Appendix I
Economics

Table of Contents

Appendix I. Economics

1 BACKGROUND INFORMATION

1.1 INTRODUCTION

General. This appendix presents an economic evaluation of the riverine flood risk reduction measures for the River des Peres General Re-Evaluation Report. The evaluation area includes the section of the River Des Peres watershed within University City, Missouri, as well as a small portion upstream in Overland and Olivette. The report was prepared in accordance with Engineering Regulation (ER) 1105-2-100, Planning Guidance Notebook, and ER 1105-2-101, Planning Guidance, Risk Analysis for Flood Damage Reduction Studies. The National Economic Development Procedures Manual for Flood Risk Management and Coastal Storm Risk Management, prepared by the Water Resources Support Center, Institute for Water Resources, was also used as a reference, along with the User's Manual for the Hydrologic Engineering Center Flood Damage Analysis Model (HEC-FDA).

The economic appendix consists of a description of the methodology used to determine National Economic Development (NED) damages and benefits under existing conditions, Regional Economic Development (RED) values, and project costs. During 2021, the damages and costs of all alternatives in the final array were calculated using the FY 2021 Federal discount rate of 2.5 percent and a period of analysis with the year 2025 as the base year. Subsequent refinement of the alternatives that had positive net annual benefits (Alternatives 2, 3a, 3b, 6, and 8) resulted in updated costs which were calculated using FY 2022 price levels and annualized using the FY 2022 Federal discount rate of 2.25 percent and a period of analysis of 50 years with the year 2025 as the base year. The expected annual damage and benefit estimates were compared to the annual construction costs and the associated OMRR&R costs for each of the project measures.

Past Flood Damages. Flood damages from the upper River Des Peres in University City have been documented since at least the 1980s, but especially recently. Damages from major flood events occurred in 2008, 2011, 2013, 2014, 2019, and 2020. The flood event of 2008 saw two fatalities, while significant damage to structures has been recorded in other years. The city's dated sewer system is overtopped during flood events, which causes the system to discharge untreated sewage into the River Des Peres.

NED Benefit Categories Considered. The NED procedure manuals for riverine and urban areas recognize four primary categories of benefits for flood risk management measures: inundation reduction, intensification, location, and employment benefits. Most of the benefits attributable to a project measure generally result from the reduction of actual or potential damages caused by inundation. Inundation reduction includes the reduction of physical damages to structures, contents, and vehicles and indirect losses to the national economy.

Physical Flood Damage Reduction. Physical flood damage reduction benefits include the decrease in potential damages to residential and commercial structures and their contents.

Emergency Cost Reduction Benefits. Emergency costs are those costs incurred by a community during and immediately following a major storm. Emergency costs for this study include travel, meal, cleanup supplies, unpaid labor, and vandalism costs. These costs were applied to residential structures.

NED Benefit Categories NOT Considered. The NED benefit categories not addressed in this economic appendix prior to selection of a Tentatively Selected Plan (TSP) include the following:

- Indirect losses to the national economy as a result of disruptions in the production of goods and services by industries affected by the storm or riverine flooding
- Increased cost of operations for industrial facilities following a flood event relative to normal business operations
- Physical loss of agricultural crops grown to be sold for commercial profit
- Traffic detour time due to flooded roadways

Regional Economic Development. When the economic activity lost in a flooded region can be transferred to another area or region in the national economy, these losses cannot be included in the NED account. However, the impacts on the employment, income, and output of the regional economy are considered part of the RED account. The input-output macroeconomic model RECONS is used to address the impacts of the construction spending associated with the project alternatives. The Economic Consequence Assessment Model (ECAM) is another RED model utilized by this study to measure the effects of unmitigated floodwaters on regional production and employment.

Other Social Effects. The other social effects (OSE) account includes impacts to life safety, vulnerable populations, local economic vitality, and community optimism. Impacts on these topics are a natural outcome of civil works projects and are most qualitatively discussed in the OSE account. Life loss modeling software such as HEC-LifeSim can quantify loss of life for a given alternative to determine if life safety risk decreases or is induced as a result of federal investment. Depth and velocity flood forces are examined to determine critical road segments that pose a risk of life loss in the existing condition. A LifeSim model was developed to measure the existing condition risk of life loss, as well as the impact of proposed infrastructure and the detailed results are outlined in Appendix K – Life Safety Risk Assessment.

1.2 DESCRIPTION OF THE STUDY AREA

Geographic Location. The study area is located on the eastern border of St. Louis County and includes the University City portion of the River Des Peres, as well as a small portion of the river upstream in Overland and Olivette. The study area is largely urban with mostly residential structures. An inventory of residential and non-residential structures was developed using the National Structure Inventory (NSI) version 2.0 for the portions of the county impacted by riverine flooding. The structure inventory for the economic analysis includes all structures within the extent of inundation for the 0.2% annual exceedance probability (AEP) event in the future without project condition. Figure 1 shows the structure inventory and the boundaries of the counties and municipalities.

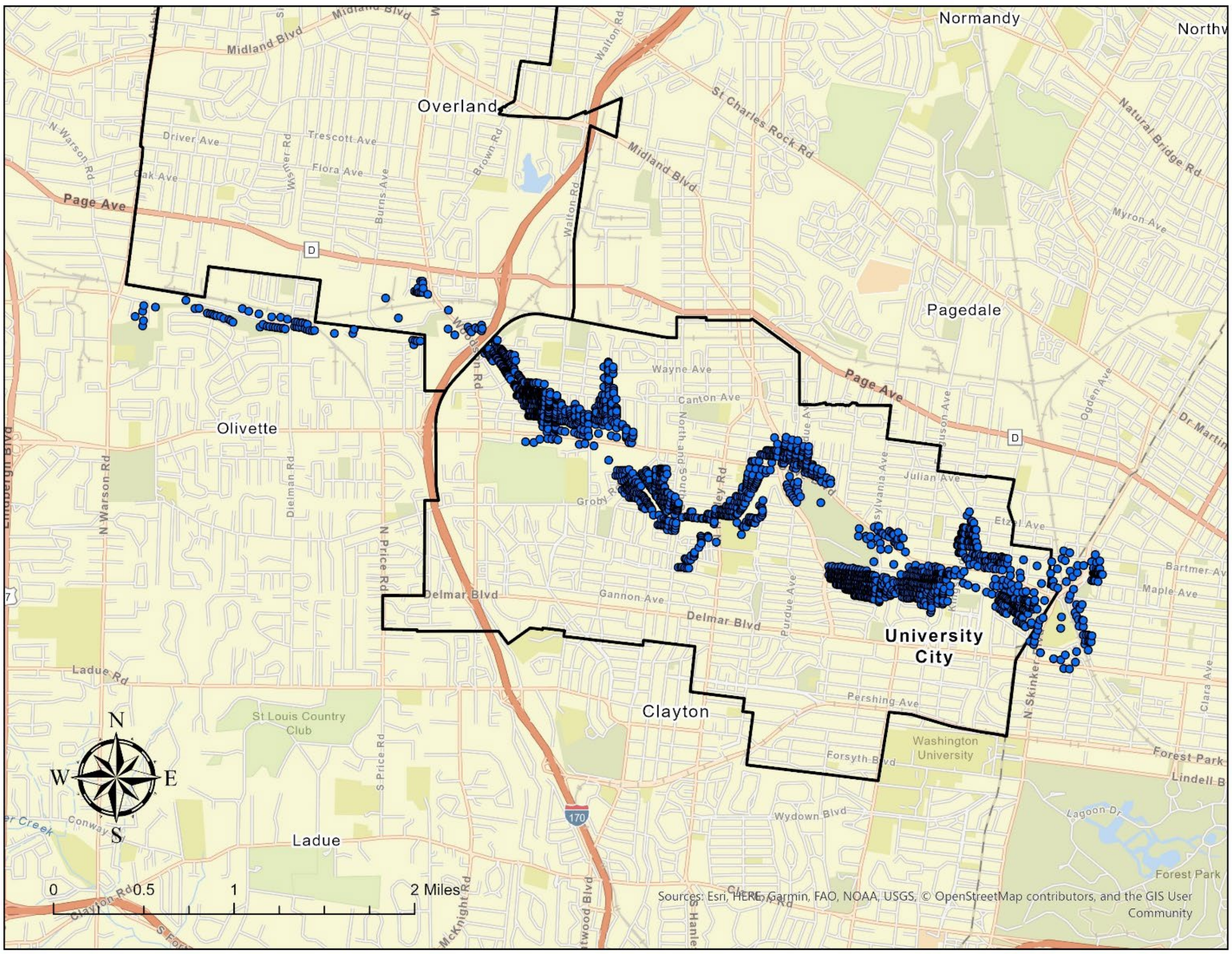

Figure 1. County and Municipal Boundaries, and Structure Inventory

Reaches. The study area was divided into reaches, which were designed by the economist in coordination with the full USACE team and the Flood Risk Management Planning Center of Expertise (FRM-PCX), with a focus on nonstructural aggregation (see criteria on page 8). The reaches begin with Reach 1, which is the furthest upstream, and increase while moving downstream and ending with reach 20. Table 1 shows the structure count by reach and structure type (residential and non-residential). Non-residential structures include commercial, industrial, and public structures. The study area has a total of 1,692 structures. Figure 2 shows the study area reach boundaries.

Table 1. Structure Count by Structure Type and Reach

Reach	Residential Count	Non-Residential Count	Total
1	17	16	33
2	7	18	25
3	12	13	25
4	172	1	173
5	219	3	222
6	6	20	26
7	90	0	90
8	23	0	23
9	28	3	31
10	200	2	202
11	14	18	32
12	97	1	98
13	201	0	201
14	5	27	32
15	123	0	123
16	54	11	65
17	75	18	93
18	3	53	56
19	72	1	73
20	44	25	69
Total	1462	230	1692

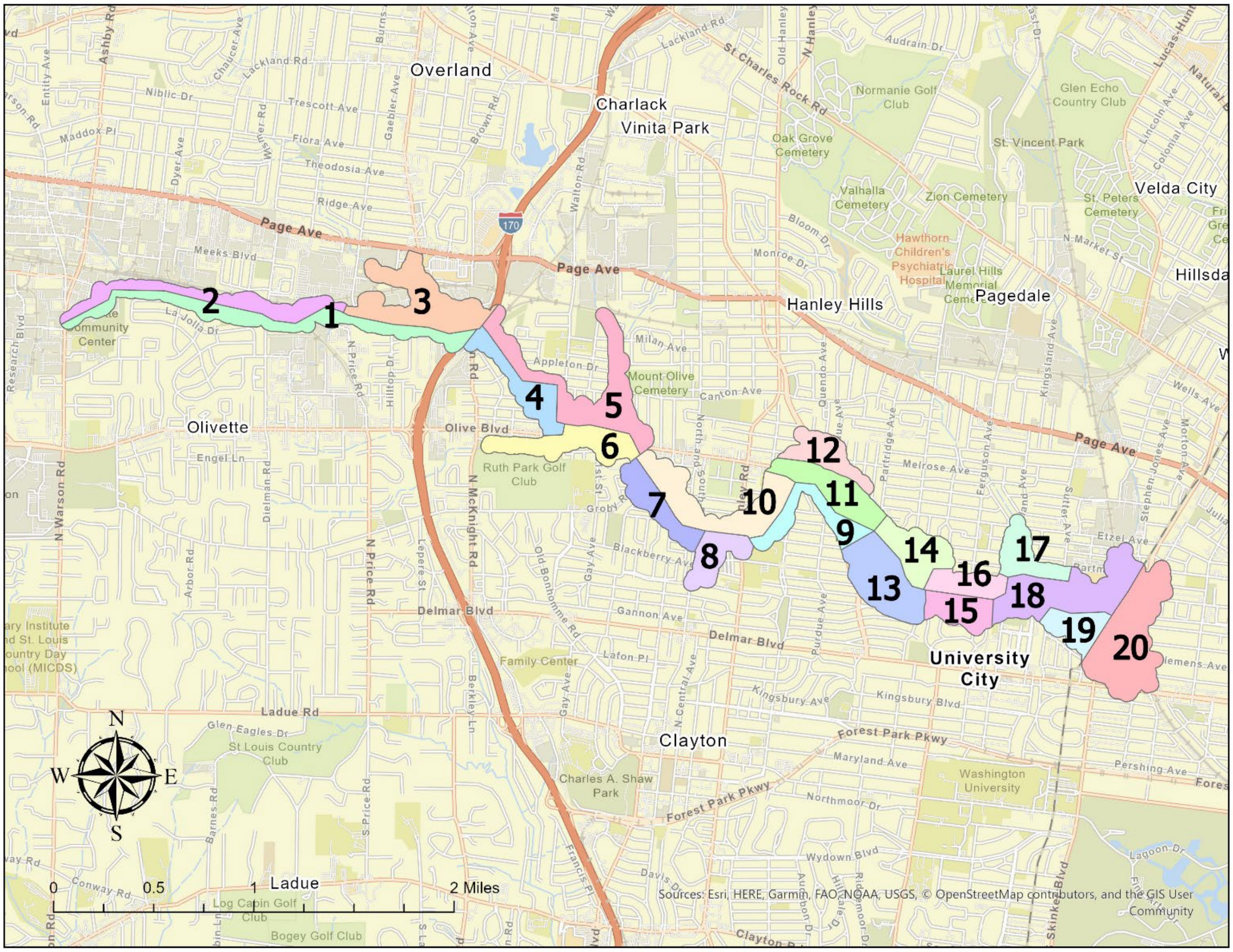

Figure 2. Study Area Reaches

Reaches were designed in part with a focus on nonstructural aggregation. Per USACE National Nonstructural Committee (NNC) guidance, criteria used to delineate the reach boundaries included:

- Hydraulic Characteristics
- Left Bank/Right Bank
- Structure Characteristics
- Structure Type
- Historic Areas or Neighborhoods
- Community Characteristics
- Shared Socioeconomics
- Political Jurisdictions

Table 2 shows a breakdown of each reach and the criteria used to group the structures into individual reaches.

Table 2. Applicable Structure Grouping Criteria by Reach

Reach	Left/Right Bank	Structure Type	Political Jurisdiction	Socioeconomics*	Historic**
1	Right	N/A	Olivette	N/A	N/A
2	Left	N/A	Olivette	N/A	N/A
3	Left	N/A	Overland	N/A	N/A
4	Right	Residential	University City	Yes	N/A
5	Left	Residential	University City	Yes	N/A
6	Right	Non-Residential	University City	N/A	N/A
7	Right	Residential	University City	N/A	N/A
8	Right	Residential	University City	N/A	N/A
9	Right	Residential	University City	N/A	N/A
10	Left	Residential	University City	N/A	N/A
11	Left	N/A	University City	N/A	N/A
12	Left	Residential	University City	N/A	N/A
13	Right	Residential	University City	Yes	N/A
14	Left	Non-Residential	University City	N/A	N/A
15	Right	Residential	University City	N/A	Yes
16	Left	N/A	University City	N/A	N/A
17	N/A	Residential	University City	Yes	N/A
18	N/A	Non-Residential	University City	N/A	N/A
19	N/A	Residential	University City	N/A	N/A
20	N/A	N/A	St. Louis City	N/A	N/A

*High proportion of non-owner occupants

**As indicated by the USACE St. Louis District Archaeologist

1.3 SOCIOECONOMIC SETTING

Population, Number of Households, and Employment. Table 3 shows the population trend in St. Louis County from 1970 to 2010 and projections through 2040. The population total has been largely stagnant for the past fifty years and is expected to remain so in the future. Table 4 shows the number of households over the same period. The total number of households has shown a steady increasing trend from 1970 to 2010 and projections through 2040.

Table 3. Historical and Projected Population

Total Population (Thousands)							
U.S. Census Bureau (BOC); Moody's Analytics (ECCA) Forecast							
1970	1980	1990	2000	2010	2020	2030	2040
953.131	975.090	995.198	1,016.178	998.803	1,002.861	1,004.924	999.196

Sources: 2000, 2010, 2017 from U.S. Census Bureau; 2025, 2045 from Moody's Analytics (ECCA) Forecast

Table 4. Historical and Projected Households

Households (Thousands)							
U.S. Census Bureau (BOC); Moody's Analytics (ECCA) Forecast							
1970	1980	1990	2000	2010	2020	2030	2040
283.691	344.986	380.785	405.177	405.139	429.378	452.144	466.605

Sources: 2000, 2010, 2017 from U.S. Census Bureau; 2025, 2045 from Moody's Analytics (ECCA) Forecast

Table 5 shows the growth of non-farm payrolls since 1970 and projections through 2040. Nonfarm payroll employment is the number of paid US workers in all businesses, excluding those who work for farms, serve in the military, volunteer for nonprofit organizations, and perform unpaid work in their own household. Self-employed, unincorporated individuals are excluded as well. The leading employment sectors for St. Louis County are Office Using Industries, Trade; Transportation; and Utilities, Professional and Business Services, and Education and Health Services. Table 6 shows the Labor Force, Employment, Unemployment, and Unemployment Rate for St. Louis County. Save for shortly after the 2008 recession, employment has been largely flat. Table 7 shows the actual and projected per capita personal income levels for St. Louis County from 1970 through 2040. Income per capita has steadily increased since 1970 and is expected to continue to do so into 2040.

Table 5. Non-farm Payrolls

Employment: Non-Farm Payroll (Thousands)								
U.S. Bureau of Labor Statistics: Census of Employment & Wages (QCEW - ES202); Moody's Analytics (ECCA) Forecast								
	1970	1980	1990	2000	2010	2020	2030	2040
Natural Resources and Mining	0.42	0.38	0.29	0.37	0.21	0.21	0.21	0.21
Construction	11.87	17.57	23.32	35.93	23.89	30.97	31.74	33.66
Manufacturing	76.10	85.56	103.23	78.38	42.86	43.52	39.66	37.90
Food; Beverage; and Tobacco Manufacturing	4.89	5.49	8.29	7.92	3.68	4.48	4.01	3.53
Textile; Fiber; and Printing Manufacturing	10.48	11.98	14.38	10.20	4.78	4.88	4.50	4.29
Chemical; Energy; Plastic; and Rubber Manufacturing	6.07	7.38	8.35	9.56	6.05	7.01	6.62	6.35
Metals and Mining Based Manufacturing	8.11	8.23	7.09	6.70	3.32	3.73	3.14	2.91
Machinery Manufacturing	8.42	8.80	10.73	11.53	4.64	4.66	3.72	3.31
Electronic and Electrical Manufacturing	8.45	9.94	8.31	5.93	2.49	2.83	2.54	2.29
Transportation Equipment Manufacturing	27.75	31.19	43.25	23.84	15.71	13.75	13.17	13.39
Furniture and Misc. Manufacturing	1.92	2.55	2.83	2.69	2.18	2.18	1.97	1.84
Trade; Transportation; and Utilities	74.35	95.57	132.47	137.83	119.32	128.87	129.98	132.39
Wholesale Trade	15.98	24.21	34.97	34.80	33.57	37.13	37.78	38.30
Retail Trade	50.59	58.94	75.48	76.34	66.70	70.03	70.67	72.65
Transportation; Warehousing; and Utilities	7.78	12.41	22.01	26.69	19.05	21.71	21.53	21.43
Transportation and Warehousing	7.38	11.56	21.00	25.99	17.93	20.68	20.62	20.62
Utilities	0.40	0.85	1.01	0.70	1.12	1.02	0.91	0.81
Information	4.88	7.25	11.66	17.46	16.39	14.95	14.87	14.98
Financial Activities	14.66	18.94	35.88	41.94	41.12	48.50	49.71	52.02
Professional and Business Services	25.69	43.24	82.88	111.38	108.05	132.71	144.63	160.60
Education & Health Services	27.55	44.52	62.52	86.64	101.13	115.62	123.35	130.80
Leisure and Hospitality	19.81	34.04	51.77	60.83	57.94	66.63	72.62	80.44
Other Services (except Public Administration)	9.76	13.13	24.16	27.56	20.02	21.17	21.38	21.71
Government	30.91	34.55	44.09	55.97	58.45	52.48	54.57	55.72
Federal Government	3.00	3.41	4.59	5.95	7.23	6.20	6.28	6.35
Local Government	23.77	26.49	33.49	42.17	44.53	41.87	43.84	44.90
State Government	4.15	4.65	6.01	7.84	6.69	4.41	4.45	4.46
Office-using Industries	50.26	76.00	136.76	178.94	172.09	196.19	204.95	217.34
High Technology Industries	14.97	20.59	28.69	38.99	33.07	37.94	40.43	42.46

Table 6. Employment

Labor Force, Employment, Unemployment, and Unemployment Rate						
BLS; Moody's Analytics (ECCA) Forecast						
	1990	2000	2010	2020	2030	2040
Labor Force, (Ths.)	548.297	554.013	535.129	559.041	573.375	593.772
Employment, (Ths.)	524.237	536.744	487.371	538.789	549.765	569.178
Unemployment, (Ths.)	24.061	17.269	47.758	20.252	23.609	24.595
Unemployment Rate, (%)	4.4	3.1	8.9	3.6	4.1	4.1

Table 7. St. Louis County per Capita Income ($)

Income: Per Capita (Dollars)							
U.S. Census Bureau (BOC); Moody's Analytics (ECCA) Forecast							
1970	1980	1990	2000	2010	2020	2030	2040
$5,233	$12,132	$26,074	$41,247	$53,782	$81,596	$118,113	$175,756

Compliance with Policy Guidance Letter (PGL) 25 and Executive Order 11988. Based on the socioeconomic data, St. Louis County has experienced little population and employment growth. Given stagnation, it is expected that little development will occur in the study area with or without riverine flood risk reduction measures, and will not conflict with PGL 25 and EO 11988, which states that the primary objective of a flood risk reduction project is to protect existing development, rather than to make undeveloped land available for more valuable uses.

1.4 CRITICAL INFRASTRUCTURE

The University City Fire Station is the only identified critical infrastructure that may have flood risk, though flood depths are expected to remain at or just below the foundation at the 0.2% AEP event. University City Senior High School is near, but not within, the 0.2% AEP extent. Figure 3 shows the Fire Station and High School as well as the extent of the 0.2% AEP event.

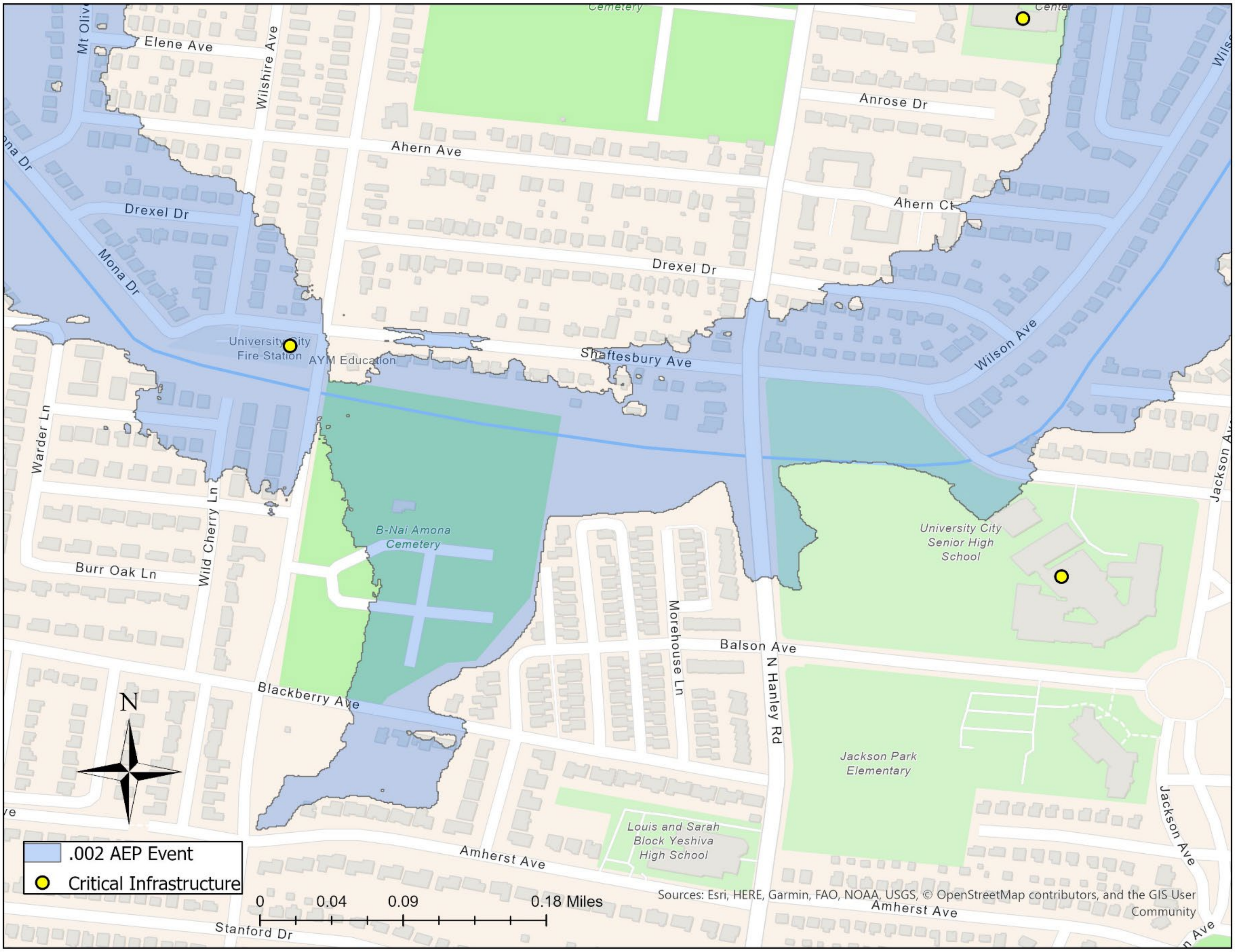

Figure 3. Critical Infrastructure

1.5 SCOPE OF THE STUDY

Problem Description. The study area is mostly an urban setting that is encroaching floodplain boundaries. Flood risk management is the only authorized purpose for the study. Recreation features may be added, if economically justified, within the limits specified by ER 1105-2-100. A total of 8 alternatives were developed for the final array; of these, 5 alternatives were carried forward. Table 8 shows these plans and their descriptions.

Table 8. Array of Alternatives

Alternative	Plan
No Action	1
Modified 1988 Authorized Plan (U12)	2
Detention Basins 3 and 4	3a
Detention Basin 4 (LPP)	3b
Nonstructural Only (Optimized)	6
Detention Basin 4 and Nonstructural (Optimized)	8

NED Plan. The NED plan includes Detention Basin 4 (Alternative 3b). The Detention Basin 4 is also the locally preferred plan.

Other plans in the final array. The other plans in the final array are the Modified 1988 Authorized Plan (Alternative 2, aka U12), Detention Basins 3 and 4 (Alternative 3a), Nonstructural-Only (Alternative 6), and Detention Basin 4 and Nonstructural (Alternative 8).

The criteria by which structures were deemed eligible for nonstructural treatment were established by the USACE team members from the economics, plan formulation, H&H engineering, civil engineering, cost engineering, and structural engineering sections with considerations for the unique characteristics of the study area.

Residential structures with depth of flooding greater than two feet above the first floor (+2 or more ft) were eligible for elevation. Residential structures with basements with substantial flooding below the first floor (-1 to 0 ft) were eligible for basement fill. Non-residential structures with up to three feet of flooding (0 to 3 ft) were eligible for dry floodproofing. Structures eligible for nonstructural treatment with costs of nonstructural treatment exceeding that of acquisition costs were indicated for acquisition. Ultimately, no structures were designated for elevation as it was too costly in all eligible cases.

Costs and benefits were estimated for nonstructural plans that include structures meeting the established criteria at the 10%, 4%, and 2% AEP events. Net benefits were then calculated for each reach and the AEP event (or no action) that reasonably maximized net benefits was chosen to be applied for alternatives 6 and 8. This results in each reach being independently optimized by AEP event to maximize net NED benefits. The results of this optimization are in Table 9.

Table 9. AEP Event Optimization by Reach

Reach	AEP Event
1	No Action
2	2%
3	2%
4	2%
5	2%
6	10%
7	No Action
8	No Action
9	No Action
10	10%
11	2%
12	2%
13	No Action
14	2%
15	2%
16	No Action
17	No Action
18	2%
19	No Action
20	2%

Evaluating a group of structures together instead of individually helps remove bias related to structure values, building type, social status, or any other contributing factor besides the combination of flood frequency and magnitude.

2 ECONOMIC AND ENGINEERING INPUTS TO THE HEC-FDA MODEL

2.1 HEC-FDA MODEL

Model Overview. The Hydrologic Engineering Center Flood Damage Analysis (HEC-FDA) Version 1.4.3 USACE-certified model was used to calculate the damages and benefits for the River Des Peres evaluation. The economic and engineering inputs necessary for the model to calculate damages for the project base year (2025) include the existing condition structure inventory, contents-to-structure value ratios, first floor and ground elevations, depth-damage relationships, and without-project and with-project stage-probability relationships.

The uncertainty surrounding each of the economic and engineering variables was also entered into the model. Either a normal probability distribution, with a mean value and a standard deviation, or a triangular probability distribution, with a most likely, a maximum and a minimum value, was entered into the model to quantify the uncertainty associated with the key economic variables. A normal probability distribution was entered into the model to quantify the uncertainty surrounding the ground elevations. A 50-year period of record was used to quantify the hydrologic uncertainty or error surrounding the stage-probability relationships in consultation with the H&H engineer.

The following economic inputs section is divided into four primary components:

1) **Structure Inventory** – discusses methodology, structural value estimation, content-to-structure value ratios, and flood related damages and costs

2) **Elevation Data & Sampling** – discusses ground surface elevation, foundation heights, first floor elevations, and sampling structural attributes

3) **Structure Inventory Uncertainty** – discusses the uncertainty distributions surrounding structure values, content-to- structure value ratios, and flood related damages and costs, and how the distributions were generated

4) **Depth Damage Relationships** – discusses the depth damage relationships, uncertainty and how the distributions were generated

2.2 ECONOMIC INPUTS TO THE HEC-FDA MODEL

Structure Inventory. A structure inventory of residential and non-residential structures for the study area was obtained using the National Structure Inventory (NSI), version 2.0. The NSI was originally created by USACE to simplify the GIS pre-processing workflow for the Modeling Mapping and Consequence center (MMC) and was recently upgraded to version 2 using upgraded data sources and algorithms. The NSI 2.0 database was significantly improved through various techniques described in subsequent sections.

NSI 2.0 sources its structural attribute data from tax assessed parcel data (available through CoreLogic), business location data available through Esri/Infogroup, and HAZUS (where other datasets were unavailable). NSI 2.0 data is not an exact representation of reality, but rather contains many county-level, state-level, or regional assumptions applied to individual structures, often by random assignment. As such, while county or other large aggregations of structures will be accurate on average, individual structure characteristics may not be accurate. Although these and other accuracy issues exist, the NSI 2.0 dataset functions as an available common and consistent standard for the United States. The chief advantage of NSI 2.0 over other national datasets is its spatial accuracy, which is a significant improvement over the census block level accuracy that NSI 1.0 relied on.

Occupancy Types. The NSI 2.0 database comes with its own list of occupancy types, which describes the type of structure more than simply residential or non-residential. Occupancy types are important because they are used to assign depth-damage relationships to determine the rate at which a structure is damaged given a depth of water. This study utilized these three different occupancy types:

1. **NSI 2.0** – Occupancy type descriptions come with the original NSI 2.0 data and were the starting point for the study. NSI 2.0 occupancy types were verified during sampling.

2. **RS Means** – To estimate costs per square foot for structures, the NSI 2.0 occupancy types were converted to RS Means occupancy types. In general, there was a unique RS Means occupancy type to match to each NSI 2.0 occupancy type, but certain structures were generalized, such as multi-occupancy apartment buildings. Professional judgment was used when combining occupancy types based on how the structure would be damaged.

3. **Depth-Damage Relationships** – Neither the NSI 2.0 nor RS Means occupancy types matched the occupancy types required to use for the depth-damage relationships that were selected for the local flooding conditions. Professional judgment was used again to sort each structure type into the most representative occupancy type that the depth damage relationships offered.

Table 10 shows the conversion process of moving structures through the three different occupancy types. Further descriptions of each occupancy type can be found in subsequent sections of the report.

Table 10. Structure Types

RS Means OccType	NSI 2.0 OccType	Depth-Damage OccType
Store, Retail	COM1	PT2 Grocery
Store, Retail	COM2	PT 11 Furniture Retail
Garage, Repair	COM3	PT 3 Convenience Store
Medical Office, 1 Story	COM7	PT 5 Medical Office
Restaurant	COM8	PT 8 Fast Food
School, High, 2-3 Story	EDU1	PT 21 School
Office, 5-10 Story	GOV1	PT 18 Protective Services
Warehouse	IND1	PT 15 Warehouse Non-Refrigerated
1 Story Residential No Basement	RES1-1SNB	One Story No Basement
2 Story Residential No Basement	RES1-2SNB	Two Stories No Basement
3 Story Residential No Basement	RES1-3SNB	Three Stories No Basement
Residential Bi-Story No Basement	RES1-SLNB	Split Level No Basement
1 Story Residential With Basement	RES1-1SWB	One Story w Basement
2 Story Residential With Basement	RES1-2SWB	Two Stories w Basement
3 Story Residential With Basement	RES1-3SWB	Three Stories w Basement
Residential Bi-Story With Basement	RES1-SLWB	Split Level w Basement
Apartment, 1-3 Story	RES3	PT 1 Apt Building

Structure Values. As previously identified in the description of NSI 2.0, the national database has limitations and oversimplifications that lead to unacceptable levels of uncertainty for a feasibility level study. To overcome the limitations and reduce uncertainty, RS Means was used to reevaluate the depreciated replacement values and multiple statistically significant samples were performed to ensure an accurate representation of structural attributes. This process is further described below.

Application of RS Means – Residential Structures

The 2022 RS Means Square Foot Costs Data catalog was used to assign a depreciated replacement cost per square foot value to residential structures. The RS Means system of valuation allows the user to customize the following primary items: exterior wall type, build quality, additions, depreciation, and regional factors.

- Exterior Wall Type - Replacement costs per square foot were provided for four exterior walls types (wood frame, brick veneer, stucco, or masonry) and an **average** cost per square foot for the **four exterior wall types** were computed since there was not enough information to determine the exact wall types per structure.

- Build Quality – Build quality of a structure helps determine how high the starting cost per square foot should be for structures. Based on windshield surveys (using Google Street View), it was determined that the characteristics of the structures in the area were consistent with those of the **average build quality** (economy and luxury/custom homes existed, but were in the minority).

- Depreciation – Depreciation of a structure is based on the observed condition (effective age) of the structure and can be described as the structure's wear and tear since it was constructed or last rehabilitated. Based on windshield surveys (using Google Street View), it was determined that the average condition of residential structures in the area was **30 years old**, and therefore structure values were **depreciated on average 30 percent** based on RS Means depreciation schedule. See the "Structure Value Uncertainty" on how uncertainty in observed condition impacts the uncertainty surrounding structure values.

- Region - A regional adjustment factor was applied to the cost per square foot to account for construction costs (**1.0 for residential**) consistent with the **St. Louis, Missouri area**.

- Additions – RS Means allows for users to enter additional structural features that may be present beyond the default features. No additional features were added to residential structures.

Application of RS Means – Non-residential Structures

The 2022 RS Means Square Foot Costs Data catalog was used to assign a depreciated replacement cost per square foot value to non-residential structures. The RS Means system of valuation allows the user to customize the following primary items: exterior wall type, build quality, additions, depreciation, and regional factors.

- Exterior Wall Type - Replacement costs per square foot were provided for six exterior wall types (decorative concrete with steel frame and with bearing walls frame, face brick with concrete block back-up with steel frame and with bearing walls frame, metal sandwich panel with steel frame, and precast concrete panel with bearing walls frame), and an **average** cost per square foot for the **six exterior wall types** was computed since there was not enough information to determine the exact wall types per structure.

- Build Quality – Build quality of a structure helps determine how high the starting cost per square foot should be for structures. Based on windshield surveys (using Google Street View), it was determined that the characteristics of the structures in the area were consistent with those of the **average build quality**, which is the only option for non-residential structures.

- Depreciation – Depreciation of a structure is based on the observed condition (effective age) of the structure and can be described as the structures wear and tear since it was constructed or last rehabilitated. Based on windshield surveys (using Google Street View), it was determined that the average condition of non-residential structures in the area was **30 years old**, and therefore structure values were **depreciated on average 35 percent** based on RS Means depreciation schedule. See the "Structure Value Uncertainty" on how uncertainty in observed condition impacts the uncertainty surrounding structure values.

- Region - A regional adjustment factor was applied to the cost per square foot to account for construction costs (**1.01 for non-residential**) consistent with the **St. Louis, Missouri area**.

- Additions – RS Means allows for users to enter additional structural features that may be present beyond the default features. No additional features were added to non-residential structures.

The formula to determine depreciated replacement value for structures is simplified as follows:

$$Avg.\, Cost\ per\ sq\ ft * Avg.\ depreciation\ factor * Regional\ adjustment\ factor$$

The mean final cost per square foot by occupancy type was then applied to every structure in the inventory to determine depreciated replacement values. The square footage for each of the individual residential structures was multiplied by the size-specific depreciated cost per square for the average construction class to obtain a total depreciated cost.

Square Foot Estimation. Square foot estimates were sampled using structures within the 0.2% AEP aggregation. Microsoft Building Footprints were utilized to improve the data source of the square foot estimate.

Microsoft Building Footprints is a GIS outline of each structure generated from an algorithm that recognizes building pixels on aerial imagery and converts the building pixels into polygons. Final square footage estimates per building footprint were spatially joined to the underlying structure points in GIS. Each occupancy type received an average square footage estimate based on the individual structures included within that occupancy type. The square footages sampled for each occupancy type have not been compared to other square footage estimates within the region or country, but will be by the final report.

Table 11 shows the distribution of square foot estimates for each of the RS Means and NSI 2.0 occupancy types. The table shows the results of the RS Means valuation analysis, which is the triangular distribution of cost per square foot by occupancy type. More information on RS Means triangular distribution is provided in subsequent sections.

Table 11. RS Means Structure Inventory Statistics

NSI 2.0 OccType	RS Means OccType	Avg Sq Ft	Minimum	Most Likely	Maximum
COM1	Store, Retail	6,119	$ 66	$ 107	$ 139
COM2	Store, Retail	6,119	$ 66	$ 107	$ 139
COM3	Garage, Repair	7,352	$ 66	$ 107	$ 140
COM7	Medical Office, 1 Story	1,306	$ 105	$ 170	$ 223
COM8	Restaurant	13,154	$ 94	$ 153	$ 200
EDU1	School, High, 2-3 Story	32,884	$ 94	$ 153	$ 200
GOV1	Office, 5-10 Story	10,673	$ 107	$ 174	$ 228
IND1	Warehouse	6,835	$ 66	$ 107	$ 140
RES1-1SNB	1 Story Residential No Basement	1,353	$ 74	$ 115	$ 147
RES1-2SNB	2 Story Residential No Basement	1,850	$ 62	$ 96	$ 123
RES1-3SNB	3 Story Residential No Basement	1,850	$ 62	$ 96	$ 123
RES1-SLNB	Residential Bi-Story No Basement	1,147	$ 79	$ 123	$ 158
RES1-1SWB	1 Story Residential With Basement	1,391	$ 92	$ 143	$ 184
RES1-2SWB	2 Story Residential With Basement	1,426	$ 83	$ 130	$ 167
RES1-3SWB	3 Story Residential With Basement	1,426	$ 83	$ 130	$ 167
RES1-SLWB	Residential Bi-Story With Basement	1,418	$ 79	$ 122	$ 157
RES3	Apartment, 1-3 Story	2,373	$ 86	$ 140	$ 183

Structure Inventory Uncertainty. The uncertainty surrounding the residential structure values includes the depreciation percentage applied based on the effective age and condition of the structures as well as the four exterior wall types. A triangular probability distribution was developed for residential structures using the following RS Means information:

- Minimum Depreciation – Effective Age: 15 Years & Good Condition
- Most Likely Depreciation – Effective Age: 30 Years & Average Condition
- Maximum Depreciation – Effective Age: 50 Years & Poor Condition

Effective age for this uncertainty analysis was defined as the average observed age of a structure as recorded during the windshield survey. These values were then converted to a percentage of the most-likely value with the most-likely value equal to 100 percent of the average value for each exterior wall type and occupancy category. The triangular probability distributions were entered into the HEC-FDA model to represent the uncertainty surrounding the structure values in each residential occupancy category.

The uncertainty surrounding the non-residential structure values was based on the depreciation percentage applied to the average replacement cost per square calculated from the six exterior wall types. A triangular probability distribution was developed for non-residential structures using the following RS Means information:

- Minimum Depreciation – Effective Age: 15 Years & Masonry on Masonry/Steel
- Most Likely Depreciation – Effective Age: 30 Years & Masonry on Wood
- Maximum Depreciation – Effective Age: 40 Years & Frame

These values were then converted to a percentage of the most-likely value with the most-likely value being equal to 100 percent and the minimum and maximum values equal to percentages of the most-likely value. The triangular probability distributions were entered into the HEC-FDA model to represent the uncertainty surrounding the structure values for each non-residential occupancy category.

Residential and Non-Residential Content-to-Structure Value Ratios. Based on Economic Guidance Memorandum (EGM), 04-01 and EGM 01-03, a content-to-structure value ratio (CSVR) of 100 percent was applied to all of the residential structures in the structure inventory and the error associated with CSVR was set to zero. The EGMs state that the 100 percent CSVR is to be used with the generic depth-damage relationships developed for residential structures, which were also used for this study.

The content-to-structure value ratios (CSVRs) and uncertainty applied to the non-residential structure occupancies were taken from the Nonresidential Flood Depth-Damage Functions from Expert Elicitation (URS Group, Inc., Revised 2013), which conducted an expert elicitation to derive CSVRs and depth-damage functions for non-residential structures. The elicitation was used to develop CSVR's for non-residential structures that are not regionally specified.

Elevation Data & Sampling. Elevation data associated with the ground surface, foundation heights, and first floors of structures are critical to the economic analysis and feasibility of studies. Given the low-resolution of foundation height data provided with the NSI 2.0 database, a statistically significant sample was calculated to inform a windshield survey to improve the estimates associated with foundation and subsequent first floor elevations. The sample was also utilized to measure a handful of other structural attributes, detailed later in this section.

Two Google Street View windshield surveys were conducted:

1. The first was a preliminarily survey completed prior to calculating the formula in Figure 4 to determine the standard deviation of the average residential and commercial structures foundation height (S).

2. Once the standard deviation was estimated, it was entered into the formula in Figure 4 to determine how many structures to sample based on the designated stratification. The second windshield survey was the final survey performed.

The first (preliminary) survey in Google Street view included the maximum and minimum foundation height expected by occupancy type in this study area. 60 residential and 15 non-residential structures were included in the initial sample. The information gathered from the preliminary survey, such as the range (max – min) of foundation heights informed how many additional structures would need to be sampled to meet the statistically significant threshold based on the Z-Value and allowable error used in the formula (See Figure 4).

The second survey included an additional 35 residential and 20 non-residential structures to the sample count based on the results of the first sample. The structures selected were distributed evenly throughout the study area.

A third in-person windshield survey was conducted. Several hundred structures were surveyed for foundation height, relative depreciated state, placement, and other structure characteristics. The structures selected were distributed evenly throughout the study area. See Figure 5 for the statistically significant sample size formula utilized for this study.

$$n = \left(\frac{Z * S}{E}\right)^2 \text{, where}$$

n = Sample size

Z = Z-Value (1.96)

$$S = \frac{Foundation\ Height_{High} - Foundation\ Height_{Low}}{6}$$

E = Allowable error (0.20 feet)

Figure 4. Statistically Significant Sample Size Formula

The standard deviation of the final survey was compared to the preliminary survey and verified that the amount of structures sampled exceeded the minimum calculated in the formula. The variables sampled included:

- Foundation height – measured from the bottom of the front door to adjacent ground, each step was assumed to be 8 inches
- Foundation type – designated as either slab on grade, crawlspace, or basement
- Story count – measured as either one, or two or more stories
- Existing condition – qualitative judgment of the condition of the exterior of the structure condition
- Verification of occupancy type – confirmation of the purpose of occupancy

Ground Surface Elevations. Topographical data was provided by the St. Louis District H&H Engineer. The LiDAR data was used to assign ground elevations to structures.

First Floor Elevations. The ground elevation was added to the height of the foundation of the structure above the ground to obtain the first floor elevation of each structure in the study area.

First Floor Elevation Uncertainty. The uncertainty surrounding the foundation heights was determined by referencing the HEC-FDA user manual. A Google Street View survey was assumed to be less accurate than use of stadia, but more accurate than an aerial survey with a 5 ft contour interval. This resulted in the uncertainty around foundation height being determined as distributed normally with a .5 ft standard deviation. This estimate will be further refined post-TSP when a new field survey will be conducted.

Depth-Damage Relationships. Each occupancy type has its own depth-percent of value damaged curves for structure and contents. The USACE generic depth-damage relationships for one-story and two-story residential structures with and without basement from EGM 04-01, and EGM 01-03 were used in the analysis.

Site-specific non-residential depth-damage relationships were not available for this study area. The depth-damage functions for non-residential structures were based on the data presented from the Nonresidential Flood Depth-Damage Functions from Expert Elicitation (URS Group, Inc., Revised 2013). Twenty-one core non-residential structures were evaluated by a panel of experts recruited from across the United States. The resulting data from the panel included nationally relevant depth-damage relationships for use in estimating the value of damages expected to occur from a flood event. Each DDF is applicable to businesses across the Nation. These FEMA/USACE expert engineered depth-damage relationships were used for non-residential structures in the study area.

Uncertainty Surrounding Depth-Damage Relationships. For residential structures, a normal distribution with a standard deviation for each damage percentage provided at the various increments of flooding was used to determine the uncertainty surrounding the generic depth-damage relationships used for residential structures and vehicles. This information for residential structures was also sourced from EGM 04-01 and EGM 01-03.

For non-residential structures, the Nonresidential Flood Depth-Damage Functions from Expert Elicitation (URS Group, Inc., Revised 2013) reference was utilized to source a triangular distribution for non-residential structures.

2.3 ENGINEERING INPUTS TO THE HEC-FDA MODEL

Stage-Probability Relationships. Stage-probability relationships were provided for the existing without-project condition (2025) and future without-project condition (2075). Future condition hydraulics are equal to existing condition hydraulics, as no change is expected.

The H&H engineer provided water surface profiles from HEC-RAS for eight AEP events including the 50%, 20%, 10%, 4%, 2%, 1%, 0.5%, and 0.2%. The without-project water surface profiles were based on riverine flood events. Hydraulic data was provided in geo-referenced 2D format.

Uncertainty Surrounding the Stage-Probability Relationships. A 50-year equivalent record length was used to quantify the uncertainty surrounding the stage-probability relationships for the study area. Based on this equivalent record length, the HEC-FDA model calculated the confidence limits surrounding the stage-probability functions.

3 NATIONAL ECONOMIC DEVELOPMENT (NED) FLOOD DAMAGE AND BENEFIT CALCULATIONS

3.1 HEC-FDA MODEL CALCULATIONS

The HEC-FDA model was utilized to evaluate flood damages using risk-based analysis. Damages were reported for each of the 20 study area reaches. A range of possible values, defined by the probability distributions for each economic variable (first floor elevation, structure and content values, and depth-damage relationships), were entered into the HEC-FDA model to calculate the uncertainty surrounding the elevation-damage, or stage-damage, relationships for structures and contents. The model also used the number of years that stages were recorded to determine the hydrologic uncertainty surrounding the stage-probability relationships.

The possible occurrences of each variable are determined through a Monte Carlo process, which samples random values from each defined probability distribution. The number of iterations performed affects the simulation execution time and the quality and accuracy of the results. This process was conducted simultaneously for each economic and hydrologic variable. The resulting mean value and probability distributions represent an estimate of the full set of possible outcomes.

3.2 STAGE-DAMAGE RELATIONSHIPS WITH UNCERTAINTY

The HEC-FDA model used the economic and engineering inputs to generate a stage-damage relationship for each structure category in the study area under existing conditions (2025). The possible occurrences of each economic variable were derived by Monte Carlo simulation. A total of 1,000 iterations were executed in the model for the stage-damage relationships. The sum of all sampled values was divided by the number of samples to yield the expected value for a specific simulation. A mean and standard deviation was automatically calculated for the damages at each stage.

3.3 STAGE-PROBABILITY RELATIONSHIPS WITH UNCERTAINTY

The HEC-FDA model used an equivalent record length of 50 years for this study area to generate a stage-probability relationship with uncertainty for the without-project condition under base year (2025) conditions by graphical analysis. 50 years was selected by the hydraulic engineer to represent the length of records analyzed during the calibration process that the hydraulic model underwent. The model used the eight stage-probability events together with the equivalent record length to define the full range of the stage-probability functions by interpolating between the data points. Confidence bands surrounding the stages for each of the probability events were also provided.

3.4 WITHOUT-PROJECT EXPECTED ANNUAL DAMAGES

The model used Monte Carlo simulation to sample from the stage-probability curve with uncertainty. For each of the iterations within the simulation, stages were simultaneously selected for the entire range of probability events. The sum of all damage values divided by the number of iterations run by the model yielded the expected value, or mean damage value, with confidence bands for each probability event. The probability-damage relationships are integrated by weighting the damages corresponding to each magnitude of flooding (stage) by the percentage chance of exceedance (probability). From these weighted damages, the model determined the expected annual damages (EAD) with confidence bands (uncertainty). For the without-project alternative, the expected annual damages (EAD) were totaled for the study area to obtain the total without-project EAD under base year (2025) conditions. Table 12 displays the damages by reach and type of structures that are damaged for the year 2025 under without-project conditions.

Table 12. Existing Condition Total Economic Damage by Reach and Structure Type for 2025 ($1,000s)

Reach	Non-Residential	Residential	Total
1	$0	$0	$0
2	$39	$1	$40
3	$439	$3	$442
4	$16	$141	$157
5	$58	$635	$693
6	$304	$16	$320
7	$8	$86	$94
8	$0	$1	$1
9	$5	$23	$28
10	$52	$413	$465
11	$219	$50	$269
12	$14	$84	$98
13	$28	$344	$372
14	$195	$35	$230
15	$69	$395	$464
16	$76	$150	$226
17	$8	$11	$19
18	$324	$4	$328
19	$12	$106	$118
20	$467	$5	$472
Total	$2,336	$2,501	$4,837

*FY 2022 price levels

3.5 STRUCTURE INVENTORY ADJUSTMENTS FOR HIGH FREQUENCY INUNDATION

Adjustments were made to the structure inventory to more accurately reflect the most-likely future without-project and with-project conditions. Under without-project and with-project conditions, residential and non-residential structures that were identified as being inundated above the first floor elevation from the 50% and 20% AEP events were modified to have the stages below the ground surface elevation by at least nine feet to ensure high frequency damages were mitigated in the existing and future without-project conditions. This adjustment is consistent with the FEMA floodplain regulations that require residents to rebuild above the base flood elevation after a structure receives greater than 50 percent damage to the structural components as a result of a flood.

3.6 WITH-PROJECTED EXPECTED ANNUAL DAMAGES

The alternatives were run through HEC-FDA, which allows for determining damages reduced by damage category. Table 13 shows the damages reduced and residual damages for each plan. The Modified 1988 Authorized Plan and detention basin combination alternatives are most effective at reducing damages, while Detention Basin 4 and the Nonstructural Only show the greatest remaining residual risk.

Figures 5, 6, and 7 show the existing condition damages for the 4%, 2%, and 1% AEP flood frequencies respectively.

Table 13. With-Project Expected Annual Damages (Residual Risk) by Damage Category ($1,000's) for Final Array Alternatives

Alternative	Residential Damages	Non-Residential Damages	Total With-Project Damages	Damages Reduced
1 No Action*	$2,501	$2,336	$4,837	$0
2 Modified 1988 Authorized Plan*	$1,045	$1,244	$2,289	$2,548
3a Detention Basins 3 and 4*	$1,354	$1,202	$2,556	$2,280
3b Detention Basin 4 (LPP)*	$1,974	$1,673	$3,647	$1,190
4 Levee/Floodwall and DB3 & 4**	$1,727	$1,221	$2,948	$1,889
5 Nonstructural – Acquisition**	$379	$216	$596	$4,241
6 Nonstructural Only (Optimized)*	$1,340	$2,269	$3,608	$1,229
7 Nonstructural – Elevation**	$2,815	$2,318	$5,133	-$296
8 Detention Basin 4 and Nonstructural (NED)*	$1,224	$1,778	$3,002	$1,835

*FY 2022 price levels and 2.25% discount rate

**FY 2021 price levels and 2.5% discount rate (alternatives not developed beyond July 2021 Draft Report)

50-year period of analysis

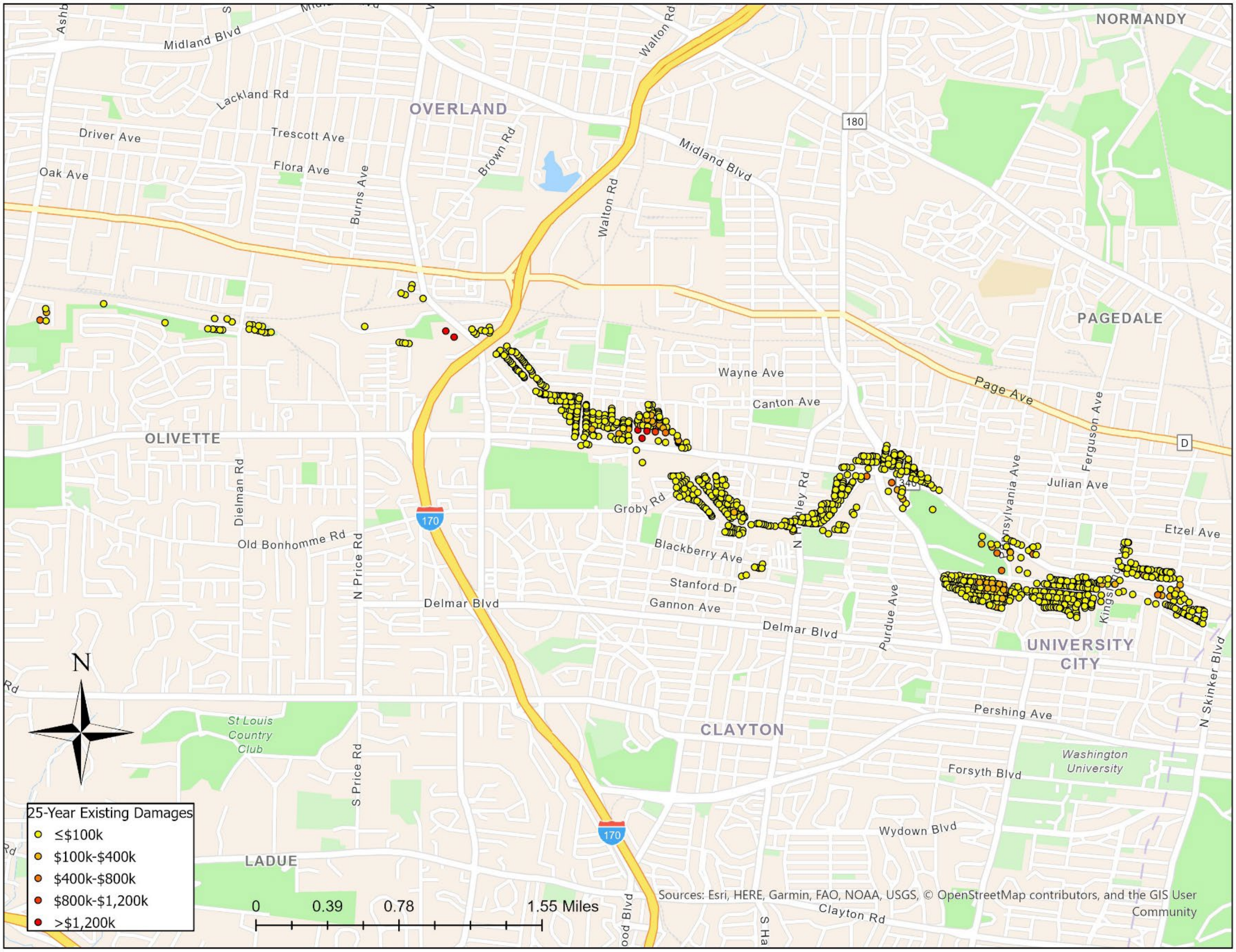

Figure 5. Existing Condition 4% AEP Damages

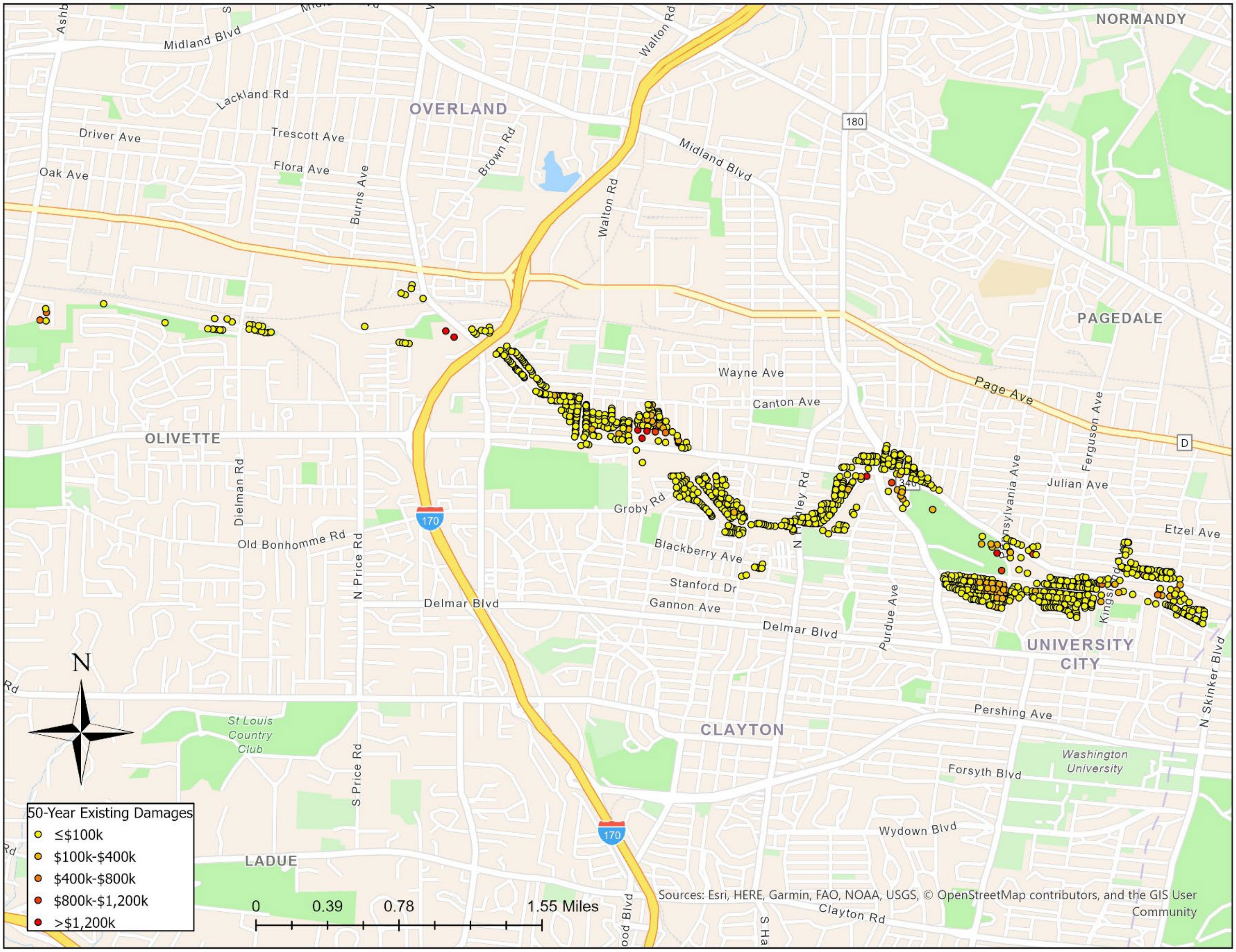

Figure 6. Existing Condition 2% AEP Damages

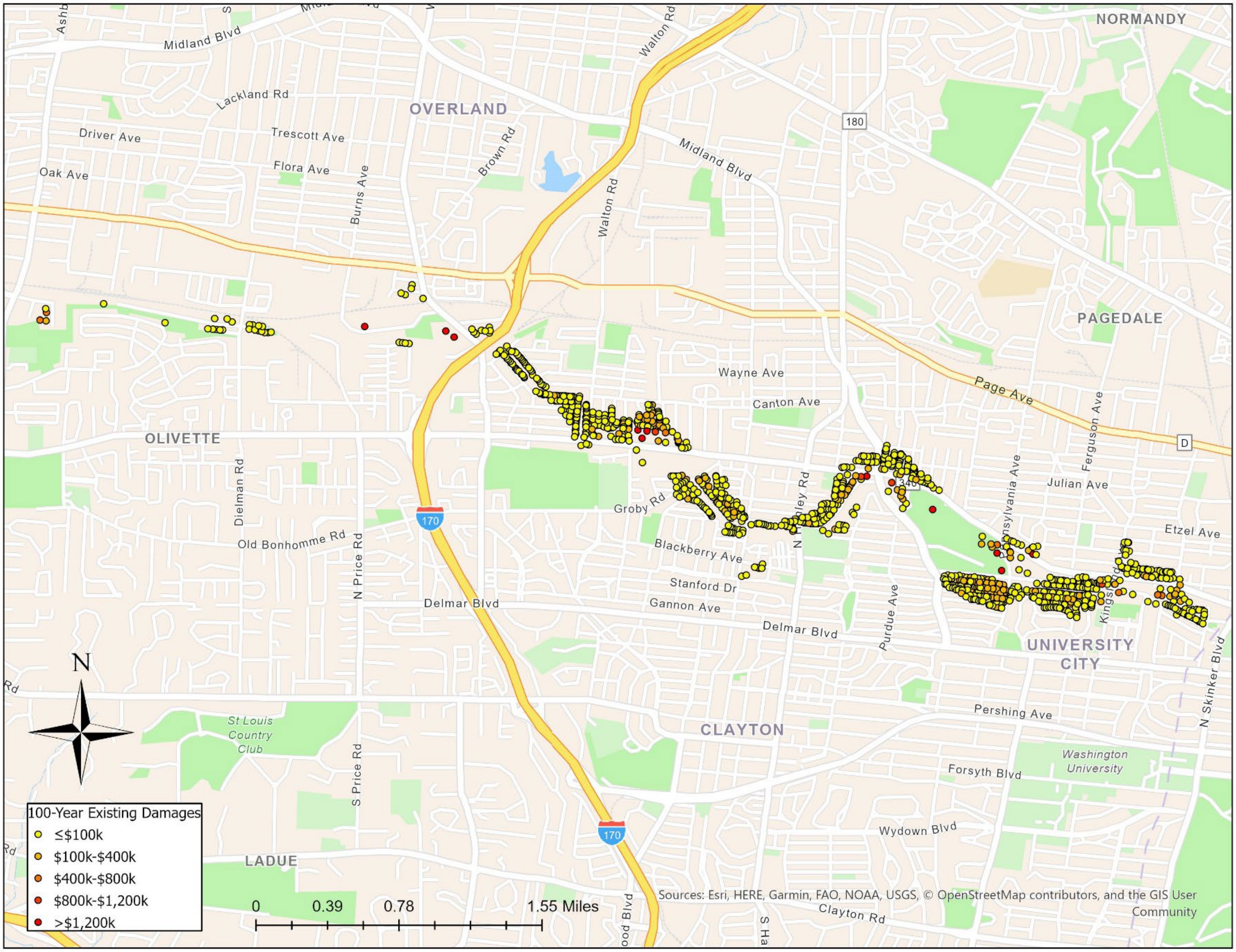

Figure 7. Existing Condition 1% AEP Damages

4 PROJECT COSTS

Construction Schedule. For the purposes of computing interest during construction (IDC), construction of the nonstructural components of the plans is expected to begin in the year 2025 and will continue for a period of six months. Construction of Detention Basin 4 is expected to last one year. Construction of the Detention Basins 3 and 4 alternative is expected to last 18 months. The levee/floodwall construction is estimated to last two years. Construction of the Modified 1988 Authorized Plan is expected to last 18 months.

Interest during construction was calculated for each of the alternatives. Interest during construction was calculated using a mid-year payment schedule and 2.25% discount rate.

Cost estimates for the final array were developed by the St. Louis District Cost Engineering Branch. An abbreviated cost risk analysis was completed to determine the contingencies used for all structural and nonstructural measures.

Annual Project Costs. Life cycle cost estimates were provided for the nonstructural measures in FY22 price levels. The initial construction costs (first costs) and the schedule of expenditures were used to determine the interest during construction and gross investment cost at the end of the installation period (2025). The FY 2022 Federal interest rate of 2.25 percent was used to discount the costs to the base year and then amortize the costs over the 50-year period of analysis.

Operations, maintenance, relocations, rehabilitation, and repair (OMRR&R) costs associated with each of the structural measures was estimated by the cost engineering branch. There is no OMRR&R assumed to be associated with the nonstructural measures. Table 14 summarizes costs for each of the alternatives carried forward.

Table 24. Summary of Costs for Alternatives Carried Forward

	Alternative				
	2	3a	3b	6	8
Total Project Costs					
First Cost	$62,036,000	$46,481,000	$9,867,000	$28,584,000	$30,450,000
Interest During Construction	$2,116,000	$1,585,000	$223,000	$320,000	$453,000
Total Investment Cost	$64,152,000	$48,066,000	$10,090,000	$28,904,000	$30,903,000
Estimated Annual Costs					
Annualized Project Costs	$2,150,000	$1,611,000	$338,000	$969,000	$1,036,000
Annual OMRR&R	$40,000	$20,000	$10,000	-	$10,000
Total Annual Costs	$2,190,000	$1,631,000	$348,000	$969,000	$1,046,000

FY 2022 price levels; 2.25% discount rate
50 year period of analysis

5 RESULTS OF THE ECONOMIC ANALYSIS

5.1 NET BENEFIT ANALYSIS

Calculation of Net Benefits. The expected annual benefits attributable to the alternatives carried forward after the July 2021 Draft Report were compared to the annual costs to develop a benefit-to-cost ratio for the alternatives. The net benefits for the alternatives were calculated by subtracting the annual costs from the expected annual benefits. The net benefits were used to determine the economic justification of the alternatives. Net benefit calculations for the with-project condition were computed using the HEC-FDA that contained the stage frequency-damage relationships for the study. Table 15 shows the net benefits and benefit-cost ratio for the alternatives.

Table 35. Economic Net Benefits and BCR of Alternatives Carried Forward

Alternative	Average Annual Costs	Average Annual Benefits	Net Annual Benefits	Benefit to Cost Ratio
2 -Modified 1988 Authorized Plan	$2,190,000	$2,611,000	$421,000	1.19
3a – Detention Basins 3 and 4	$1,631,000	$2,280,000	$649,000	1.40
3b – Detention Basin 4 (NED)	$348,000	$1,190,000	$842,000	3.42
6 – Nonstructural Only (Optimized)	$969,000	$1,228,000	$259,000	1.27
8 – Detention Basin 4 and Nonstructural (Optimized)	$1,046,000	$1,834,000	$788,000	1.75

FY 2022 price levels
50-year period of analysis
2.25% discount rate

The plan that reasonably maximizes net benefits and is therefore the NED plan is Alternative 3b, the Detention Basin 4 alternative. Table 16 shows the cost and benefit summary of the NED plan. Table 17 breaks down the nonstructural features of the NED plan by floodproofing, basement fill, and acquisition components.

Table 46. Summary of Costs and Benefits for Alternative 3b, the NED Plan

Detention Basin 4	
Total Project Costs	
First Cost	$9,867,000
Interest During Construction	$223,000
Total Investment Cost	$10,090,000
Estimated Annual Costs	
Annualized Project Costs	$338,000
Annual OMRR&R	$10,000
Total Annual Costs	$348,000
Average Annual Benefits	
Total Annual Benefits	$1,190,000

Net Annual Benefits	$842,000
Benefit to Cost Ratio	3.42
Residual Risk	$3,647,000

FY 2022 price levels
50-year period of analysis
2.25% discount rate

5.1.1 Nonstructural Participation Rate Sensitivity Analysis

Alternative 8 includes some nonstructural measures, participation in which is voluntary. The estimates of benefits and costs are based on 100% participation, which is unlikely to be realized during implementation. This may lead to inaccurate estimates in the analysis, and so a participation rate sensitivity analysis was conducted to determine the impact of participation less than 100%. Best Practice Guide (BPG) 2020-02 outlines five factors that are identified as significant contributors to participation in nonstructural plans:

- Temporal Proximity of Severe Flood Damage
- Decent, Safe, and Sanitary Living Conditions
- Free of Hazardous, Toxic, Radioactive Waste
- Ability to be Temporarily Relocated
- Physical Disability Requirements

A high degree of uncertainty exists for these factors in this study area. Because of this, an even spread of participation rates was selected to provide decision-makers with a broad range of possible outcomes: 25%, 50%, and 75%. A random sample was selected among the structures indicated as eligible according to the established criteria for the plan at each of the participation rates. The benefits of the nonstructural measures were then computed in HEC-FDA. The costs were then scaled down for each participation rate at the associated percentage of the first project cost of nonstructural measures. Net benefits and BC ratios were then calculated to compare the different participation rates. The results show that as nonstructural participation declines from 100%, total benefits for Alternative 8 decrease but net benefits increase.

Table 19. Participation Rate Sensitivity Analysis Results

Detention Basin 4 + 100% NS		0.75		0.5		0.25	
Total Project Costs		Total Project Costs		Total Project Costs		Total Project Costs	
First Cost	$ 30,449,970	First Cost	$ 25,304,145	First Cost	$ 20,158,320	First Cost	$ 15,012,495
Interest During Construction	$ 453,274	Interest During Construction	$ 395,706	Interest During Construction	$ 338,137	Interest During Construction	$ 280,569
Total Investment Cost	$ 30,903,244	Total Investment Cost	$ 25,699,851	Total Investment Cost	$ 20,496,457	Total Investment Cost	$ 15,293,064
Estimated Annual Costs		Estimated Annual Costs		Estimated Annual Costs		Estimated Annual Costs	
Annualized Project Costs	$ 1,036,000	Annualized Project Costs	$ 861,000	Annualized Project Costs	$ 687,000	Annualized Project Costs	$ 513,000
Annual OMRR&R	$ 10,000	Annual OMRR&R	$ 10,000	Annual OMRR&R	$ 10,000	Annual OMRR&R	$ 10,000
Total Annual Costs	$ 1,046,000	Total Annual Costs	$ 871,000	Total Annual Costs	$ 697,000	Total Annual Costs	$ 523,000
Average Annual Benefits		Average Annual Benefits		Average Annual Benefits		Average Annual Benefits	
Total Annual Benefits	$ 1,833,600	Total Annual Benefits	$ 1,715,540	Total Annual Benefits	$ 1,637,230	Total Annual Benefits	$ 1,488,720
Net Annual Benefits	$ 787,600	Net Annual Benefits	$ 844,540	Net Annual Benefits	$ 940,230	Net Annual Benefits	$ 965,720
Benefit to Cost Ratio	1.8	Benefit to Cost Ratio	2.0	Benefit to Cost Ratio	2.3	Benefit to Cost Ratio	2.8
Residual Risk (average annual)	$ 3,003,520	Residual Risk (average annual)	$ 3,121,580	Residual Risk (average annual)	$ 3,199,890	Residual Risk (average annual)	$ 3,348,400

The method of project cost estimation used in the sensitivity analysis comes with a high degree of risk as it is unlikely that project costs would go down by exactly 25% when participation goes down by 25%, for example, because nonstructural costs per structure are not linear. Therefore, the results of the participation rate sensitivity analysis should not be compared directly with the results of the final array of alternatives without consideration for the limitations of the cost estimation in the sensitivity analysis.

5.2 RISK ANALYSIS

The risk analysis is a section of the report that discusses the risk and uncertainty associated with the HEC-FDA model and the economic benefits. The HEC-FDA model was utilized for the existing condition and with project alternatives. The risk analysis uses expected annual damages instead of equivalent annual damages since future conditions are the same as existing conditions.

5.3 BENEFIT EXCEEDANCE PROBABILITY RELATIONSHIP

The HEC-FDA model incorporates the uncertainty surrounding the economic and engineering inputs to generate results that can be used to assess the performance of proposed plans. The HEC-FDA model was used to calculate expected annual without-project and with-project damages and the damages reduced for each of the project alternatives. Table 20 and Table 21 show the mean expected annual benefits and the benefits at the 75, 50, and 25 percentiles for the NED and LPP plans. These percentiles reflect the percentage chance that the benefits will be greater than or equal to the indicated values. The table indicates the percent chance that the expected annual benefits will exceed the expected annual costs therefore the benefit cost ratio is greater than one and the net benefits are positive.

Table 20 can be understood to show that there is a 75% chance that the expected annual damages reduced (annual benefits) of the NED plan will exceed $1,190, and therefore a 75% chance that the BCR will exceed 1.9.

Table 20. Probability Benefits Exceed Costs (NED)

NED Plan	**0.75**	**0.5 (Median)**	**Mean**	**0.25**
Total Average Annual Cost	$348			
Total Average Annual Benefits	$669	$1,085	$1,190	$1,576
Net Benefits	$321	$737	$842	$1,228
BCR	1.9	3.1	3.4	4.5

FY 2022 price levels
50 year period of analysis
2.25% discount rate

5.4 RESIDUAL RISK

The flood risk that remains in the floodplain after the proposed alternatives are implemented is known as the residual flood risk. For this study, the residual risk is best illustrated in Table 11 in section 3.6 of this appendix. While the NED plan reasonably maximized net benefits, it does not provide the most damages reduced (minimizing residual damages). The plan that reduces the most amount of damages is Alternative 2, the Modified 1988 Authorized Plan .

5.5 LIFE SAFETY

Life Loss Estimates on Roads

To estimate the risk of life loss on roads, depth times velocity (DxV) grids were georeferenced to roadways. Referencing the HEC-LifeSim user manual, a depth times velocity relationship was obtained to show when vehicles will begin to lose traction and potentially be swept off the road (Table 22). Figures 8 and 9 show dots with graduated colors that indicate road segments with varying potential for life loss for the 1% AEP event in the existing condition. Those include portions of Groby Rd, Glenside Pl, Mona Dr, Shaftesbury Ave, Wilson Ave, N Hanley Rd, Midland-Olive intersection, Vernon Ave, Pennsylvania Ave, and Cabanne Ave. Figure 10 shows the depth times velocity relationship with uncertainty bands.

Each of the structural alternatives are expected to reduce the risk of life loss on roads by reducing the probability of flooding. The Nonstructural Only plan (Alternative 6) does not reduce the probability of flooding, so the risk of direct life loss on roads or the risk of indirect life loss due to emergency services being unable to reach residents is unmitigated.

Table 22. Hydraulic Threshold for Vehicle Stability

	Low Clearance Vehicles			**High Clearance Vehicles**		
Hydraulic Threshold	Low	Best Estimate	High	Low	Best Estimate	High
Depth (ft)	0.98	3.94	4.92	1.64	4.92	6.56
Velocity (ft/s)	9.84	14.76	19.69	9.84	19.69	19.69
DxV (ft^2/s)	0.98	2.62	4.27	1.97	3.94	7.87

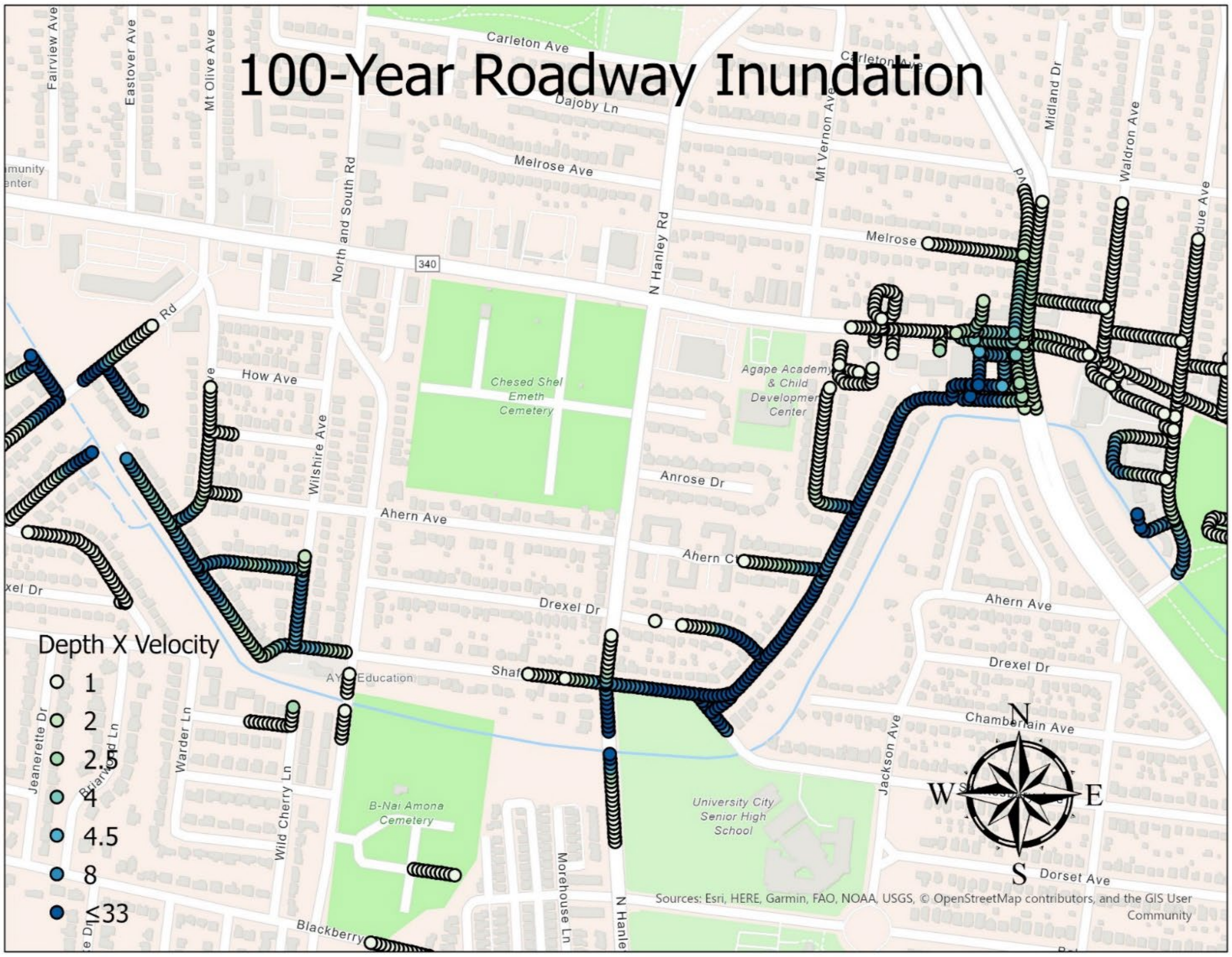

Figure 8. Depth Times Velocity on Roadways (Wilson Ave, Shaftesbury Ave)

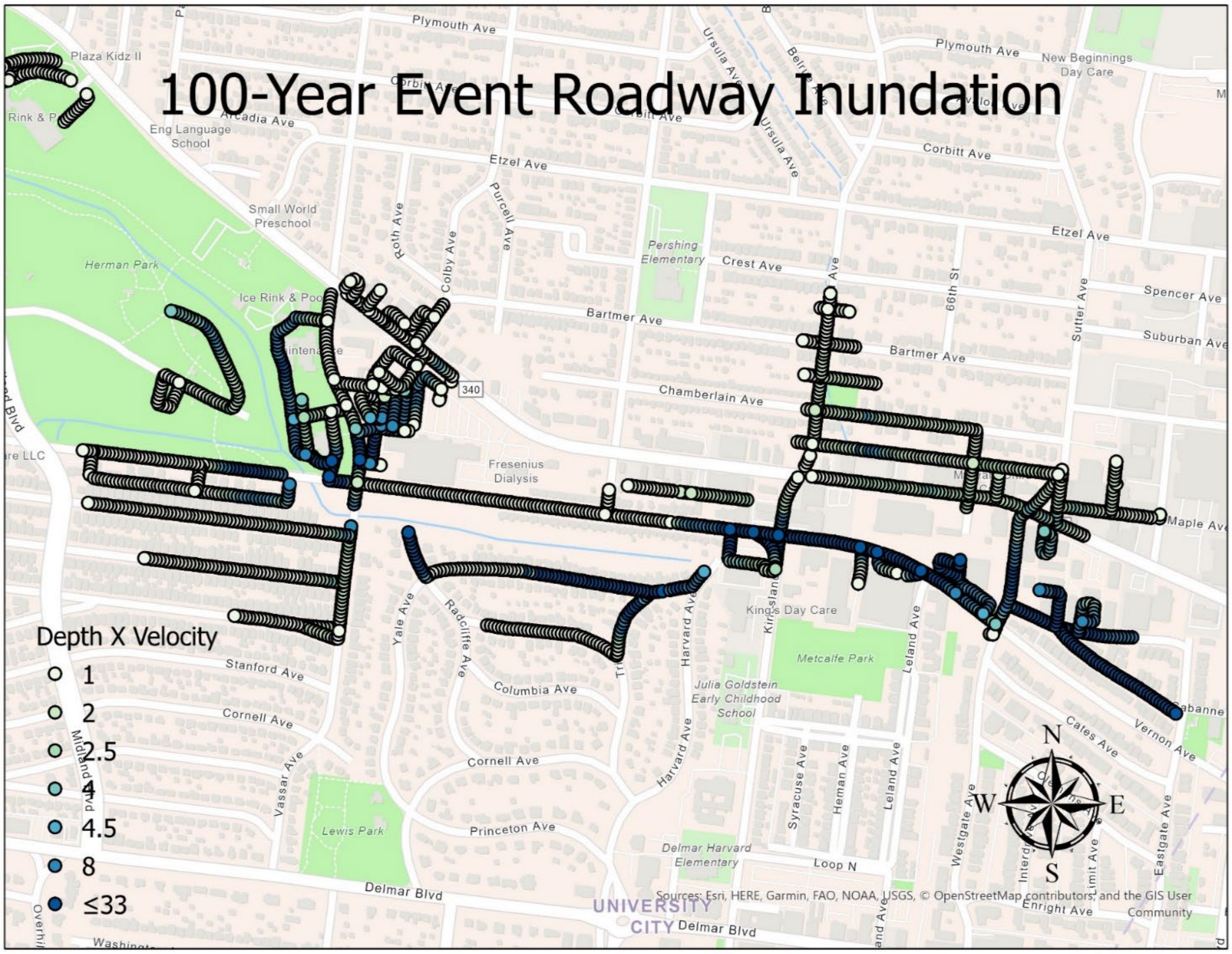

Figure 9. Depth Times Velocity on Roadways (Vernon Ave, Pennsylvania Ave)

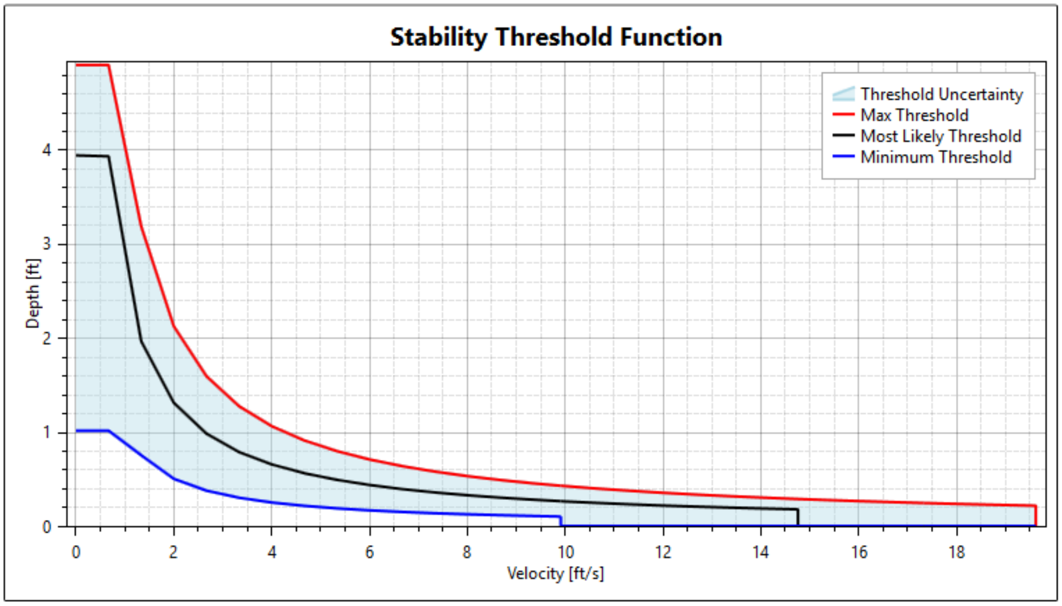

Figure 10. HEC-LifeSim Vehicular Stability Function

Life Loss Estimates in Structures

Further analysis of life safety in structures was conducted using the HEC-LifeSim model. Roadway evacuation simulation was not conducted for this LifeSim model. Estimates of life loss were computed for the existing condition and with Detention Basin 4 for the 1%, .5%, and .2% AEP events. The results of the LifeSim model are in Table 23, Table 24, Table 25, and Table 26. Simulations were conducted for two extremes of warning time, minimal and ample. The impact of a Flood Warning System is best measured by the difference in the minimal and ample warning scenarios. Simulations were also conducted for day and night scenarios. For more detailed information about the LifeSim model, see Appendix K.

Table 23. Life Loss Estimates – Existing Condition with Minimal Warning Time

Minimal Warning - Without Project					
Scenario Name	Structures Inundated	Population at Risk		Median Total Life Loss	
		Day	Night	Day	Night
.2% AEP Event	980	3200	3100	7	8
.5% AEP Event	850	2900	2700	4	5
1% AEP Event	720	2500	2300	2	2

Table 24. Life Loss Estimates – Existing Condition with Ample Warning Time

Ample Warning - Without Project					
Scenario Name	Structures Inundated	Population at Risk		Median Total Life Loss	

		Day	Night	Day	Night
.2% AEP Event	980	3200	3200	5	6
.5% AEP Event	850	2900	2800	2	3
1% AEP Event	720	2500	2400	1	2

Table 25. Life Loss Estimates – Detention Basin 4 with Minimal Warning Time

Minimal Warning – Detention Basin 4					
Scenario Name	Structures Inundated	Population at Risk		Median Total Life Loss	
		Day	Night	Day	Night
.2% AEP Event	932	3175	2929	5	7
.5% AEP Event	782	2778	2544	2	3
1% AEP Event	635	2341	2144	1	2

Table 26. Life Loss Estimates – Detention Basin 4 with Ample Warning Time

Ample Warning - Detention Basin 4					
Scenario Name	Structures Inundated	Population at Risk		Median Total Life Loss	
		Day	Night	Day	Night
.2% AEP Event	932	3152	3034	3	5
.5% AEP Event	782	2759	2636	1	2
1% AEP Event	635	2325	2218	1	1

The results show there is an existing risk of life loss in structures. Detention Basin 4 reduces the risk of life loss in structures, structures inundated, and the population at risk. Figure 11 shows life loss in the existing condition at the .2% AEP event. This figure was chosen to best illustrate distribution of risk of life loss in the existing condition.

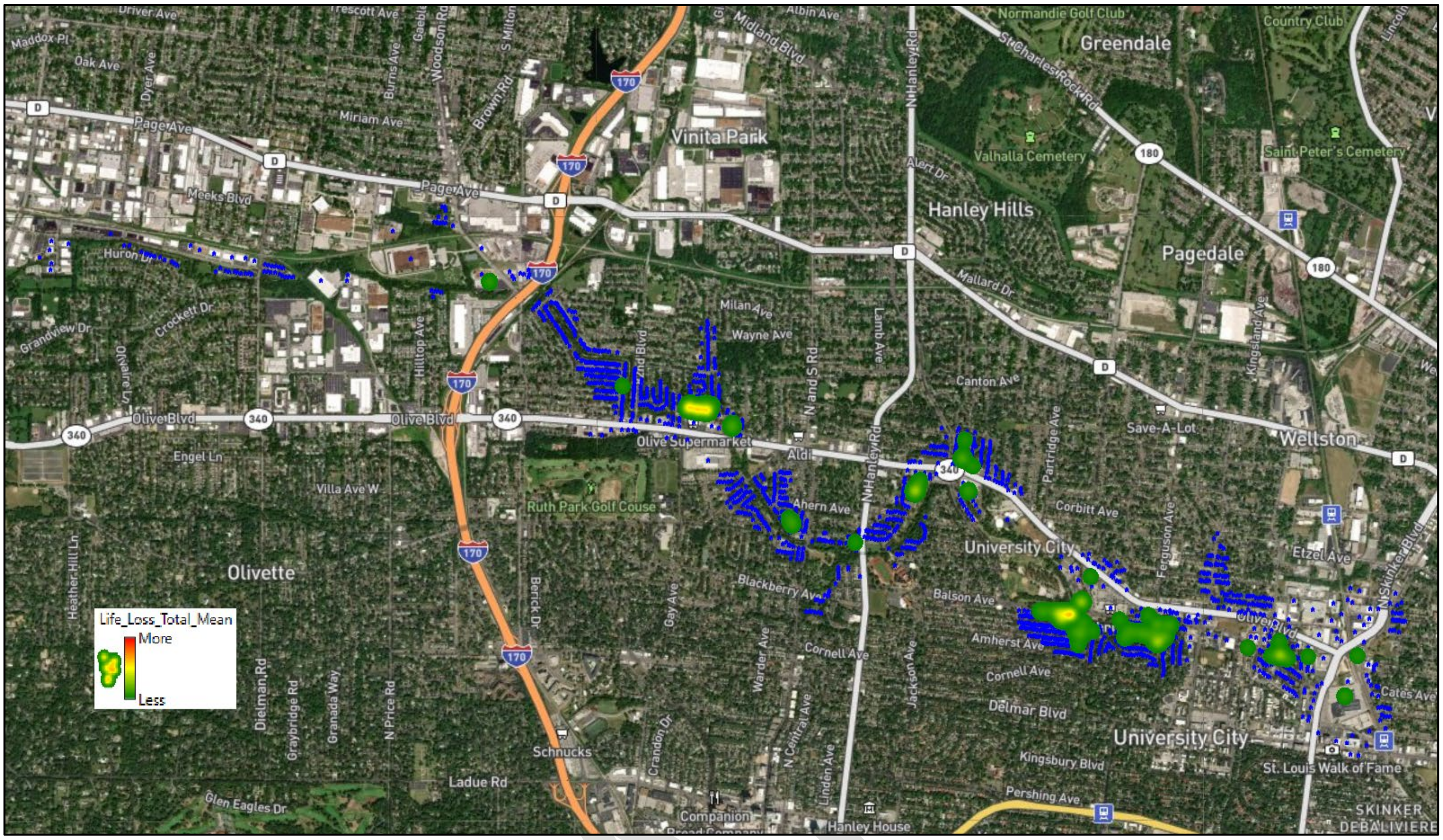

Figure 11. Life Loss Heat Map – Existing Condition, Minimal Warning

5.6 COMPLIANCE WITH SECTION 308 OF WRDA 1990

Section 308 of the Water Resource Development Act (WRDA) 1990 limits structures built or substantially improved after July 1, 1991 in designated floodplains not elevated to the 1% AEP flood elevation from being included in the benefit base of the economic analysis. An evaluation of the available parcel data, the structure inventory, and the 1% AEP flood model shows that none of the structures included in the structure inventory were built after July 1991 with a FFE below the 1% AEP flood level.

6 RESULTS OF THE REGIONAL ECONOMIC DEVELOPMENT ANLYSIS (RED)

When the economic activity lost in a flooded region can be transferred to another area or region in the national economy, these losses cannot be included in the NED account. However, the impacts on the employment, income, and output of the regional economy are considered part of the RED account. The input-output macroeconomic model USACE Regional Economic System (RECONS) can be used to address the impacts of the construction spending associated with the project alternatives. The RECONS model utilizes a total construction cost of a project that is attributable to contracts being awarded to complete the construction of the project. This cost excludes USACE labor associated with planning, engineering, and design, as well as economic costs like interest during construction. The general equilibrium Economic

Consequence Assessment Model (ECAM) can also be used to address the RED account by showing regional damages associated with major flood events.

RECONS

The RECONS model was used to estimate the positive benefits of the final array for this study. The model estimates the positive impact of USACE construction projects. Model results for the alternatives carried forward after the July 2021 Draft Report (Alternatives 2, 3a, 3b, 6, and 8) are shown below.

Alternative 2 – Modified 1988 Authorized Plan

The expenditures associated with the Modified 1988 Authorized Plan (Alternative 2) are estimated to be $58,565,428. Of this total expenditure, $46,619,661 will be captured within the local impact area. The remainder of the expenditures will be captured within the state impact area and the nation. These direct expenditures generate additional economic activity, often called secondary or multiplier effects. The direct and secondary impacts are measured in output, jobs, labor income, and gross regional product (value added) as summarized in the following tables. The regional economic effects are shown for the local, state, and national impact areas. In summary, the expenditures $58,565,428 support a total of 704.6 full-time equivalent jobs, $56,545,024 in labor income, $56,925,643 in the gross regional product, and $96,251,140 in economic output in the local impact area. More broadly, these expenditures support 1,008.9 full-time equivalent jobs, $76,236,391 in labor income, $92,596,904 in the gross regional product, and $159,114,881 in economic output in the nation. Table 27 summarizes the results of the model.

Table 27. Overall RECONS Summary of Alternative 2

Area	Local Capture	Output	Jobs*	Labor Income	Value Added
Local					
Direct Impact		$46,619,661	441.4	$38,459,552	$27,686,690
Secondary Impact		$49,631,478	263.2	$18,085,471	$29,238,953
Total Impact	$46,619,661	$96,251,140	704.6	$56,545,024	$56,925,643
State					
Direct Impact		$49,573,769	472.5	$39,952,501	$30,254,027
Secondary Impact		$55,897,959	303.9	$19,335,927	$31,811,759
Total Impact	$49,573,769	$105,471,728	776.4	$59,288,428	$62,065,786
US					
Direct Impact		$55,886,167	541.0	$43,350,150	$36,312,314
Secondary Impact		$103,228,714	467.9	$32,886,241	$56,284,590
Total Impact	$55,886,167	$159,114,881	1,008.9	$76,236,391	$92,596,904

* Jobs are presented in full-time equivalence (FTE)					

Alternative 3a – Detention Basin 3 and 4

The expenditures associated with Detention Basin 3 and Detention Basin 4 are estimated to be $43,010,580. Of this total expenditure, $34,237,583 will be captured within the local impact area. The remainder of the expenditures will be captured within the state impact area and the nation. These direct expenditures generate additional economic activity, often called secondary or multiplier effects. The direct and secondary impacts are measured in output, jobs, labor income, and gross regional product (value added) as summarized in the following tables. The regional economic effects are shown for the local, state, and national impact areas. In summary, the expenditures $43,010,580 support a total of 517.4 full-time equivalent jobs, $41,526,791 in labor income, $41,806,318 in the gross regional product, and $70,687,050 in economic output in the local impact area. More broadly, these expenditures support 740.9 full-time equivalent jobs, $55,988,174 in labor income, $68,003,371 in the gross regional product, and $116,854,320 in economic output in the nation. Table 28 summarizes the results of the model.

Table 28. Overall RECONS Summary of Alternative 3a

Area	Local Capture	Output	Jobs*	Labor Income	Value Added
Local					
Direct Impact		$34,237,583	324.1	$28,244,780	$20,333,166
Secondary Impact		$36,449,467	193.3	$13,282,010	$21,473,152
Total Impact	$34,237,583	$70,687,050	517.4	$41,526,791	$41,806,318
State					
Direct Impact		$36,407,086	347.0	$29,341,205	$22,218,624
Secondary Impact		$41,051,585	223.2	$14,200,347	$23,362,626
Total Impact	$36,407,086	$77,458,670	570.2	$43,541,553	$45,581,250
US					
Direct Impact		$41,042,924	397.3	$31,836,446	$26,667,844
Secondary Impact		$75,811,396	343.6	$24,151,728	$41,335,528
Total Impact	$41,042,924	$116,854,320	740.9	$55,988,174	$68,003,371
* Jobs are presented in full-time equivalence (FTE)					

Alternative 3b – Detention Basin 4

The expenditures associated with Detention Basin 4 are estimated to be $9,259,909. Of this total expenditure, $7,371,138 will be captured within the local impact area. The remainder of the expenditures will be captured within the state impact area and the nation. These direct expenditures generate additional economic activity, often called secondary or multiplier effects. The direct and secondary impacts are measured in output, jobs, labor income, and gross regional product (value added) as summarized in the following tables. The regional economic effects are shown for the local, state, and national impact areas. In summary, the expenditures $9,259,909 support a total of 111.4 full-time equivalent jobs, $8,940,459 in labor income, $9,000,639 in the gross regional product, and $15,218,481 in economic output in the local impact area. More broadly, these expenditures support 159.5 full-time equivalent jobs, $12,053,905 in labor income, $14,640,702 in the gross regional product, and $25,158,006 in economic output in the nation. Table 29 summarizes the results of the model.

Table 29. Overall RECONS Summary of Alternative 3b

Area	Local Capture	Output	Jobs*	Labor Income	Value Added
Local					
Direct Impact		$7,371,138	69.8	$6,080,925	$4,377,604
Secondary Impact		$7,847,343	41.6	$2,859,534	$4,623,036
Total Impact	$7,371,138	$15,218,481	111.4	$8,940,459	$9,000,639
State					
Direct Impact		$7,838,218	74.7	$6,316,978	$4,783,531
Secondary Impact		$8,838,150	48.0	$3,057,246	$5,029,828
Total Impact	$7,838,218	$16,676,369	122.8	$9,374,225	$9,813,359
US					
Direct Impact		$8,836,286	85.5	$6,854,188	$5,741,420
Secondary Impact		$16,321,721	74.0	$5,199,716	$8,899,281
Total Impact	$8,836,286	$25,158,006	159.5	$12,053,905	$14,640,702
* Jobs are presented in full-time equivalence (FTE)					

Alternative 6 – Nonstructural Only (Optimized)

The expenditures associated with the Nonstructural Only alternative are estimated to be $26,623,740. Of this total expenditure, $21,193,216 will be captured within the local impact area. The remainder of the expenditures will be captured within the state impact area and the nation. These direct expenditures generate additional economic activity, often called secondary or multiplier effects. The direct and secondary impacts are measured in output, jobs, labor income, and gross regional product (value added) as summarized in the following tables. The regional economic effects are shown for the local, state, and national impact areas. In summary, the expenditures $26,623,740 support a total of 245.9 full-time equivalent jobs, $19,659,856 in labor income, $25,183,404 in the gross regional product, and $38,930,472 in economic output in the local impact area. More broadly, these expenditures support 391.9 full-time equivalent jobs, $28,663,575 in labor income, $40,237,697 in the gross regional product, and $66,853,598 in economic output in the nation. Table 30 summarizes the results of the model.

Table 30. Overall RECONS Summary of Alt. 6

Area	Local Capture	Output	Jobs*	Labor Income	Value Added
Local					
Direct Impact		$21,193,216	150.6	$13,163,267	$14,704,932
Secondary Impact		$17,737,256	95.3	$6,496,589	$10,478,472
Total Impact	$21,193,216	$38,930,472	245.9	$19,659,856	$25,183,404
State					
Direct Impact		$22,536,148	170.9	$13,841,959	$15,704,361
Secondary Impact		$21,490,452	118.4	$7,231,259	$12,025,222
Total Impact	$22,536,148	$44,026,600	289.4	$21,073,218	$27,729,583
US					
Direct Impact		$25,405,752	202.1	$15,386,524	$17,545,771
Secondary Impact		$41,447,846	189.8	$13,277,051	$22,691,926
Total Impact	$25,405,752	$66,853,598	391.9	$28,663,575	$40,237,697
* Jobs are presented in full-time equivalence (FTE)					

Alternative 8 – Detention Basin 4 and Nonstructural (Optimized)
The expenditures associated with Detention Basin 4 and Nonstructural are estimated to be $28,960,717. Of this total expenditure, $23,053,513 will be captured within the local impact area. The remainder of the expenditures will be captured within the state impact area and the nation. These direct expenditures generate additional economic activity, often called secondary or multiplier effects. The direct and secondary impacts are measured in output, jobs, labor income, and gross regional product (value added) as summarized in the following tables. The regional economic effects are shown for the local, state, and national impact areas. In summary, the expenditures $28,960,717 support a total of 325.8 full-time equivalent jobs, $26,126,839 in labor income, $27,927,943 in the gross regional product, and $46,120,035 in economic output in the local impact area. More broadly, these expenditures support 478.7 full-time equivalent jobs, $35,889,038 in labor income, $45,228,188 in the gross regional product, and $77,039,536 in economic output in the nation. Table 31 summarizes the results of the model.

Table 31. Overall RECONS Summary of Alt. 8

Area	Local Capture	Output	Jobs*	Labor Income	Value Added
Local					
Direct Impact		$23,053,513	203.2	$17,711,587	$14,331,208
Secondary Impact		$23,066,523	122.6	$8,415,252	$13,596,736
Total Impact	$23,053,513	$46,120,035	325.8	$26,126,839	$27,927,943
State					
Direct Impact		$24,514,324	220.4	$18,449,853	$15,549,690
Secondary Impact		$26,439,337	144.2	$9,083,538	$14,982,550
Total Impact	$24,514,324	$50,953,661	364.6	$27,533,391	$30,532,240
US					
Direct Impact		$27,635,817	254.3	$20,129,997	$18,267,544
Secondary Impact		$49,403,719	224.4	$15,759,041	$26,960,645
Total Impact	$27,635,817	$77,039,536	478.7	$35,889,038	$45,228,188
* Jobs are presented in full-time equivalence (FTE)					

Economic Consequence Assessment Model (ECAM)

The ECAM is a computable general equilibrium (CGE) model. Estimates of the loss of labor and capital due to a disaster event can be provided as inputs to the model which will then provide detailed outputs about the expected loss in economic activity for the industries in a particular county. During major storm events, people may be unable to go to work or businesses may have to close, and the ECAM is a tool to estimate the regional economic damages of this.

For River Des Peres, total capital and total labor for St. Louis County was derived from NSI 2.0. The sum of the population under the age of 65 in residential structures was the value used for total labor. The sum of the structure values for all non-residential structures was the value used for total capital. The storm events analyzed were the 4%, 1%, and .2% AEP events. Lost labor and lost capital were estimated by summing the population and structures values that had positive flood depths at the respective AEP events. The percentages of lost labor and capital to total labor and capital respectively were then used as inputs to ECAM. The results for the existing condition are in Table 32. These estimates assume that most (95%) of the affected businesses and laborers will rebuild or recover with 1 month for the .2% event, 2 weeks for a 1% event, and 1 week for a 4% event. The flashy nature of the flooding in the study area was used to inform professional judgement to development these estimates of recovery time.

Table 32. Results of ECAM Model

	4% AEP Event	1% AEP Event	.2% AEP Event
ECAM Inputs			
Capital Loss (%)	0.10%	0.13%	0.60%
Labor Loss (%)	0.02%	0.05%	0.09%
ECAM Outputs			
GDP Lost	$ 83,350,000	$ 138,550,000	$ 461,100,000
Number of Jobs Lost	10	303	248

Total capital in St. Louis County is estimated at about $72.5 billion. Total labor is estimated at about 800,000. Table 33 shows the breakdown of how the inputs for ECAM were derived.

Table 33. ECAM Input Calculation

	4% AEP Event	1% AEP Event	.2% AEP Event
Total Capital	$ 72,466,046,647	$ 72,466,046,647	$ 72,466,046,647
Total Labor	800,033	800,033	800,033
Capital Lost	$ 71,529,178	$ 94,994,023	$ 433,217,444
Labor Lost	166	440	700
Percent Capital Lost	0.10%	0.13%	0.60%
Percent Labor Lost	0.02%	0.05%	0.09%