic analysis for this study is focused on the West Lyons (pale yellow line in Figure 1) and McCook Levees (red line in Figure 1). The McCook Levee was originally constructed around the turn of the 20th century by the Metropolitan Water Reclamation District of Chicago (MWRDGC), then known as the Sanitary District of Chicago. The levee comprises two sections: the southern portion and the northern portion. Each of the McCook Levee alternatives are focused on the northern portion which extends northeast from Lawndale Avenue approximately 4,100 feet to the Chicago & Illinois Railroad tracks. The levee continues approximately 550 feet north to tie into high ground at 47th Street. The leveed portion of the project is primarily industrial. Throughout this document the northern portion of the McCook Levee will be referred to as "Reach A" or "McCook Levee."

The West Lyons Levee is a separate system from the McCook Levee and it extends approximately 1,400 feet between 47th Street and 45th Street. The date of construction for this system is unknown. The leveed area is primarily residential. Throughout this document the West Lyons Levee is referred to as "Reach B" or "West Lyons Levee."

1.2 Economic Analyses: Purpose and Methodology

The analyses described herein are used to evaluate the effectiveness and efficiency of potential flood risk reduction measures under consideration for federal investment. The U.S. Army Corps of Engineers (USACE) follows a conceptual flood risk model which is a function of the hazard, performance, and consequences. The hazard, or potential cause for harm, in the case of this study refers to a flood originating from the Des Plaines River. The performance refers to the system's reaction to the hazard, or how the existing levees are anticipated to handle various flood loadings. Finally, the consequences refer to the potential economic and/or non-economic harm that result from a single occurrence of the hazard. Each of these terms are discussed more completely in ER 1105-2-101 "Risk Assessment for Flood Risk Management Studies" dated 17 July 2017 and depicted in Figure 2, below.

Figure 2. Flood Risk Conceptualized



The hazard and performance inputs incorporated in the economic analyses are developed by the hydrologic and geotechnical engineers. Brief descriptions of the development are included within this appendix and additional information can be found in *Appendix D – Hydrology and Hydraulics* and *Appendix E – Geotechnical Analysis*.

The bulk of this appendix is focused on the development of the consequence information, including the application of the hazard and performance inputs to quantify the overall flood risk. The methodology for valuing structures, assigning structure types and damage functions, and estimating foundation and beginning damage elevations closely resembles the work performed for the Forest View, IL Section 205 study (approved February, 2017) as it is located across of the river from the McCook study area (purple line in Figure 1). The analyses described herein utilize risk-based estimates in order to objectively evaluate alternatives and the associated contributions to NED.

Important assumptions employed in the evaluation of alternatives are:

(1) All inputs in this analysis are estimates, and therefore subject to varying degrees of uncertainty, as such, an attempt has been made to quantify this uncertainty and better inform interested parties, including decision-makers;
(2) All benefits and costs are expressed in October 2017 price levels;
(3) The project period of evaluation is estimated to be 50 years, including necessary costs for operation, maintenance, repair, replacement and rehabilitation activities;
(4) The FY18 federal discount rate of 2.75 percent is used for the evaluation of NED benefits and costs (unless otherwise noted);
(5) All structural computations are based on industrial, commercial and residential depreciated replacement values (DRVs) and do not include land values;
(6) Resources have potential alternative uses and, consequently, opportunity costs;
(7) Individuals are risk neutral and rational economic agents;
(8) All elevations are expressed in feet and are understood to represent “Ft. NAVD88” (Feet North American Vertical Datum 1988);
(9) The leveed area is fully developed and will remain so throughout the period of analysis;
(10) For consistency, all annualized benefits and costs were calculated using an end of year discounting method, including interest during construction;
(11) All economic damages and benefits displayed reflect the best estimate case, or most likely probability of failure scenario, unless otherwise noted.

2 Without Project Condition

According to the Planning Guidance Notebook (ER 1105-2-100), potential project alternatives are to be compared to the future without project (FWOP) condition. For the purpose of this analysis, the FWOP is assumed to closely mirror the existing condition. The leveed areas are relatively small, but completely developed. Publicly available historic imagery and records (Cook County imagery, assessor data, and Google imagery) show that the primary structural features (roads, ditches, and buildings) within the area have been in the same location for decades. While the future precipitation in Cook

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County Illinois is expected to increase in intensity and frequency[1], these impacts were not quantified at this time. Additionally, the levee is expected to continue to erode over time if not addressed. However, the fragility curves were developed based on current conditions so the associated risk estimates over the period of analysis may be understated. Each of these critical inputs are discussed in the following sections.

2.1 Hazard

The Des Plaines River water surface profiles (WSPs) for the economic analysis were provided by the H&H engineers. The values below represent mean WSPs for a given exceedance probability at stations upstream and downstream of the index location. The index location was selected to correspond with the weakest point of the levee; the following stages for the fragility estimates are based on the identified index locations. The exceedance probabilities below can also be referred to as annual chance exceedance (ACE), referring to the chance (or probability) for which a given stage is anticipated to be met or exceeded each year. Reach B and Reach A share a boundary at station 82725.92, so this row is displayed in an attempt to visually identify that this station is a part of both reaches.

Table 1. Future Without Project Condition Water Surface Profiles

Reach	River Station	Stage by Annual Chance Exceedence[1]							
		0.99	0.5	0.2	0.1	0.04	0.02	0.01	0.002
West Lyons Levee 47th to 45th (Reach B)	83788.26	592.57	596.51	598.06	598.95	599.84	600.50	601.14	602.50
	83026.35	592.43	596.42	597.99	598.88	599.77	600.43	601.07	602.43
	82725.92	592.36	596.37	597.94	598.82	599.71	600.37	601.01	602.36
McCook Levee Lawndale to 47th (Reach A)	82415.00	592.31	596.34	597.90	598.79	599.68	600.34	600.97	602.33
	77614.32	592.01	595.96	597.46	598.27	599.12	599.69	600.22	601.32

[1] *Mean modeled river stages in feet NAVD88*

For example, a 0.5 ACE event is anticipated to result in a mean stage of 596.51 feet at the river station upstream end of Reach B (station 83788.26). The H&H model results for the study area are listed in Table 1, above. A complete explanation of the H&H model development and results can be found in *Appendix D* and in the *Lyons Levee H&H Technical Memo*.

[1] Markus M, Angel J, Byard G, Zhang C, Zaloudek Z, & McConkey S. Communicating the Impacts of Potential Future Climate Change on the Expected Frequency of Extreme Rainfall Events in Cook County, Illinois. Champaign, IL. Illinois State Water Survey, Prairie Research Center; 2016 May. 67 p. Report No.: 2016-05.

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The uncertainty associated with the hydrology (flows) was based on a 100 year gage record, while the uncertainty associated with the rating curve stages was estimated to have a normal distribution with a standard deviation of 0.22 feet (*Appendix D* and the *Lyons Levee H&H Technical Memo*). These estimates were derived in accordance with EM 1110-2-1619 "Risk-Based Analysis for Flood Damage Reduction Studies" dated 1 August 1996.

2.2 Performance

Understanding how a levee is expected to perform is an important aspect in estimating how often and to what depth structures may be inundated during any given flood event. If the levee were expected to perform as designed, it would remain intact and fully functional, but still be subject to overtopping when the river climbs to stages in excess of the crest elevation (600.6 ft for Reach A and 602.4 ft for Reach B). This is almost the exact scenario that the area endured during April 2013.

The tables (Table 2 & Table 3) and figures (Figure 3 & Figure 4) below outline the performance estimates derived by the geotechnical analyses, applied in the estimation and evaluation of the various future with and future without project scenarios. For each reach, the geotechnical engineer reviewed available information resulting from prior studies and inspections. Based on this information, three relationships were developed, relying on the naming conventions outlined in the July 2017 version of the Draft Levee EC, to define the uncertainty associated with levee performance or fragility. The techniques for defining the probable non-failure (PNP) and probable failure point (PFP) for each levee were based on existing guidance (EM 1110-2-1619). For example, the PNP equates to the loading elevation for the levee at which the engineer believes that it is "highly likely" that the levee will remain intact, while the PFP represents the point where the engineer believes that the failure is "highly likely." These "highly likely" values equate to a 0.85 probability that the levee will fail or survive. Additionally the Hydrologic Engineering Center's Flood Damage Analysis Program (HEC-FDA) uses linear interpolation to estimate the failure probabilities between these specific nodes, with the crest always receiving a 1.00 probability of failure. HEC-FDA requires the definition of the 1.00 probability of failure within the levee fragility module, so the crest elevation was entered 0.001 feet higher within the software as compared to what was provided by the engineers. This modification allows the fragility curve to be completely defined and sampled within the software, especially when the estimated PFP is at the same elevation as the top of the levee, or if the PNP is at the same elevation as the bottom of the levee.

In accordance with paragraph 7.9(f) of the DRAFT Levee EC (11 July 2017) and EM 1110-2-1619, the geotechnical engineer used available information to assess the uncertainty in these estimates by assigning these points for three different scenarios; (1) the best estimate case or most likely probability of failure, (2) the best reasonable case or low likelihood of failure, and (3) the worst reasonable case or high likelihood of failure. During plan formulation, evaluation, and comparison, the economic consequences were derived using the most likely scenario. The low and high likelihoods of failure were combined with the most likely condition to communicate the uncertainty surrounding the recommended plan only (see section 5.1.3 for more information regarding these combined estimates).

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Table 2. Future Without Project Condition Probability of Failure (Reach A)

Failure Node	Probability of Failure by Node	Elevation Assignment for Failure Condition[1]		
		Best Estimate Case (Most Likely Probability of Failure)	**Best Reasonable Case** (Low Likelihood of Failure)	**Worst Reasonable Case** (High Likelihood of Failure)
Levee Crest[2]	1.00	600.601	600.601	600.601
Probable Failure Point (PFP)	0.85	600.6	600.6	597.0
Probable Non-Failure Point (PNP)	0.15	593.5	599.0	593.001
Levee Toe	0.00	593.0	593.0	593.0

[1] Estimates were developed by the geotechnical engineer(s) and are described in the geotechnical appendix (Appendix E).
[2] Levee crest elevations are entered into HEC-FDA with a 0.001 foot higher elevation than provided in the geotechnical appendix to accurately depict the fragility curve within software constraints.

These levee performance tables and figures were developed to convey the uncertainty surrounding these levee performance estimates. The figures represent the most likely estimate with a solid line, while the high and low scenarios are plotted using a dashed line. The levee crest and toe are represented with a solid horizontal line and the mean stages by ACE are displayed with dotted horizontal lines. There is a set of tables and figures for each separate levee, or reach, of the study area.

Figure 3. Future Without Project Condition Probability of Failure (Reach A)

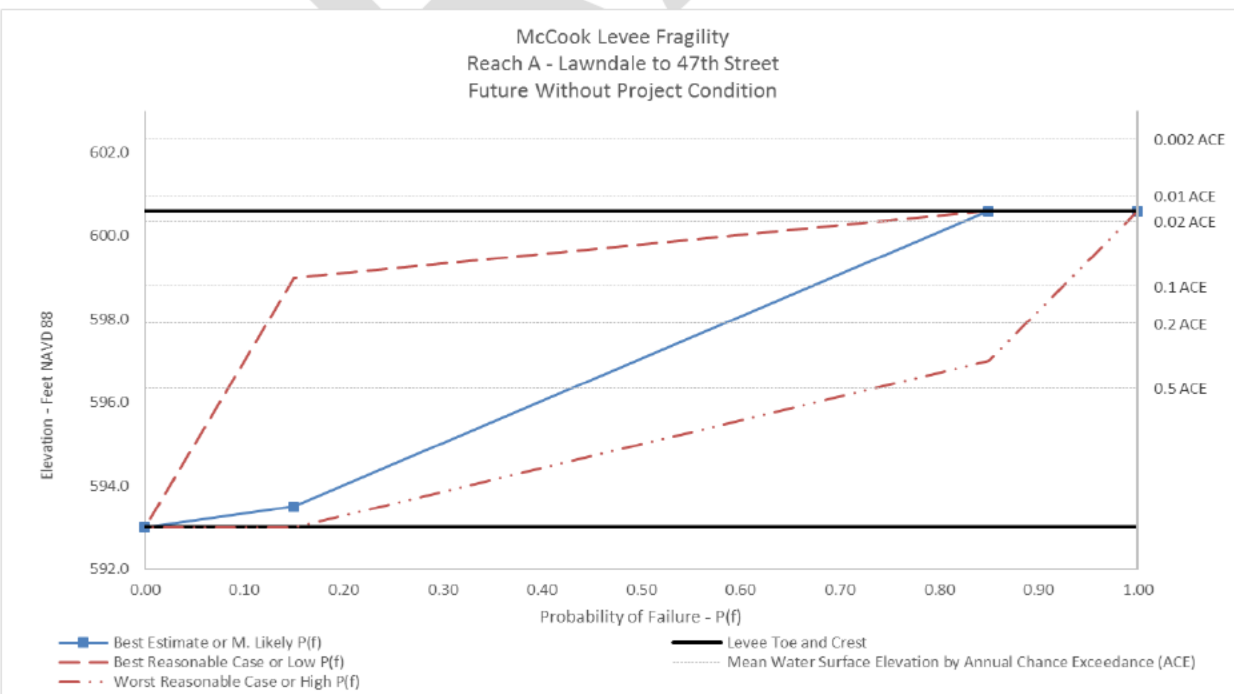

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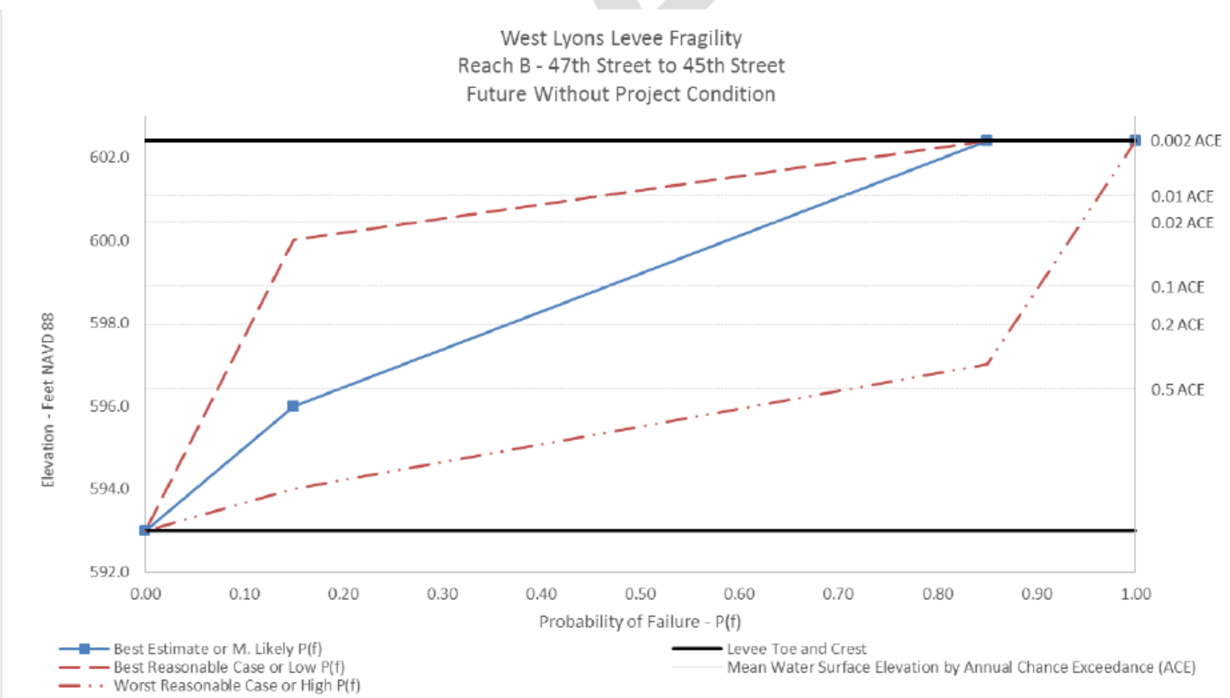
Table 3. Future Without Project Condition Probability of Failure (Reach B)

Failure Node	Probability of Failure by Node	Elevation Assignment for Failure Condition[1]		
		Best Estimate Case (Most Likely Probability of Failure)	**Best Reasonable Case** (Low Likelihood of Failure)	**Worst Reasonable Case** (High Likelihood of Failure)
Levee Crest[2]	1.00	602.401	602.401	602.401
Probable Failure Point (PFP)	0.85	602.4	602.4	597.0
Probable Non-Failure Point (PNP)	0.15	596.0	600.0	594.0
Levee Toe	0.00	593.0	593.0	593.0

[1] Estimates were developed by the geotechnical engineer(s) and are described in the geotechnical appendix (Appendix E).
[2] Levee crest elevations are entered into HEC-FDA with a 0.001 foot higher elevation than provided in the geotechnical appendix to accurately depict the fragility curve within software constraints.

Figure 4. Future Without Project Condition Probability of Failure (Reach B)



The long-term conditional non-exceedance probability by events for the without project condition and with-project alternatives is discussed in section 5.1.4 and displayed in Table 26 and Table 27.

2.3 Consequences

As discussed in section 1.2, the consequences are defined as a product of hazard, performance, exposure, and vulnerability. The following sections outline how the consequence information was developed and utilized in the comparison and evaluation of potential alternatives.

2.3.1 Structure Inventory

The structure inventory provides the economic basis for damage estimation and alternative evaluation. This inventory includes damages to structures, contents, vehicles, and emergency costs incurred during and immediately following a flood event. The development of each of these inputs, as well as the associated uncertainty, is discussed in the following sections.

2.3.1.1 Methodology

In this section of the analysis, the methodology used to compile an inventory of the residential, commercial, and industrial structures in the study area will be discussed. The methods used in the valuation of these structures, contents, and the vehicles associated with these structures will be presented. Finally, the procedures used to assign elevations to the structures, contents, and vehicles will be provided. The uncertainty inherent in the methods used to estimate each of these economic variables is addressed by the risk-based analysis included in this section of the report.

2.3.1.2 Available Data

The structure inventory developed for this feasibility study relied heavily on Cook County assessor and GIS data. These data included parcel boundaries, the use of a structure, and the assessed value (for residential, commercial, and industrial buildings). The structure elevations were derived from the Cook County digital elevation model (DEM).

2.3.1.3 Structure Depreciated Replacement Values (DRVs)

According to Engineering Regulation 1105-2-100 (D-15), building values should be evaluated as an estimate of depreciated replacement value (DRV) of the structure. While neither RS Means nor Marshall & Swift estimation software packages were used to directly develop DRVs, other studies conducted by the Chicago District have relied on local assessor's data to estimate these values. Additionally, the NED Procedures Manual states "appraised values can be used in lieu of DRVs if deemed appropriate." Currently, the Cook County appraised values are relatively in-line with these estimate methodologies.

Table 4. McCook and West Lyons Structure Inventory

Category	Number of Structures	Average DRV ($1,000)	Total DRV[1] ($1,000)
Residential	53	$134	$7,101
Commercial	6	$261	$1,565
Industrial	45	$218	$9,815
Total[2]	**104**	**$613**	**$18,481**

[1]Depreciated replacement values (DRVs) presented at October 2017 price levels.
[2]All counts and values represent the entire leveed area (Reach A & Reach B).

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Among the various assessor information categories, the Fair Market Value (FMV) for structures proved to be the most valuable in estimating depreciated replacement values. The county provided FMVs for the total parcel, as well as structure only, and land only. Only the structure values were used in the economic analysis. The Cook County Assessors estimate the assessed value as a percentage of the structure's FMV. For example, residential structures are assessed at 10% of the FMV, while commercial and industrial structures are assessed at 25% of the FMV. These ratios are provided by structure class in the Cook County Assessor's Definitions for the Codes for Classification of Real Property, which can be found online. These ratios were used to develop the structures FMVs, or appraised values, from the available assessed values.

The uncertainty associated with structure values was represented using a normal distribution with a standard deviation of 50%, consistent with the Forest View, IL Study and the Great Lakes Mississippi River Interbasin Study (GLMRIS). While this uncertainty appears to be larger than most USACE studies to date, it seems to more accurately represent the uncertainty in structure values based on current inventory development methods.

2.3.1.4 Structure Content Values

Structure contents are usually defined as everything within the structure that are not permanently installed, such as rugs, appliances, and store or warehouse inventories. The residential content-to-structure-value-ratio damages are provided within the generic curves provided by the Corps' Institute for Water Resources (Economic Guidance Memorandum 01-03). These content-damage functions are based on the structure value and vary by structure type. For all residential, commercial, industrial, and public structures, the content-to-structure-value-ratio is estimated at 100 percent. Each of these curves was developed to estimate content damages based on the structure value (discussed further in section 2.5).

The uncertainty associated with residential content values is captured in each depth-damage function in accordance with Economic Guidance Memorandum (EGM) 01-03 (4.c.3). The uncertainty associated with the non-residential content values is not known and was not included in the current estimates.

2.3.1.5 Inventory of Vehicles

Damages to vehicles can also result from flooding in the study area. These damages are based on the number of commercial automobiles directly impacted per business. The majority of the businesses within the leveed area require significant numbers of large commercial vehicles for shipping goods or handling materials. The automobile damages are then calculated by correlating depth of flooding, depth-damage per automobile, and damage per inundated automobile. The total number of vehicles within the study area were estimated using 2010 United States Census data and satellite imagery for non-residential structures. For residential structures, it was assumed that the vehicles could quickly be moved to higher ground and are not likely significant contributors to the consequence estimates. The average depreciated value per automobile was determined to be $23,000, based on the HAZUS 2.2 dataset.

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Table 5. McCook and West Lyons Vehicle Inventory

Category	Number of Vehicles	Average DRV ($1,000)	Total DRV[1] ($1,000)
Vehicles	235	$23	$5,405
Total[2]	**235**	**$23**	**$5,405**

[1]Depreciated replacement values (DRVs) presented at October 2017 price levels.
[2]All counts and values represent the entire leveed area (Reach A & Reach B).

The uncertainty associated with vehicle values was estimated using a normal distribution with a standard deviation of 50 percent. This uncertainty is believed to sufficiently cover the wide range in possible values for the various types of vehicles within the leveed areas, but is not currently based on data specific to the study area. However, a review of commercial and industrial vehicle values similar to those found in the study area confirmed the potential for significant damages due to flooding. Most of the vehicles in the McCook leveed area are semis or heavy construction equipment, where values can range from $15,000 to greater than $100,000 based on the age.

2.3.1.6 Structure and Vehicle Elevation Estimates

No physical elevation surveys were completed as a part of this analysis. Instead, these estimates reflect the best available information, to include work completed for the Great Lakes and Mississippi River Interbasin Study (GLMRIS) and imagery available on GoogleEarth. The GLMRIS structure elevation analysis included a survey of 6,647 residential, commercial, industrial, and public structures including a section of the Forest View study area, directly adjacent to the McCook study area. The average foundation height for residential structures was 4.5 feet for residential structures and 1.5 feet for commercial, industrial, and public (CIP) structures.

A Google Street View survey was performed to refine the structure inventory specific to this study, estimating first floor elevations using the stair counting method. On average, each step is about 8 inches high – therefore, if there are 3 steps to get into the front door, the first floor elevation is 2 feet. This is a standard method used by economists to estimate first floor elevations. Based on the Street View survey, the residential structure foundation height was estimated to be 1.5 feet, rather than the 4.5 feet average for the larger GLMRIS inventory. While the commercial inventory survey resulted in an estimated average of 0.5 feet for the first floor elevations, as compared to the GLMRIS estimate of 1.5 feet.

Once the foundation height estimates were developed, they were paired with digital elevation model (DEM) elevations using GIS. The first floor elevation (FFE) is the sum of the lowest-adjacent-grade (LAG) to the structure and the structure's foundation height. The most efficient way to estimate LAGs is using DEM's, where available. The spatially referenced points for each structure are related to the DEM using a variety of geo-processing tools. The DEM used for this study was a terrain model (DTM) built using the Cook County LiDAR dataset collected between November 2008 and April 2009.

To determine the elevation uncertainty associated with the field elevation estimates for GLMRIS, a random sample of structures was identified. A structure elevation sample was selected by identifying the nearest benchmark to each structure and was limited to structures located within eight-hundred

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feet of a benchmark. This reduced the sampling population to 1,109 structures, of which a sample of 70 structures was taken. Each of these 70 structure elevations was determined using survey equipment. The surveyed elevations were then compared to geospatially assigned elevations from three using a method where LAG = The DTM value at a point in the center of the structure.

The uncertainty associated with first floor elevations, based on the GLMRIS samples described above, is estimated to have a normal distribution with a standard deviation of 2 feet. This estimate for elevation uncertainty appeared to be appropriate for this study area and was retained for both the Forest View and McCook studies. Chicagoland residential and non-residential structures have a large variance in foundation heights, so this uncertainty range is likely larger than most USACE studies.

2.3.1.7 Transportation Delays

There are no significant transportation delays anticipated as a result of flooding within the leveed area. The project area is relatively confined and adjacent to primary thoroughfares, but no roads with significant traffic would be impacted by a levee failure or overtopping event. The two largest transportation routes within the leveed area are 47th Street and two separate railroad lines. Since transit along these routes is relatively unaffected by flood stages below 602.5 feet, the apparent elevation of the levee crest as originally designed, no effort was made to estimate the impacts of flooding and resulting transportation disruptions.

2.3.1.8 Emergency Costs

When an area experiences flooding, the direct economic impact expands beyond the damage sustained to structures, contents, vehicles, and transportation delays. Emergency costs, such as evacuation activities, debris removal and cleanup, impacts to utilities and infrastructure (for which there are few existing depth-damage curves), as well as increased demand for public services, can add up quickly. These additional impacts can be difficult to account for, as they are not always easily accessible or complete. For example, the leveed area incurred significant costs to flood fight utilities and pump water out after the April 2013 overtopping event, but those estimates were not easily attained for use in this study.

Instead, this analysis relied on the available data contained within the *Development of Depth-Emergency Cost and Infrastructure Damage Relationships for Selected South Louisiana Parishes May 2012 Report*. This report was developed for the USACE New Orleans District in support of multiple flood risk analyses. Below, Table 6, provides the values applied to each damage category and structure type within the study structure inventory.

The following cost estimates were derived through an expert-opinion elicitation to determine NED emergency costs and infrastructure damages for various flooding events. The dollar values in the table below refer to the mean estimated damage value for a given category, if it were to be faced with 12 feet of inundation. The percent depth-damage functions are used within HEC-FDA to estimate the emergency costs incurred as a result of flood depths from 0 to 12 feet above the first floor. Category 1 includes the costs associated with transportation utilized during an evacuation event, the displacement time households experience due to flooding scenarios, National Guard activities in response to flooding, search and rescue activities, temporary housing and substance assistance, value of lost time associated

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with flood evacuation and recovery activities, and storage or moving costs incurred during displacement times. Category 2 covers the costs associated with debris removal and cleanup including street and highway clearing for emergency response, and structure-related debris costs. While these estimates were developed with South Louisiana as the subject, many of the assumptions used in the expert elicitation are reasonable for almost any region within the United States, including this study area. Furthermore, the uncertainty associated with the depth-damage functions accounts for some of the in-exactness in estimating exactly what actions would be taken in preparation for, or response to, flooding.

Table 6. Emergency Costs by Category

Emergency Damage Categories[1]		
Group 1. Evacuation Activities	**Inventory Values[2] ($1000)**	**Applications[3]**
Category 1. Evacuation, Subsistence, and Reoccupation ($ per household)	$5.5	Applied to each residential structure- 53 total
Category 2. Debris Cleanup		
General Residential ($ per structure) (based on weighted average of all residential structures listed in the Emergency Cost Report, Table 4-2 by square feet)	$7.2	Applied to each residential structure- 53 total
General Nonresidential ($ per structure) (based on weighted average of all nonresidential structures listed in the Emergency Cost Report, Table 4-2 by square feet)	$34.8	Applied to each non-residential structure- 51 total

All tables referenced above refer to the Emergency Cost and Infrastructure Report
[1] Development of Depth-Emergency Cost and Infrastructure Damage Relationships for Selected South Louisiana Parishes March 2012
[2] Rounded to the nearest hundred
[3] Description of how these were applied in the structure inventory for HEC-FDA

2.3.1.9 Depth-Damage Functions

A depth-damage relationship defines how much damage occurs at a given building (or structure) for an incremental depth of flooding. The deeper the flooding is, the higher the damage will be. These relationships are usually expressed as a percent of total structure value, which makes it easy to use one damage curve for many structures, as long as they fall within the same basic category. Below, Table 7 displays the depth-damage functions used for this study. Some of these were developed specifically for GLMRIS.

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Table 7. Depth-Damage Functions

Category Name	Occupancy Name	Occupancy Description	Source
RES	Oreswbsmt	One Story, With Basement	1
	Treswbsmt	Two Or More Stories, With Basement	1
	Splitwbsmt	Split Level, With Basement	1
	Oreswoutbsmt	One Story, No Basement	1
	Treswoutbsmt	Two Or More Stories, No Basement	1
COM	COM-ELEC-OD5B	Electronics Retailer, with basement, 5 stories or less	2
	COM-CONV	Store, convenience	2
	COM-OFF-OD5B	Office building , with basement, 5 stories or less, suburban	2
IND	IND-WH-OD5	Warehouse, non-refrigerated , w/o basement, 5 stories or less, suburban	2
	IND-WH-OD5B	Warehouse, non-refrigerated , w/ basement, 5 stories or less, suburban	2
AUTO	Pickups	Pickup Trucks	3

[1] *EGM 04-01, Generic Depth-Damage Relationships for Residential Structures with Basements*
[2] *Great Lakes Mississippi River Interbasin Study Depth-Damage Relationships*
[3] *EGM 09-04, Generic Depth-Damage Relationships for Vehicles*

2.3.2 Risk to Life Safety

The life safety risk refers to the possibility of life loss as a result of inundation. This risk is driven by factors including the product of flood depth and velocity, flood warning time, and population vulnerability. Due to the warning time, the risk to life safety is expected to be minimal during overtopping events. While the risk is increased during a breach (due to increased depths and velocities), there are multiple points of high ground directly adjacent or within the leveed area. The distance required to evacuate the lowest areas within the leveed area ranges anywhere between 25 and 1000 feet. These potential evacuation routes include lesser traveled local roads and sidewalks with relatively gentle gradient from low to high ground.

2.3.2.1 Flood Warning Time

After the April 2013 flood event, The Village of Forest View worked with USACE to install a river gage and develop a flood warning plan and alert system. This warning system helps to keep residents informed for possible overtopping events, but it does not include any monitoring or warning for a breach. Since the initial breach risk occurs relatively frequently (the 503.5 ft PNP is met or exceeded between the 0.999 and 0.5 ACE flood events), the warning time for a potential breach can be much shorter than that of an overtopping event.

2.3.2.2 Depth of Flooding

The depth of flooding for the leveed area was modeled to estimate the exterior-interior relationship and the viability of non-structural measures, but it also provides a better understanding of the risk of life loss, or life safety risk. The two dimensional (2D) modeling indicated that the depths would be roughly

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equivalent for the breach and overtopping scenarios. In the areas closest to the levee, depths are anticipated to reach 7 feet or more during an event where the Des Plaines River experiences a 0.1 ACE flow (or greater). Note that the depths are not uniform throughout the leveed area as the ground elevation increases as distance from the river increases.

2.3.3 FWOP Damage Estimates

As stated previously, the estimation of the FWOP damages is required as the effectiveness for all potential alternatives shall be measured against the FWOP condition. The following sections provide a discussion of the FWOP damages by event and how these estimates were developed.

2.3.4 Stage-Damage

In order to calculate the damages from the inundation of structures (and associated contents) that would occur at each stage, three relationships were developed: depth-damage relationships, stage-frequency relationships, and levee system performance probabilities. The depth-damage relationship is the estimated amount of damage that will occur to structures (and associated contents) as the elevation of the water (or stage) rises. The stage-frequency relationship is the probability of the water stages reaching various levels for each hydrologic reach. The levee system probabilities of failure are the estimated likelihood of the levee system failing, as the water level rises.

The uncertainties associated with the development of these relationships are addressed by risk-based analysis. A range of possible values, with a maximum and a minimum value, or a standard deviation, was calculated for each economic variable (structure and content values, first floor elevation, and depth-damage relationships). These statistics were entered into the HEC-FDA version 1.4.2 to calculate the uncertainty or error surrounding the elevation - or stage-damage curves (shown below). The program also used the number of years that stages were recorded at a given gage to determine the hydrologic uncertainty surrounding the stage-frequency curves. The possible occurrences of each variable were derived through the use of Monte Carlo simulation, which used randomly selected numbers to simulate the values of the selected variables from within the established ranges and distributions. For each variable, a sample was used from within the range of possible values. Within each sample, or iteration, a different value was selected. The number of iterations performed affects the simulation execution time and the quality and accuracy of the results.

The sum of all sampled values, divided by the number of samples, yielded the expected value, or mean. This process was conducted simultaneously for each economic and hydrologic variable. The resulting mean and probability distributions formed a comprehensive picture of all possible outcomes.

HEC-FDA does not currently calculate risk and uncertainty associated with the levee fragility curves. The values associated with the levee performance are most likely values estimated by the geotechnical engineers (the economic impacts resulting from the uncertainty associated with levee performance is discussed in *section 5.1.3*). The following table estimates the expected damage at a given flood stage, not accounting for levee fragility. Based on the amount of development in the leveed area, this relationship remains the same for both the without and with-project conditions for all model runs (except non-structural).

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Table 8. Aggregated Stage-Damage Function Without Levee Fragility (Reach A)

River Stage	Damages by Category in Thousands				Total
	Structures & Contents		Other Damages		
	Residential	Non-Residential	Vehicles	Emergency	
591	$0.0	$16.3	$0.0	$0.0	$16.3
592	$0.0	$54.3	$2.4	$0.0	$56.7
593	$0.0	$107.9	$9.8	$0.0	$117.7
594	$0.0	$197.4	$22.1	$28.7	$248.1
595	$0.0	$324.1	$53.5	$93.2	$470.8
596	$0.0	$510.4	$109.8	$206.1	$826.3
597	$0.0	$733.8	$194.8	$287.8	$1,216.3
598	$0.0	$1,019.2	$316.7	$314.7	$1,650.6
599	$0.0	$1,334.2	$453.1	$367.6	$2,154.9
600	$0.0	$1,701.0	$619.2	$451.6	$2,771.8
601	$0.0	$2,112.6	$798.9	$551.5	$3,463.0
602	$0.0	$2,555.4	$986.3	$624.2	$4,165.8
603	$0.0	$3,096.9	$1,200.6	$655.7	$4,953.1

HEC-FDA Output; October 2017 Price Levels

Table 9. Aggregated Stage-Damage Function Without Levee Fragility (Reach B)

River Stage	Damages by Category in Thousands				Total
	Structures & Contents		Other Damages		
	Residential	Non-Residential	Vehicles	Emergency	
591	$1.5	$0.0	$0.0	$0.0	$1.5
592	$3.9	$0.0	$0.0	$0.0	$3.9
593	$10.4	$0.0	$0.0	$0.0	$10.4
594	$25.0	$0.0	$0.0	$0.0	$25.0
595	$49.8	$0.0	$0.0	$0.0	$49.8
596	$91.8	$0.0	$0.0	$0.0	$91.8
597	$158.9	$0.0	$0.0	$0.0	$158.9
598	$256.4	$0.0	$0.0	$0.0	$256.4
599	$394.4	$0.0	$0.0	$0.0	$394.4
600	$578.9	$0.0	$0.0	$0.0	$578.9
601	$814.3	$10.3	$0.0	$8.3	$832.8
602	$1,104.2	$34.9	$0.0	$33.1	$1,172.2
603	$1,449.1	$82.6	$0.0	$65.1	$1,596.8

HEC-FDA Output; October 2017 Price Levels

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3 Non-Structural Alternatives

The non-structural alternatives were developed on a conceptual level, using modeled flood depths to identify which measures would be applicable to which structures. There are two basic non-structural measures which were considered for the study area. The first measure, dry floodproofing, would result in the modification of the exterior of a structure so that it could withstand low levels of inundation (less than three feet above the first floor). The second measure would be to evacuate/ buyout the structures if the mean inundation was estimated to exceed three feet above the first floor. The mean stage associated with the 0.01 ACE event was used to determine whether a flood would meet or exceed this three foot limit.

Alternative 1A (McCook Non-Structural) – This alternative was developed by identifying which structures in the McCook leveed area were likely to be impacted by an overtopping or breach event. This alternative assesses the effectiveness of potential non-structural modifications, including the dry floodproofing of 7 structures and the evacuation (buyout) of 21 structures.

Alternative 1B (McCook Non-Structural) – This alternative was developed by identifying which structures in the West Lyons leveed area were likely to be impacted by an overtopping or breach event. This alternative assesses the effectiveness of potential non-structural modifications, including dry floodproofing 12 structures and the evacuation (buyout) of 6 structures.

3.1 Hazard

The hazard remains unchanged under this set of alternatives as no modifications are made which would affect river flows or stages. Therefore, these alternatives use the same H&H information as the without project condition (see section 2.1).

3.2 Performance

The levee performance remains unchanged under this set of alternatives as no modifications are made to the existing levees. Therefore, these alternatives use the same levee fragility information as the without project condition (see section 2.2).

The long-term conditional non-exceedance probability by events for the without project condition and with-project alternatives is discussed in section 5.1.4 and displayed in Table 26 and Table 27.

3.3 Consequences

Unlike structural alternatives, non-structural alternatives are developed as a way to directly affect potential consequences, rather than altering the hazard or performance of an existing system. As a result, there would be less structures and people subject to future inundation.

3.3.1 Structure Inventory

The non-structural alternatives were formed by conceptually improving various structures (residential & non-residential) to achieve a greater level of resistance to damage due to inundation. These improvements would result in fewer structures in the study area. The structure inventory summary for this alternative is outlined below in Table 10 and Table 11.

Table 10. McCook and West Lyons Structure Inventory

Category	Structures	Average DRV ($1,000)	Total DRV[1] ($1,000)
Residential	47	$129	$6,066
Commercial	2	$528	$1,056
Industrial	28	$167	$4,684
Total[2]	**77**	**$824**	**$11,807**

[1]Depreciated replacement values (DRVs) presented at October 2017 price levels.
[2]All counts and values represent the entire leveed area (Reach A & Reach B).

Furthermore, fewer vehicles will be permanently located within the study area as the associated businesses would be bought out. Below, Table 11 provides the estimate for the number and value of structures exposed to potential flooding under this alternative.

Table 11. McCook and West Lyons Vehicle Inventory

Category	Vehicles	Average DRV ($1,000)	Total DRV[1] ($1,000)
Vehicles	120	$23	$2,760
Total[2]	**120**	**$23**	**$2,760**

[1]Depreciated replacement values (DRVs) presented at October 2017 price levels.
[2]All counts and values represent the entire leveed area (Reach A & Reach B).

3.3.2 Life Safety

This non-structural alternative affects the overall life safety impacts by removing structures through buyouts, or altering the level of inundation anticipated within structures through floodproofing modifications. The buyouts will reduce the population at risk in the areas anticipated to receive the highest depths of flooding (greater than 3 feet), while the floodproofed structures would reduce the exposure of the population residing in modified buildings. This alternative does not eliminate the risk to life safety, but it does result in a significant risk reduction.

3.3.2.1 Flood Warning Time

The flood warning time remains the same as the FWOP (section 2.3.2.1) as neither the hazard nor levee performance are altered under this alternative.

3.3.2.2 Depth of Flooding

The depth of flooding remains the same as the FWOP (section 2.3.2.2) as neither the hazard nor levee performance are altered under this alternative.

3.3.3 Stage-Damage

The buyout of 21 structures and floodproofing modifications to 7 structures within Reach A results in a reduction of potential damages as compared to the without project condition. For example (Table 12) if the landside area were inundated to an elevation of 599 feet, the study area would be expected to experience $496,100 in damages after non-structural modifications as compared to $2,514,900 for the FWOP condition.

Table 12. Aggregated Stage-Damage Function for Non-Structural Alternative (Reach A)

River Stage	Damages by Category in Thousands				Total
	Structures & Contents		Other Damages		
	Residential	Non-Residential	Vehicles	Emergency	
591	$0.0	$0.0	$0.0	$0.0	$0.0
592	$0.0	$0.0	$2.4	$0.0	$2.4
593	$0.0	$0.0	$9.8	$0.0	$9.8
594	$0.0	$0.0	$22.1	$0.0	$22.1
595	$0.0	$0.4	$53.5	$0.0	$53.8
596	$0.0	$1.9	$109.8	$0.0	$111.7
597	$0.0	$3.3	$194.8	$0.0	$198.0
598	$0.0	$6.0	$316.7	$0.0	$322.7
599	$0.0	$9.0	$453.1	$34.0	$496.1
600	$0.0	$13.3	$619.2	$34.2	$666.8
601	$0.0	$16.3	$798.9	$34.5	$849.7
602	$0.0	$20.0	$986.3	$34.7	$1,041.0
603	$0.0	$22.4	$1,200.6	$34.9	$1,257.9

HEC-FDA Output; October 2017 Price Levels

The buyout of 6 structures and floodproofing modifications to 12 structures within Reach B results in a reduction of potential damages as compared to the without project condition (Table 13). For example, if the landside area were inundated to an elevation of 599 feet, the study area would be expected to experience $66,000 in damages after non-structural modifications as compared to $394,400 for the without project condition.

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Table 13. Aggregated Stage-Damage Function for Non-Structural Alternative (Reach B)

River Stage	Damages by Category in Thousands				Total
	Structures & Contents		Other Damages		
	Residential	Non-Residential	Vehicles	Emergency	
591	$0.0	$0.0	$0.0	$0.0	$0.0
592	$0.0	$0.0	$0.0	$0.0	$0.0
593	$0.0	$0.0	$0.0	$0.0	$0.0
594	$0.0	$0.0	$0.0	$0.0	$0.0
595	$0.0	$0.0	$0.0	$0.0	$0.0
596	$0.0	$0.0	$0.0	$0.0	$0.0
597	$7.4	$0.0	$0.0	$0.0	$7.4
598	$26.0	$0.0	$0.0	$0.0	$26.0
599	$66.0	$0.0	$0.0	$0.0	$66.0
600	$156.4	$0.0	$0.0	$0.0	$156.4
601	$306.7	$0.0	$0.0	$8.3	$315.0
602	$536.1	$0.0	$0.0	$33.1	$569.1
603	$845.0	$0.0	$0.0	$65.1	$910.1
HEC-FDA Output; October 2017 Price Levels					

4 Levee Repair Alternatives

Potential project alternatives are to be compared to the FWOP condition (ER 1105-2-100). For the purpose of this analysis, the FWOP is assumed to be essentially the same as the existing condition (see section 2).

Alternative 2A (McCook Existing Levee Repair) – This alternative was developed by identifying which structural issues needed to be addressed in order for the levee to perform as designed. Currently, the levee is faced with many deficiencies and has a crest elevation of 600.6 feet. After this levee is repaired, in its current configuration, it would have a crest elevation of 602.5 feet and would be expected to withstand a full loading without breaching.

Alternative 2Ba (West Lyons Existing Levee Repair with Existing Freeboard) – This alternative was developed by identifying which structural issues needed to be addressed in order for the levee to perform as designed. Currently, the levee is faced with many deficiencies and has a crest elevation of 602.4 feet. After this levee is repaired, in its current configuration, it would have a crest elevation of 602.5 feet and would be expected to withstand a full loading without breaching.

Alternative 2Bb (West Lyons Existing Levee Repair with Two Feet of Freeboard) – This alternative was developed by identifying which structural issues needed to be addressed in order for the levee to perform as designed. Currently, the levee is faced with many deficiencies and has a crest elevation of 602.4 feet. After this levee is repaired, in its current configuration, it would have a crest elevation of 603 feet and would be expected to withstand a full loading without breaching.

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Alternative 3A (McCook Segmented Repair) – This alternative was developed by identifying which structural issues needed to be addressed in order for the levee to perform as designed. Currently, the levee is faced with many deficiencies and has a crest elevation of 600.6 feet. After this levee is repaired, it would have a crest elevation of 602.5 feet and would be expected to withstand a full loading. The configuration of the levee will be slightly altered, reducing the total length of levee to be repaired.

4.1 Hazard

The hazard remains unchanged under this set of alternatives as no modifications are made which would affect river flows or stages. Therefore, these alternatives use the same H&H information as the without project condition (see section 2.2). Finally, each of these alternatives was designed to be compliant with the Illinois State Department of Natural Resources (IDNR) regulations regarding the need to avoid increasing flood stages for events up to the 0.01 ACE (100-yr recurrence interval) event.

4.2 Performance

Since this set of alternatives deals with modifications to the levee, the performance is expected to improve as compared to the without project condition. It is assumed that the repair of the levees, to current standards, would essentially eliminate the risk of the levees breaching. This near-zero risk of failure is analyzed in HEC-FDA as a levee that will not breach prior to overtopping. However, the residual risk of flooding due to an event that exceeds the crest elevation (overtopping) remains.

The long-term conditional non-exceedance probability by events for the without project condition and with-project alternatives is discussed in section 5.1.4 and displayed in Table 26 and Table 27.

4.3 Consequences

These alternatives do not directly alter the consequences, as such the economic inputs for these alternatives remain the same as the FWOP condition (section 2.3).

4.3.1 Structure Inventory

The structure inventory for the levee modification alternatives remains the same as the FWOP condition.

4.3.2 Life Safety

Based on the modifications made under these alternatives, the risk to life safety is anticipated to be greatly reduced, primarily through the increase in flood warning time.

4.3.2.1 Flood Warning Time

The flood warning time, at individual structures, is anticipated to be significantly increased through the various levee repair alternatives. By addressing performance concerns, the levee would be anticipated to withstand a full loading as well as overtopping events. While the hazard remains the same, the performance improvements would “buy time” for evacuation. The flood warning plan and river gage could inform the population to the possibility of the levee being overtopped, providing ample time to plan evacuation as the river approaches the crest elevation. Through these performance modifications, the risk to life safety remains, but is expected to be significantly reduced.

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4.3.2.2 Depth of Flooding

The depth of flooding remains the same as the FWOP (section 2.3.2.2) as neither the hazard nor levee performance are altered under this alternative.

4.3.3 Stage-Damage

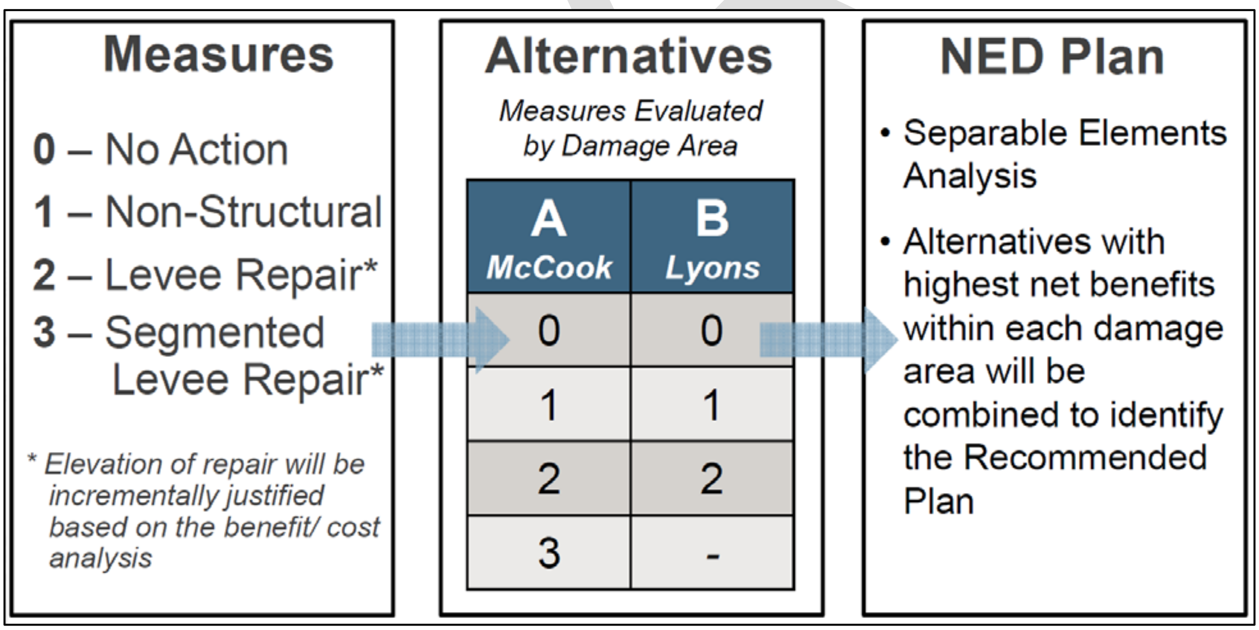
The stage-damage curves for the levee modification alternatives remain the same as the future without project condition, see section 2.3.4.

5 Alternative Evaluation and Comparison

The alternative evaluation and comparison planning steps require an examination of the potential risk across several categories (economic, engineering, environmental). The following sections describe the alternative impacts based on monetary damages and damage reductions, while other impacts are discussed in the main report.

Each alternative was developed as a separate element. The evaluation and comparison process is used to identify the alternatives which maximize net benefits, then possibly combine an alternative for each reach, if it incrementally increases the total net benefit. Figure 5 provides a conceptual outline the alternatives which have been discussed herein.

Figure 5. Measures to Alternatives to NED Plan



5.1 Benefit-Cost Analysis

The benefit-cost analysis is completed to assist in the identification of the recommended plan. The primary selection criteria is for the recommended plan to "reasonably maximize net benefits" (ER 1105-2-100). The economic evaluation is not the sole metric to be used in plan selection, so this final decision is documented in the main report. The following sections outline the estimates used for the economic evaluation of alternatives, including the amortization of project costs and benefits.

5.1.1 Project Benefits

The project benefits were estimated using the previously discussed inputs and software. Table 14 the average annual damages for the future without project condition, the with project condition for each alternative, the damages reduced by alternative, and the probability distribution of damages reduced by alternative. For example, the average without project damages for Reach A were estimated to be $587,800, while Alternative 1A would be expected to reduce these damages by $472,600. And we have a confidence level of 75 percent that the expected annual damages reduced by this alternative exceeds $371,900. Based on the economic information outlined in Table 14, alternatives 2 and 3 reduce more damages than Alternative 1.

Table 14. Expected Annual Damages by Alternative

McCook Study Alternative Evaluation								
Stream Information			(EAD in $1,000)			Probability Damage Reduced Exceeds Indicated Values		
Alternative Description	Alternative	Damage Reach Description	Total Without Project	Total With Project	Damage Reduced	0.75	0.5	0.25
Alt. 1 Non-Structural Improvements	1A	Reach A 47th to Lawndale	$587.8	$115.2	$472.6	$371.9	$460.9	$559.3
	1B	Reach B 45th to 47th	$67.5	$15.2	$52.4	$43.2	$51.3	$60.4
Alt. 2 Repair Existing Levee	2A	Reach A 47th to Lawndale	$587.8	$3.7	$584.1	$463.0	$572.8	$694.6
	2Ba	Reach B 45th to 47th	$67.5	$2.0	$65.5	$50.2	$64.1	$79.0
	2Bb	Reach B 45th to 47th	$67.5	$0.03	$67.5	$50.3	$64.2	$81.1
Alt. 3 Segmented Repair	3A	Reach A 47th to Lawndale	$587.8	$3.7	$584.1	$463.0	$572.8	$694.6
October 2017 Price Levels; 2.75% Federal Discount Rate for FY2018; 50 year period of analysis								

5.1.2 Project Costs

Chicago District cost and civil engineers developed quantities and cost estimates for each of the potential alternatives, outlined in the tables below. Each of these cost estimates assumed a three-year construction schedule. The base construction estimate, engineering and design, and construction management costs account for the work necessary to design and build each alternative. The real estate estimate accounts for the costs associated with the lands, easements, rights of way, relocations, and

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disposal (LERRDs) costs. The interest during construction (IDC) accounts for the time value of money, based on the construction schedule and federal discount rate (FDR). For this project, the IDC is based on the assumption that the LERRDs expenditures will occur 2 years prior to the base year (year when benefits begin to accrue), with the design and construction costs occurring in the year leading up to the base year. The total first cost and IDC are summed, then annualized using the FDR over a 50-year period of analysis to develop the annualized first cost. This total is added to the annual operations, maintenance, replacement, repair, and rehabilitation cost estimate in order to estimate the average annual cost associated with each potential alternative.

For each of the following alternatives, the current construction schedule assumes minor expenditures for acquisitions during the first year, primarily LERRDs, followed by the construction starting and completing in year two.

Table 15. Preliminary Alternative Cost Estimates for Reach A

McCook Levee Cost Estimate	Estimated Cost ($1,000)		
	Alt. 1A Non-Structural	Alt. 2A Repair to 602.5 ft	Alt. 3A Segmented Repair to 602.5 ft
Construction[1]	$900	$4,200	$3,800
Engineering and Design (12.5%)	$113	$525	$475
Construction Management (13.5%)	$122	$567	$513
LERRDs	$8,400	$45	$55
Total First Costs	$9,535	$5,337	$4,843
Interest During Construction[2]	$489	$97	$89
Annualized First Costs	$371	$201	$183
Annual OMRR&R	$25	$80	$50
Average Annual Cost	$396	$281	$233

[1] Construction Estimate includes a contingency
[2] Interest During Construction accounts for the time value of money, prior to project implementation
2021 Base Year; October 2017 Price Levels; 2.75% Federal Discount Rate for FY2018; 50 year period of analysis

The interest during construction (IDC) calculations for Reach A alternatives are outlined below, in Table 16. These estimates were derived using end of year compounding over a three year construction schedule. This accounts for the time value of the money used to construct each potential alternative. For each alternative, it was assumed that the LERRDs and Engineering and Design costs, outlined in the table above, would be expended in the first year of project implementation. Then, the construction and construction management costs would be realized in the second and third years, with the project coming “online” prior to the end of year three. The current federal discount rate was used to approximate the time value of money, as is consistent with USACE guidance and procedures.

Table 16. Preliminary Interest During Construction Estimates for Reach A

Reach A Interest During Construction Calculations					
	Year[1]	**2019**	**2020**	**2021**	**Total**
	Period[2]	-2	-1	0	
	Present Worth (PW) Factor[3]	1.0558	1.0275	1.0000	
Alt. 1A Non-Structural	**Construction Cost Schedule**	$8,513	$511	$511	**$9,534**
	PW Costs	$8,987	$525	$511	**$10,023**
	IDC	$475	$14	$0	**$489**
Alt. 2A Repair to 602.5 ft	**Construction Cost Schedule**	$570	$2,384	$2,384	**$5,337**
	PW Costs	$602	$2,449	$2,384	**$5,434**
	IDC	$32	$66	$0	**$97**
Alt. 3A Segmented Repair to 602.5 ft	**Construction Cost Schedule**	$530	$2,157	$2,157	**$4,843**
	PW Costs	$560	$2,216	$2,157	**$4,932**
	IDC	$30	$59	$0	**$89**

[1] Year refers to the year in which project costs occur
[2] Period refers to the relative timing of expenditures as compared to the year in which project implementation is complete, or begins accruing benefits
[3] The present worth factor is derived using end of year compounding and the current federal discount rate

The preliminary cost estimates for Reach B alternatives are displayed below in Table 17, followed by the IDC calculations for Reach B alternatives in Table 18.

Table 17. Preliminary Alternative Cost Estimates for Reach B

McCook Levee Cost Estimate	**Estimated Cost ($1,000)**		
	Alt. 1B Non-Structural	**Alt. 2Ba Repair to 602.5 ft**	**Alt. 2Bb Repair to 603 ft**
Construction[1]	$1,000	$500	$1,200
Engineering and Design (12.5%)	$125	$63	$150
Construction Management (13.5%)	$135	$68	$162
LERRDs	$1,500	$21	$21
Total First Costs	$2,760	$650	$1,533
Interest During Construction[2]	$106	$12	$28
Annualized First Costs	$106	$25	$58
Annual OMRR&R	$15	$25	$25
Average Annual Cost	$121	$50	$83

[1] Construction Estimate includes a contingency
[2] Interest During Construction accounts for the time value of money, prior to project implementation
2021 Base Year; October 2017 Price Levels; 2.75% Federal Discount Rate for FY2018; 50 year period of analysis

Table 18. Preliminary Interest During Construction Estimates for Reach B

Reach B Interest During Construction Calculations					
	Year[1]	**2019**	**2020**	**2021**	**Total**
	Period[2]	-2	-1	0	
	Present Worth (PW) Factor[3]	1.0558	1.0275	1.0000	
Alt. 1B Non-Structural	**Construction Cost Schedule**	$1,625	$568	$568	**$2,760**
	PW Costs	$1,716	$583	$568	**$2,866**
	IDC	$91	$16	$0	**$106**
Alt. 2Ba Repair to 602.5 ft	**Construction Cost Schedule**	$83	$284	$284	**$651**
	PW Costs	$88	$292	$284	**$663**
	IDC	$5	$8	$0	**$12**
Alt. 2Bb Repair to 603 ft	**Construction Cost Schedule**	$171	$681	$681	**$1,533**
	PW Costs	$181	$700	$681	**$1,561**
	IDC	$10	$19	$0	**$28**

[1] Year refers to the year in which project costs occur
[2] Period refers to the relative timing of expenditures as compared to the year in which project implementation is complete, or begins accruing benefits
[3] The present worth factor is derived using end of year compounding and the current federal discount rate

5.1.3 The National Economic Development (NED) Plan

The NED plan is determined by comparing average annual net benefits (AANB), the difference between AAB and AAC. Based on the economic criteria, the NED plan should consist of Alternative 3A (segmented repair) and Alternative 2Ba (repair existing levee), as these each maximize net benefits.

Table 19. Preliminary Net Benefits

Reach	**Plan Name**	**Plan Description**	**Values in Thousands**		
			Average Annual Benefits	**Average Annual Costs**	**Average Annual Net Benefits**
Reach A - 47th to Lawndale	Alt. 1A	Non-Structural Improvements	$473	$396	$77
	Alt. 2A	Repair Existing Levee (602.5 ft)	$584	$281	$303
	Alt. 3A	Segmented Repair (602.5 ft)	$584	$233	$351
Reach B - 45th to 47th	Alt. 1B	Non-Structural Improvements	$52	$121	($69)
	Alt. 2Ba	Repair Existing Levee (602.5 ft)	$65	$50	$15
	Alt. 2Bb	Repair Existing Levee (603 ft)	$67	$83	($16)

October 2017 Price Levels; 2.75% Federal Discount Rate for FY2018; 50 year period of analysis

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5.1.3.1 Recommended Plan Certified Costs

For this project, the NED plan is the recommended plan. Once the recommended plan has been identified, the cost engineers perform a final review and update of the total plan to provide a better understanding of the necessary investment and implementation assumptions. This process results in a "certified" cost estimate, which typically varies from the parametric, or preliminary estimates used for plan formulation. This final cost estimate is used for making a final determination regarding the project's feasibility, budgeting decisions, and potential cost sharing agreements for project implementation. The certified estimate and the annualized economic cost is provided below, in Table 20.

Table 20. Certified Cost Estimate for the Recommended Plan

McCook Levee Recommended Plan Cost Estimate	**Estimated Cost ($1,000)** **Alt. 3A & 2Ba Segmented Repair To 602.5 ft**
Construction[1]	$4,182
Engineering and Design (15.6%)	$652
Construction Management (8.8%)	$367
LERRDs	$111
Total First Costs	$5,312
Interest During Construction2	$105
Annualized First Costs	$201
Annual OMRR&R	$76
Average Annual Cost	$277

[1] Construction Estimate includes a contingency
[2] Interest During Construction accounts for the time value of money, prior to project implementation
2021 Base Year; October 2017 Price Levels; 2.75% Federal Discount Rate for FY2018; 50 year period of analysis

Below, Table 21 outlines the IDC estimate for the recommended plan. The same methods were followed as presented in section 5.1.2. This plan assumes a three year implementation schedule with real estate acquisitions and engineering & design occurring two years prior to the base year, then construction continuing in the following two years. The construction expenditures were assumed to occur equally during 2020 and 2021.

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Table 21. IDC Calculations for the Recommended Plan

Recommended Plan Interest During Construction Calculations					
	Year[1]	2019	2020	2021	Total
	Period[2]	-2	-1	0	
	Present Worth (PW) Factor[3]	1.0558	1.0275	1.0000	
Alt. 3A & Alt. 2Ba	Construction Cost Schedule	$763	$2,275	$2,275	$5,312
	PW Costs	$806	$2,337	$2,275	$5,417
	IDC	$43	$63	$0	$105

[1] Year refers to the year in which project costs occur
[2] Period refers to the relative timing of expenditures as compared to the year in which project implementation is complete, or begins accruing benefits
[3] The present worth factor is derived using end of year compounding and the current federal discount rate

5.1.3.2 Recommended Plan Benefit to Cost Ratio (BCR)

Plan selection is based on optimizing net benefits, but budgetary decisions typically rely on an estimate of the return on investment, or the BCR. To estimate the BCR associated with the recommended plan, the annualized benefits are divided by the annualized costs. Since the same economic evaluation analyses were used in the plan formulation phase, the benefit estimates displayed below remain the unchanged. The costs used for the BCR comparison rely on the certified cost estimate, displayed above in section 5.1.3.1. Below, displays the BCR for the recommended plan as a single point estimate. This BCR is based on the average annual benefit and the 80% confidence interval for the cost estimate.

Table 22. Recommended Plan BCR

Recommended Plan					
Alternative Name	Alternative Description	Average Annual Benefits	Average Annual Costs	Average Annual Net Benefits	BCR
Alt. 3A & 2Ba	Segmented Repair of Reach A and Repair Existing Reach B Levee to 602.5 ft	$650	$277	$373	2.3

October 2017 Price Levels; 2.75% Federal Discount Rate for FY2018; 50 year period of analysis

5.1.3.2.1 Complete Cost and Benefit Distributions for the Recommended Plan

While the averages and distributions developed thus far in this Economics Appendix provide enough information to make a risk-informed decision regarding the NED plan, they do not account for the uncertainty in levee performance, or the full distribution of cost estimates. By combining these two pieces of information, with the information already presented, decision-makers can have a clearer understanding regarding the expected economic performance of the NED plan.

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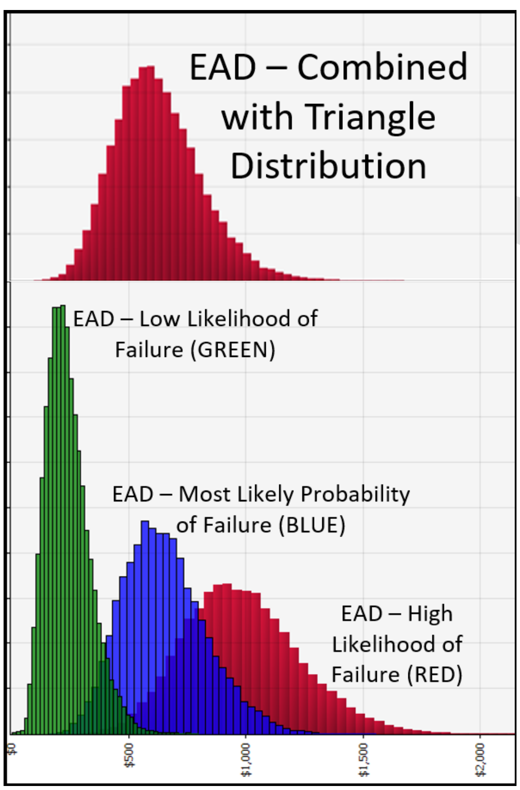
The development of the full benefit distribution required two additional HEC-FDA runs, accounting for the high and low likelihoods of failure in the benefit estimate. HEC-FDA does not account for levee fragility internally, so this estimate was performed by importing the various recommended plan benefit distributions into @Risk (an Excel add-on). The cumulative damage distributions for three failure scenarios were used as the high, most likely, and low parameters for a triangle distribution. A Monte-Carlo simulation (50,000 iterations) combined these three benefit distributions into a single distribution, using the high, most likely, and low scenarios as parameters for a triangle distribution. The triangle distribution was selected for this combined estimate because it is a continuous, left and right bounded distribution which pairs well with datasets where a minimum, maximum, and most likely can be easily identified. Table 23 displays these distribution results, comparing the full distribution of benefits to the initial most likely distribution.

Below, Figure 6 displays the probability density functions (PDFs) for each of the EAD distributions for the various levee failure scenarios, with green PDF referring to the EAD for the low likelihood of failure scenario, the blue PDF representing the most likely, and the red representing the high likelihood. The combined EAD displayed at the top of the figure. Each of the bottom three distributions were sampled with the returned value, in order of smallest to largest, used as the appropriate parameter in defining a triangle distribution. The resulting distribution is the combined distribution displayed at the top of the figure. Each of these PDFs are displayed in the same scale.

Figure 6. EAD Distribution Comparison



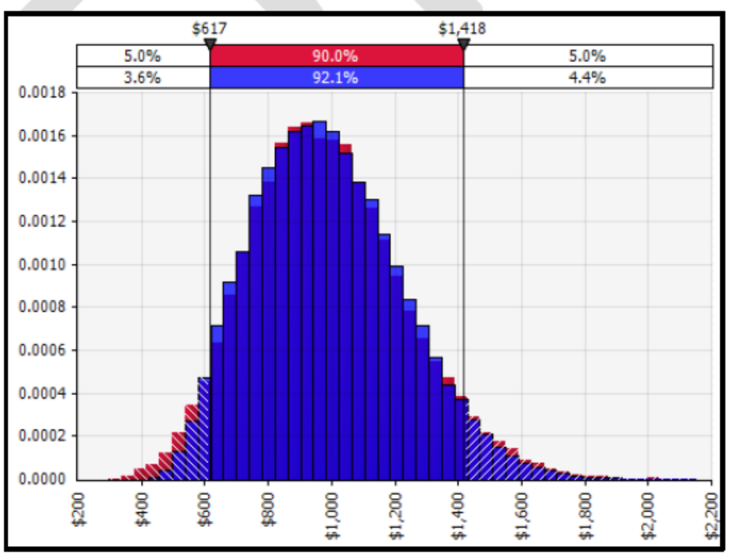
A comparison of the various scenarios and the associated five number summaries provides a clearer picture of the impacts of the uncertainty associated with levee performance. While the mean estimates for the combined expected annual damages (EAD) for the most likely and combined (triangle distribution) are relatively close, it is clear that the inclusion of the high likelihood and low likelihood scenarios have increased the spread of the overall EAD distribution (Table 23).

Table 23. Benefit Distributions with Levee Fragility Uncertainty

	Mean & Five Number Summary ($1,000)					
	Mean	Minimum	25th Percentile	50th Percentile	75th Percentile	Maximum
High Likelihood of Failure	$987	$295	$814	$970	$1,141	$2,158
M. Likely P(f)	$651	$161	$525	$636	$760	$1,552
Low Likelihood of Failure	$241	$3	$176	$229	$295	$798
EAD Reduced - Triangle	$626	$100	$496	$609	$738	$1,676
October 2017 Price Levels; 2.75% Federal Discount Rate for FY2018						

The Weibull distribution was selected for defining the uncertainty surrounding cost estimates because it is an asymmetrical continuous distribution which is flexible enough to represent various other distribution curves such the normal, logarithmic, and exponential distributions. This asymmetric shape works well for these economic variables because benefits and costs are bounded on the small end (cannot be negative in this case) and theoretically unbounded on the large end (tend to have small probabilities of relatively large values). This curve behavior is displayed in below in Figure 7. This figure provides a comparison of the PDFs where the red PDF is defined using the cumulative distribution of benefits from HEC-FDA for the high likelihood of failure scenario and the blue PDF is a Weibull distribution defined solely by the 25th, 50th, and 75th percentile values from HEC-FDA for the same scenario (Table 23). While the figure was produced using benefit information, the same relationships generally hold true for the shape of cost estimates.

Figure 7. Weibull Distribution Example



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The next step in creating a probabilistic BCR required accounting for the full cost distribution, rather than the 80 percent confidence estimate which is reported on the Total Project Cost Summary (TPCS). Since the project cost estimate falls below that which is a full cost-schedule risk analysis is required (by policy), the abbreviated risk analysis was used to estimate the amount of contingency required. This method produces only three estimates- the base estimate (equal to the 5th percentile), the 50th percentile, and the 80th percentile estimates. As discussed in the paragraph above, it was assumed that the Weibull distribution would be an appropriate proxy. The parameters for this proxy distribution were defined by the three percentile estimates provided by the cost engineer. The resulting cost distribution is displayed below, in Table 24.

Additionally, the uncertainty surrounding the OMRR&R and real estate estimates was also included using Weibull distributions. While each of these estimates were provided with defined 5th and 80th percentiles, the Beta parameter still had to be estimated in order to create an approximate distribution. In each case, the Beta was unknown, but adjusted to produce what is believed to be a reasonable estimate of the spread of potential costs.

Table 24. Cost Distribution for the Recommended Plan

	Mean & Five Number Summary ($1,000)					
	Mean	Minimum	25th Percentile	50th Percentile	75th Percentile	Maximum
Project First Cost	$4,801	$3,797	$4,445	$4,759	$5,110	$7,236
Real Estate Cost	$107	$98	$104	$107	$110	$130
Interest During Construction	$97	$77	$90	$96	$103	$145
Average Annual OMRR&R	$67	$51	$58	$65	$74	$160
Total Average Annual Project Cost	$253	$202	$237	$251	$266	$361
October 2017 Price Levels; 2.75% Federal Discount Rate for FY2018						

Finally, the total cost and benefit distributions were used to estimate the probabilistic distributions for the BCR and net benefits. These estimates, including their five number summaries, are displayed in Table 25. For example, the recommended plan is expected to produce in $626,000 in average annual benefits, with an expected annual cost of $253,000, resulting in expected annual net benefits of $374,000, and average BCR of 2.5. These averages are similar to those displayed in section 5.1, but the distributions are more clearly defined and the values presented represent the full distribution of possible values, rather than single point estimates.

The five number summaries serve to define those distributions, identifying the estimates for each quartile. These quartile values can be interpreted as the probability that the estimated value will exceed a given percentage of time, or the confidence that we expect a value to be met or exceeded. For example, we are 75 percent confident that the project's BCR will equal or exceed 2.0 and 25 percent confident that the project's BCR will equal or exceed 3.0. By displaying these ranges, decision makers can better understand the potential uncertainty in costs and benefits associated with the recommended plan.

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Table 25. Probabilistic Benefit to Cost Ratios for the Recommended Plan

	Mean & Five Number Summary ($1,000)					
	Mean	Minimum	25th Percentile	50th Percentile	75th Percentile	Maximum
Expected Annual Benefits	$626	$100	$496	$609	$738	$1,676
Expected Annual Costs	$253	$202	$237	$251	$266	$361
Expected Annual Net Benefits	$374	-$143	$242	$357	$487	$1,437
Benefit to Cost Ratio	2.5	0.42	2.0	2.4	3.0	7.0

October 2017 Price Levels; 2.75% Federal Discount Rate for FY2018

5.1.4 Long-Term Project Performance

The conditional probability of design non-exceedance for each alternative, covering a range of flood frequencies, is provided in the table below. For example, the probability of non-exceedance for the 0.02 ACE (50-year recurrence interval) flood event for the levee under alternative 3A is estimated at 100 percent. This can also be stated as, "100 percent of 0.02 ACE (50-year recurrence interval) flood events will be contained by the levee under alternative 3A." These values were derived for the best estimate case, or most likely probability of failure scenario for the without project condition.

Category Definitions:

(1) Target Stage Annual Exceedance: the probability that the river stage will exceed the levee crest elevation in any given year;
(2) Long-Term Exceedance Probability: the probability that the river stage will exceed the levee crest elevation in a 10, 30, or 50 year period;
(3) Conditional Non-Exceedance Probability by Events: the probability that a given storm event will result in a river stage that does not exceed the levee crest elevation.

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Table 26. Long-Term Project Performance (Reach A)

Reach A[1]		Without Project[2] (600.6 ft)	1A - Non-Structural[2] (600.6 ft)	2A - Levee Repair (602.5 ft)	3A - Levee Repair (602.5 ft)
Target Stage Annual Exceedance Probability	Median	0.42	0.42	0.00	0.00
	Expected	0.42	0.42	0.00	0.00
Long-Term Exceedance Probability	10 yrs	1.00	1.00	0.01	0.01
	30 yrs	1.00	1.00	0.03	0.03
	50 yrs	1.00	1.00	0.04	0.04
Conditional Non-Exceedance Probability by Events	0.1	0.33	0.33	1.00	1.00
	0.04	0.23	0.23	1.00	1.00
	0.02	0.14	0.14	1.00	1.00
	0.01	0.06	0.06	0.99	0.99
	0.004	0.01	0.01	0.93	0.93
	0.002	0.00	0.00	0.88	0.88

[1] HEC-FDA Output
[2] Best estimate case, or most likely probability of failure

Table 27. Long-Term Project Performance (Reach B)

Reach B[1]		Without Project[2] (602.4 ft)	1B - Non-Structural[2] (602.4 ft)	2Ba - Levee Repair (602.5 ft)	2Bb - Levee Repair (603 ft)
Target Stage Annual Exceedance Probability	Median	0.22	0.22	0.00	0.00
	Expected	0.23	0.23	0.00	0.00
Long-Term Exceedance Probability	10 yrs	0.92	0.92	0.01	0.00
	30 yrs	1.00	1.00	0.04	0.00
	50 yrs	1.00	1.00	0.07	0.01
Conditional Non-Exceedance Probability by Events	0.1	0.54	0.54	1.00	1.00
	0.04	0.44	0.43	1.00	1.00
	0.02	0.36	0.36	1.00	1.00
	0.01	0.29	0.29	0.97	1.00
	0.004	0.20	0.20	0.89	1.00
	0.002	0.14	0.14	0.79	1.00

[1] HEC-FDA Output
[2] Best estimate case, or most likely probability of failure

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