Public Services Department
433 Hay Street | Fayetteville, NC 28301

FAYETTEVILLE NC
AMERICA'S CAN DO CITY

ATTACHMENT L: BCA METHODOLOGY

CITY OF FAYETTEVILLE, NC

WAYLAND DRIVE DRAINAGE IMPROVEMENTS - FY2021 BRIC

Public Services Department
433 Hay Street | Fayetteville, NC 28301

FAYETTEVILLE NC
AMERICA'S CAN DO CITY

TECHNICAL MEMORANDUM

FEMA Building Resilient Infrastructure and Communities Grant Program

Project: City of Fayetteville Wayland Drive Drainage Improvement

Benefit-Cost Analysis Methodology

November 22, 2021

Contents

Appendices

Appendix A – City of Fayetteville BCA Report

Appendix B – FEMA BCA Reference Guide – Project Useful Life Table

Appendix C – Wayland Drive Homes Protected Photolog

Appendix D – Benefit-Cost Analysis Reference Guide Excerpt

Appendix E – *FEMA Standard Values Appendix C*

Appendix F – Wayland Drive Inventory Spreadsheet

1. PROJECT OVERVIEW

This technical memorandum identifies the data and methodology used to complete the benefit cost analysis (BCA) for the Wayland Drive Drainage Improvement in the City of Fayetteville. The area (Figure 1) currently has a ditch with an agricultural area to the west and a residential area to the east. When stormwater overtops the ditch banks, the water immediately begins to spill into the neighborhood.

The average ground elevation in the area is 234.7 feet, and the elevation map in Figure 2 shows a range in elevation from about 230 feet to 260 feet. The areas in red experience the worst flooding.

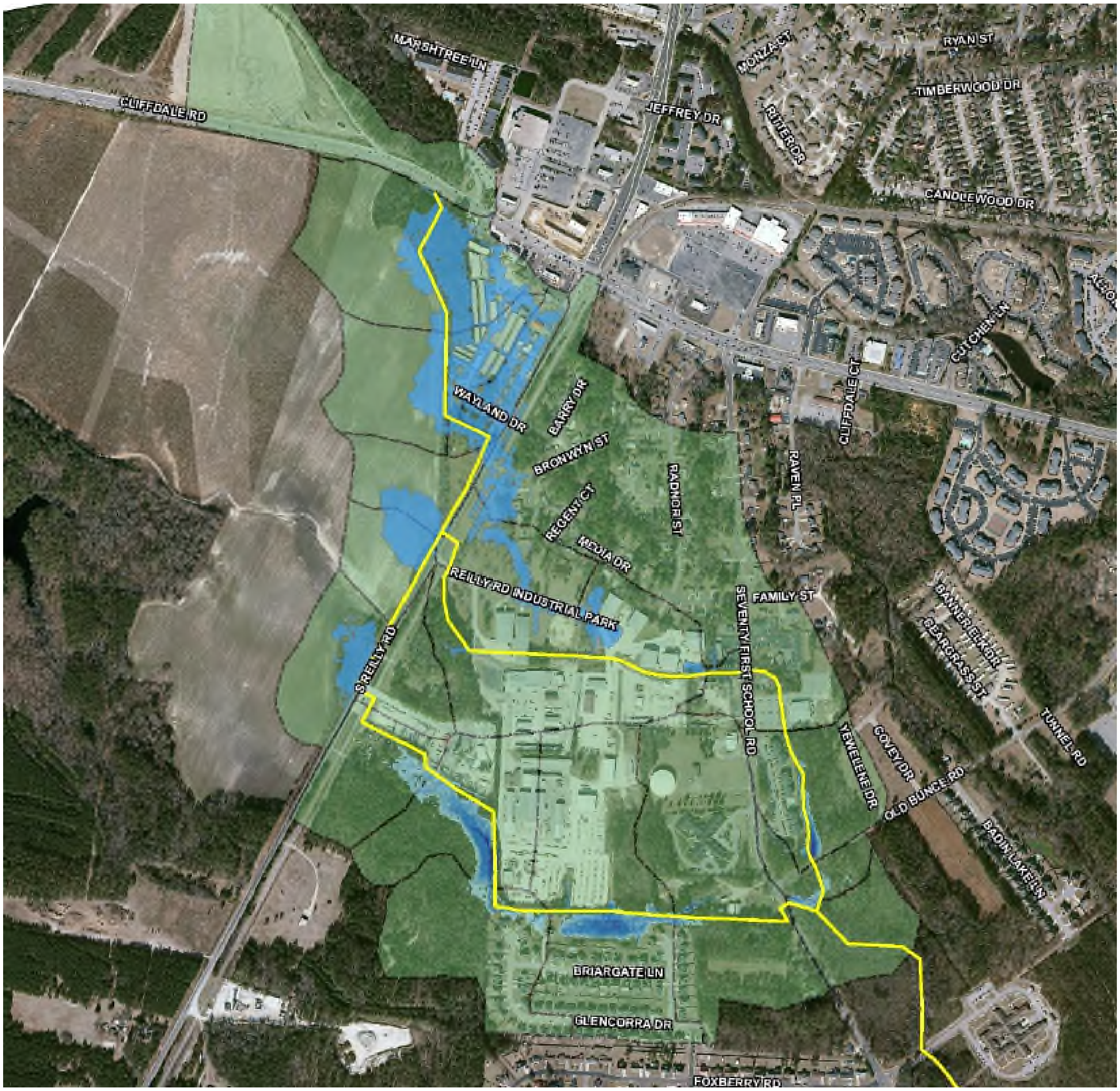
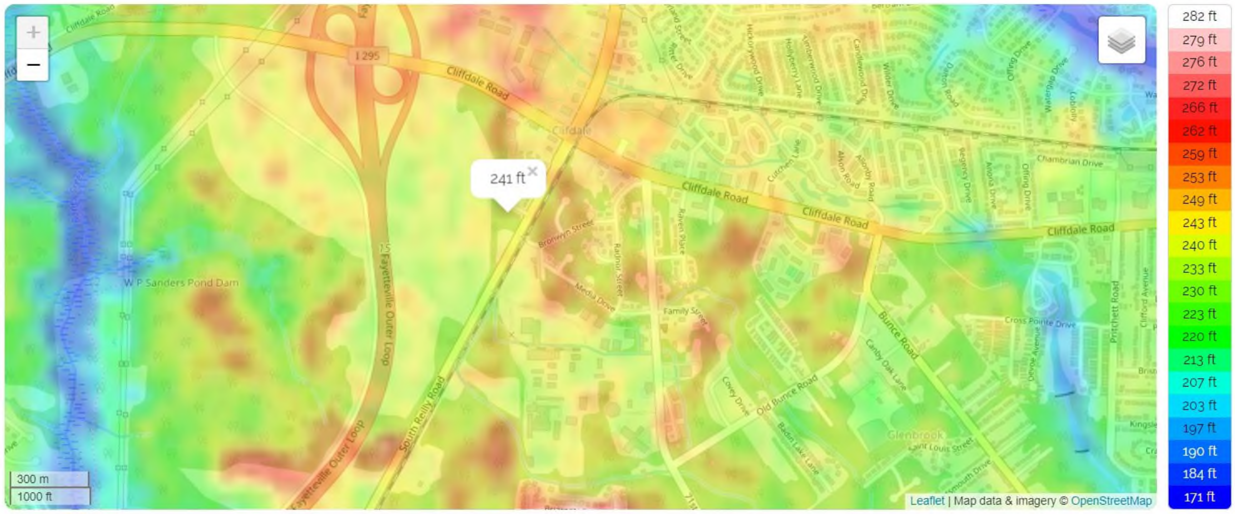


Figure 1 Modeling area used for drainage improvement assessment; existing condition 10-year storm flooding shown in blue, drainage area shown in green, and current drainage infrastructure is shown in yellow (on 2017 aerial basemap)



North Carolina, United States of America (35.67296 -79.03929)

Figure 2 Elevation Map of Study Area

Engineers have modelled three drainage improvement options and selected the one which moves the stormwater flows downstream (north) and provides nearly 5 acres of storage on a property that is located just upstream of Old Bunce Road. The proposed Wayland Drive Drainage Improvement project will reduce the frequency, severity, and duration of flooding within a residential and industrial area that spans nearly a mile north to south and half a mile from west to east. Anticipated benefits from the proposed drainage improvements include:

- **Reduction/elimination of expected building and content damages due to flooding**
- **Reduction/elimination of displacement/relocation caused by flooding**
- **Reduction/elimination of loss of road service**
- Reduction/elimination of mental stress and anxiety from impacts
- Reduction/elimination of lost productivity from impacts
- Elimination of potential injuries/casualties from flooding
- Environmental benefits from reduction in stormwater pollution
- Reduction /elimination of illness from exposure to polluted water and contamination from flooding

Only the first three benefits were quantified in this BCA. The avoided losses to buildings and contents was assessed for a conservative amount of buildings, and economic impact of road closures were quantified. Social benefits were added in the FEMA 6.0 BCA Toolkit.

The following methodology outlines the steps that were taken to calculate a BCA ratio of 1**.97**, with $3,568,362 in project costs (including $1,000 per year in maintenance over the useful life of the project) and $7,033,992 in benefits. A breakdown of the results can be viewed in **Appendix A – City of Fayetteville BCA Report**.

1.1 Project Background & Proposed Mitigation

The proposed project will include construction of a new drainage ditch which would divert stormwater from the areas which currently experience flooding. This option was chosen because it avoids storing stormwater west of South Reilly Road within the farm field, as the other two options would.

This option (

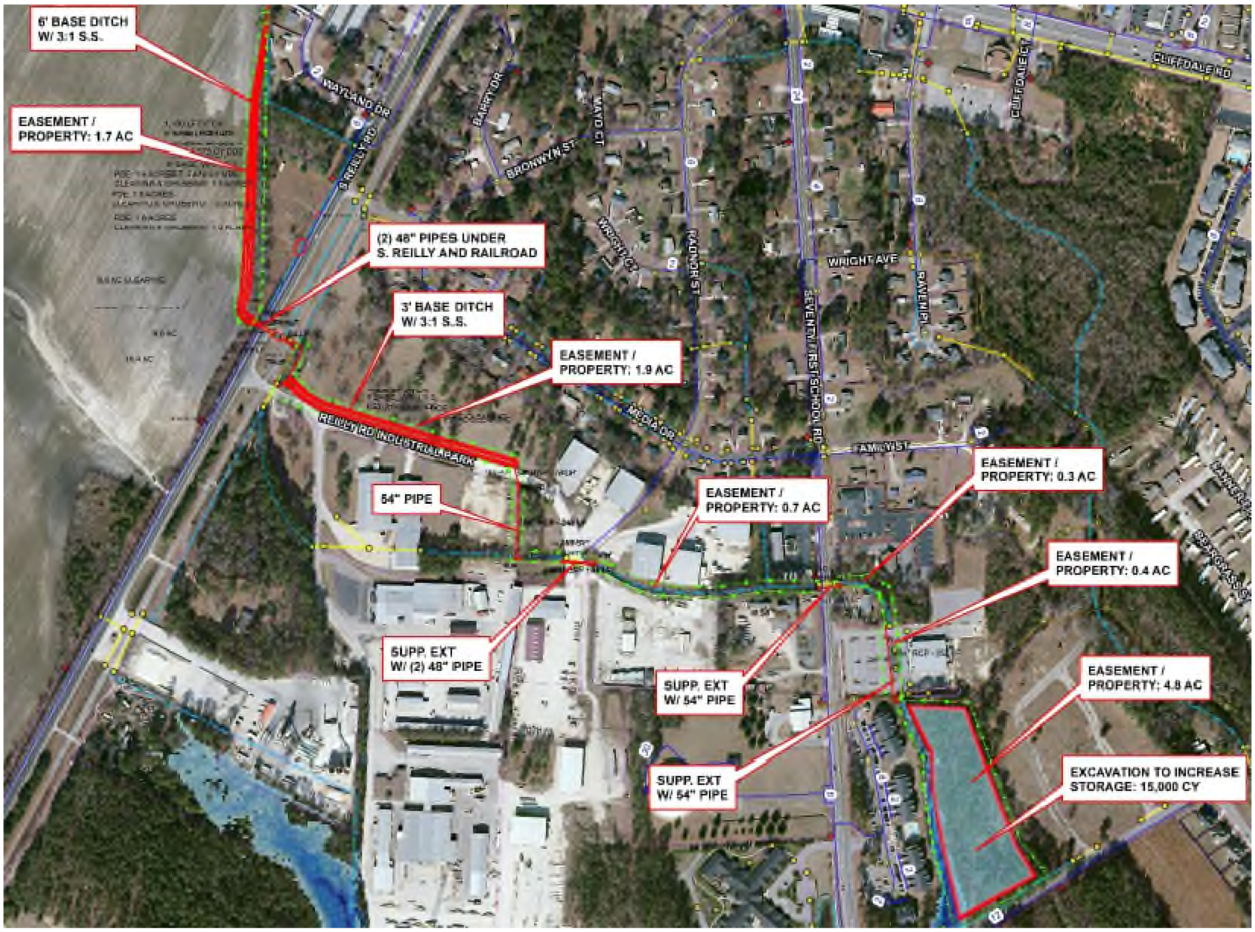


Figure 3 Option #3 proposes to grade a designated storage area in the vacant property north of Old Bunce Road) provides drainage improvements which would convey stormwater flows downstream and provide 15,000 CY of newly excavated storage. This option allows for drainage improvements under South Reilly Road and the railroad, relocating the floodwaters from the Wayland Drive area all the way down to the graded storage area north of Old Bunce Road. The proposed improvements will increase the capacity of the local storm drainage system enough to prevent losses to buildings and their contents up to the 100-year event. More information on the scope can be reviewed in the engineering report, *Wayland Drive Drainage Improvement Options Report*, provided in ATTACHMENT F of the main BRIC application. This area is a flooding hotspot within the City, and more information in the vulnerability can be found in ATTACHMENT D – Historic Losses and Project Need (also of the main BRIC application).

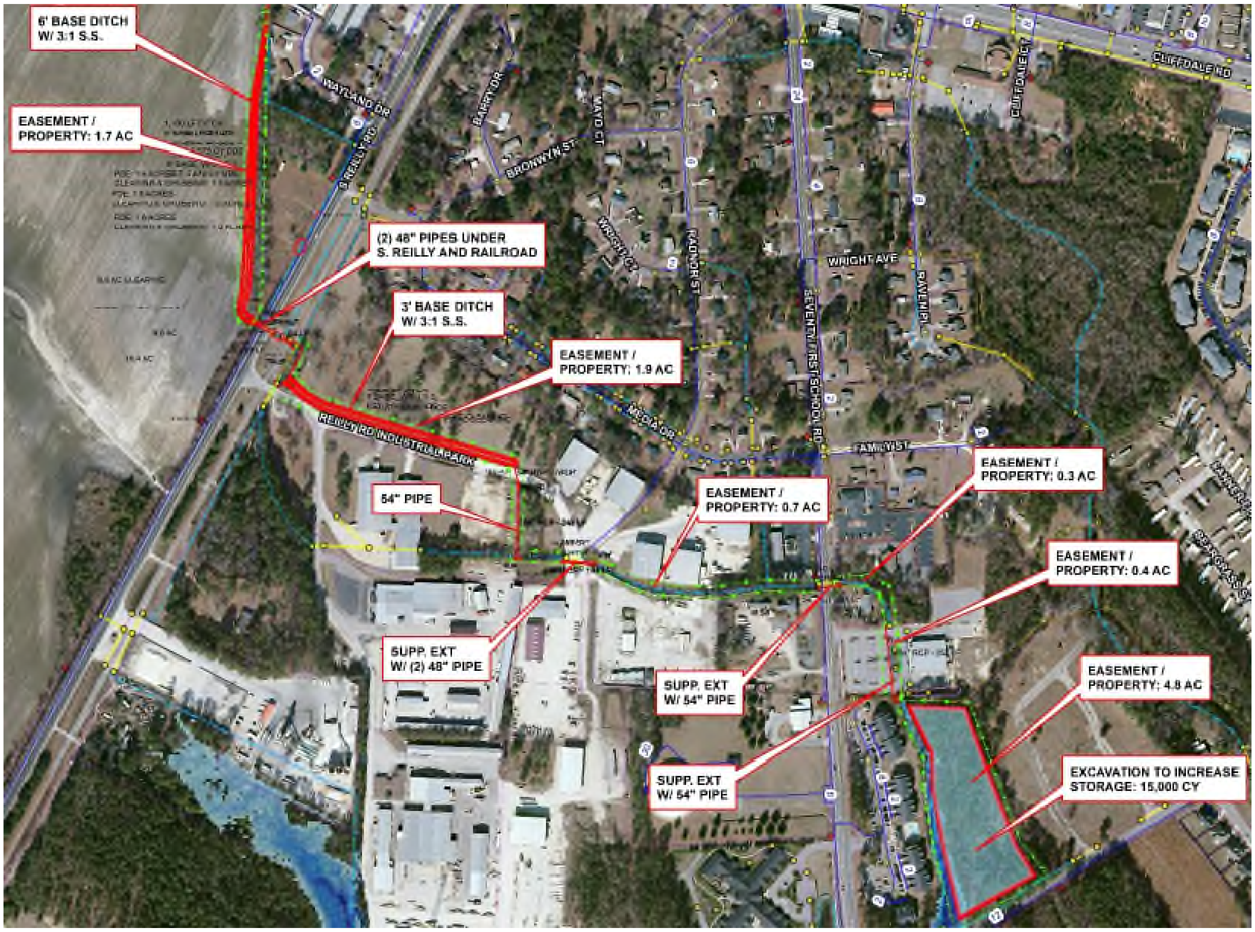


Figure 3 Option #3 proposes to grade a designated storage area in the vacant property north of Old Bunce Road

1.2 FEMA Guidance and Software

FEMA's BCA Toolkit Version 6.0 was used to obtain the Benefit-Cost Ratio (BCR) for the proposed mitigation. The following narrative provides the methodology used to obtain the BCR. Following the guidance in the FEMA BCA Reference Guide and Supplement, this analysis uses engineering assessment and statistical determinations of likely occurrence, associated damages, and building repair and rehabilitation time during and after expected events. Professional Expected Damages were used to complete a Damage Frequency Assessment (DFA) within the BCA Toolkit to prepare this BCA because there was insufficient documentation of historical loss data.

2. PROJECT AND MAINTENANCE COSTS

The total project and annual maintenance costs for implementing the proposed mitigation project is provided in **Table 1** below. Maintenance costs for the project were calculated as $1,000 per year. These costs include cost associated with the inspection, testing, and general maintenance of the City of Fayetteville.

Table 1. Wayland Drive Drainage Improvements Project and Maintenance Costs

Mitigation Activity	Project Cost	Annual Maintenance Cost
Wayland Drive Drainage Improvements	$3,554,561.60	$1,000

3. PROJECT USEFUL LIFE

According to the FEMA BCA Reference Guide – Project Useful Life Table (**Appendix B**), a design life of 50 years should be applied for drainage systems. As such, a useful life of 50 years was used for the City of Fayetteville drainage improvement mitigation measures in the BCA Toolkit.

4. LEVEL OF PROTECTION

The proposed project would protect 23 buildings and up to 1000 feet of roadway to the 25-year precipitation event, with any flooding limited to drainage ditches. Some residual risk remains for larger events, but flood levels are decreased by up to 1 foot. This level of protection is in line with Fayetteville's stormwater infrastructure guidelines which are:

- 10-yr design storm for storm sewers
- 25-y design storm for culvert (roadway) crossings

Figures 4 and **5** show the modelling results for the 25- and 100- year events. Note that Fire Station 8 is located at 1116 71st School Rd. While this critical facility does not flood at the 100-year event, the road just north does. This could compromise direct routes for the fire trucks during extreme events. Additional map for protected properties is provided in **Appendix C**.

Map 15 - Option #3 - 25-year Storm

Figure 4 Results from H&H study showing inundation from 25-year storm event

Map 16 - Option #3 - 100-year Storm

Figure 5 Results from H&H study - inundation from 100-year storm event. Red star indicates a Fire Station

5. DETERMINING PHYSICAL DAMAGES – BUILDINGS AND CONTENTS

Direct physical damages include the degradation and destruction of property due to flood inundation that would occur should the proposed actions not take place and are quantified through monetary losses. The BCA categorizes property loss as both structural damage (i.e., damage that applies to real property) and content damage (i.e., damage to personal property or inventory). Analysts evaluated these losses using Depth Damage Functions (DDFs) for input into the FEMA BCA Toolkit. The following sections describe the analysis used to determine building and content losses for the public services and the buildings that will be consolidated into the new site location.

5.1 Data Sources

BCA analysts utilized the following data sources to calculate expected structure and contents losses avoided:

- **Cumberland County, NC Tax Administration Data (2020):** Attributes from this dataset used in the direct physical damage analysis include square footage, number of stories, and building use. This dataset also provided building footprints.
- **FEMA Depth Damage Functions (DDFs):** Flood losses for a structure can be evaluated based on depth damage functions which depend on building type (residential, commercial, etc.) and building use (single family home, apartment, department store, hardware store, etc.). The United States Army Corps of Engineers (USACE) Generic Riverine DDFs were used in this analysis.
- **FEMA Contents-to-Structure Ratio Values (CSRVs):** The CSRVs used were for residential and non-residential structures, from Version 5.3.0 of the BCA Toolkit. CSRVs are a percentage of the total building replacement values.
- **LiDAR Digital Elevation Model (DEM):** A model of the ground surface, which provides the ground elevation for structures. The DEM is a raster layer of high-resolution ground elevation data based on information from bare-earth LiDAR elevation data. DEM is provided by Hydrological & Hydraulic model developed by Gradient (Attachment H of main BRIC application).
- **HAZUS Occupancy Classes:** HAZUS is a nationally applicable standardized methodology that contains models for estimating potential losses from earthquakes, floods, and hurricanes and is used for structure occupancy classes for applying appropriate DDFs and replacement values.
- **Bureau of Labor Statistics Consumer Price Index Inflation Calculator:** The Consumer Price Index (CPI) is a measure of the average change over time in the prices paid by urban consumers for a market basket of consumer goods and services.

5.2 Develop Asset Inventory

Analysts identified benefitting structures (e.g., the structures targeted within the project area and behind each alignment) and gathered building attributes necessary for examination, such as number of stories, total area, and building use, from the Cumberland County, NC Tax Administration data (**Table 2**). Analysts also used the available building footprints provided by the Cumberland County, NC Tax Administration data and merged these building footprints with the identified parcel level data using a unique building identification number within ESRI ArcGIS.

Table 2. Cumberland County, NC Building Attributes

Attribute	Analysis Use
Parcel ID	Key location identifier specific to a parcel
Unique ID	Key location identifier specific to a building
Address	Key location identifier
Living Area	Used in square footage analysis and replacement value calculation
Land Occupancy Description	Building use
Land Use Description	Secondary identifier of building use

5.3 Building and Contents Replacement Values

Based on each structure's construction class and height class, a value per square foot was provided. These values were updated to 2021 values to account for increases due to inflation and multiplied by the area of each building to determine the building replacement value (BRV). The BRV represents the cost to repair or rebuild damaged buildings in current dollars.

Contents replacement value (CRV) is typically expressed as a percentage of BRV through a Content-to-Structure Ratio Value (CSVR). To calculate the CRV, analysts multiplied the total BRV by the appropriate percentage, as determined by the BCA Toolkit Version 6.0. The contents value of all the commercial buildings in this project is 100% of BRV. Since the USACE Generic DDFs were selected, FEMA Supplement to the Benefit-Cost Analysis Reference Guide recommends using 100% of BRV to obtain contents value for residential buildings (**Appendix D)**.

Because the HAZUS Occupancy Code values used to produce BRVs were calculated based on 2006 data, adjustments were required to normalize construction costs from 2006 to 2021. The Bureau of Labor Statistics Consumer Price Index (CPI) provides an online calculator tool to adjust previous year prices and inflate these prices over time to the date of your choosing (www.bls.gov/data/inflation_calculator.htm). For the purposes of this analysis, BRV prices were adjusted from January 2006 to October 2021 as this was the latest adjustment allowable at the time the assessment was performed (**Table 3**).

Table 3. Building and Contents Replacement Values

HAZUS Occupancy Code	Occupancy Code Description	2006 BRV	2021 BRV	CSVR	2021 CRV
RES1	Single Family Dwelling	$130.34	$151.07	1.0	$151.07
COM3	Retail	$148.21	$147.40	1.0	$147.40
COM4	Office	$183.48	$142.83	1.0	$142.83
COM5	Warehouse	$276.60	$171.78	1.0	$171.78
REL1	Church/Membership Organizations	$197.03	$212.67	1.0	$212.67

5.4 Determine Flood Depth

The H&H modelling provided in Attachments H and I (of the main BRIC application, entitled Wayland Drive Drainage Improvement Options Report) includes flood depths for each building in the project area. The flood depths per event for all 23 buildings before (BM) and after mitigation (AM) are shown in **Table 4**. Refer to photolog in appendix.

Flood depths were rounded to the nearest foot as the DDFs provided within the BCA Toolkit Version 6.0 utilize 1-foot increments. It is important to note that -5 ft was used for events with no flood on the property while 0 ft was used for events with flood depths from 0 to 0.4 ft (-5 ft is an arbitrary number used to avoid physical damage costs and displacement costs evaluation since reference DDFs start with flood depth at -2 ft).

Table 4. Wayland Drive Drainage Improvements Project Area Flood Depths

Address	Structure Type	BM 2-Yr Flood Depth (ft)	BM 10-Yr Flood Depth (ft)	BM 25-Yr Flood Depth (ft)	BM 100-Yr Flood Depth (ft)	AM 2-Yr Flood Depth (ft)	AM 10-Yr Flood Depth (ft)	AM 25-Yr Flood Depth (ft)	AM 100-Yr Flood Depth (ft)
7133 Cliffdale Rd	RES1	-5	-5	0	0	-5	-5	0	0
836 S Reilly Rd	RES1	-5	0	1	1	-5	0	0	0
854 S Reilly Rd	RES1	0	1	1	1	0	0	0	0
862 S Reilly Rd	RES1	1	1	1	1	0	0	0	0
868 S Reilly Rd	RES1	0	0	0	1	0	0	0	0
874 S Reilly Rd	RES1	1	1	1	1	0	0	0	0
882 S Reilly Rd	RES1	1	1	1	1	0	0	0	0
888 S Reilly Rd	RES1	1	1	1	1	0	0	0	0
896 S Reilly Rd	RES1	1	1	1	2	0	0	0	1
820 S Reilly Rd	COM5	0	0	1	1	0	0	0	0
522 Wayland Dr	RES1	0	0	1	1	0	0	0	0
525 Wayland Dr	RES1	1	1	1	1	0	0	0	0
528 Wayland Dr	RES1	0	0	1	1	0	0	0	0
530 Wayland Dr	RES1	0	1	1	1	0	0	0	0
532 Wayland Dr	RES1	0	1	1	1	0	0	0	0
902 S Reilly Rd	RES1	1	1	1	1	0	0	0.25	0.5
524 Varga St	RES1	-5	0	0.5	0.75	-5	0	0	0
528 Varga St	RES1	-5	0	0	0	-5	0	0	0
532 Varga St	RES1	-5	0	0	0	-5	0	0	0

201 Reilly Rd Industrial Park	COM5	-5	0	0	0	-5	0	0	0
217 Reilly Rd Industrial Park	COM4	-5	-5	0.5	1.5	-5	-5	0	1
1053 Seventy First School Rd	COM3	-5	-5	0	0	-5	-5	0	0
1077 Seventy First School Rd	REL1	-5	-5	0	0	-5	-5	0	0

5.5 Depth Damage Functions (DDFs)

A DDF correlates the depth, duration, and type of flooding to a percentage of expected damage to a structure and its contents, including inventory. The USACE Generic Riverine DDFs were used to determine the amount of damage to buildings and contents based on the location and type of structure, and amount of flooding. **Tables 5-9** show the DDF values that were used for the five categories of buildings. Once BCA analysts established the expected flood depth for each flood scenario, they used the DDF to estimate the percent of structural and contents damage; this percentage is applied to a structure's BRV or CRV to produce a physical loss value in dollars.

Ultimately, benefits represent the present value of the sum of expected annual avoided damages over the project useful life. Analysts applied the annual probability of each flood scenario to expected flood impacts to calculate damages from specific frequency events. The loss values for each event were entered into the BCA Toolkit.

Table 5. Depth Damage Functions Values for Residential Buildings

Flood Depth (ft)	-2	-1	0	1	2	3	4	5	6	7
Building	0%	3%	13%	23%	32%	40%	47%	53%	59%	63%
Content	0%	2%	8%	13%	18%	22%	26%	29%	32%	34%

Table 6. Depth Damage Functions Values for Retail Buildings

Flood Depth (ft)	-2	-1	0	1	2	3	4	5	6	7
Building	1%	1%	1%	13%	20%	27%	33%	37%	40%	44%
Content	0%	0%	0%	23%	34%	44%	67%	78%	87%	95%

Table 7. Depth Damage Functions Values for Office Buildings

Flood Depth (ft)	-2	-1	0	1	2	3	4	5	6	7
Building	1%	1%	2%	13%	19%	25%	31%	34%	39%	46%
Content	1%	1%	1%	20%	34%	45%	55%	64%	73%	76%

Table 8. Depth Damage Functions Values for Warehouses

Flood Depth (ft)	-2	-1	0	1	2	3	4	5	6	7
Building	0%	0%	1%	13%	22%	29%	37%	40%	46%	50%
Content	0%	0%	0%	30%	48%	59%	66%	74%	80%	84%

Table 9. Depth Damage Functions Values for Churches

Flood Depth (ft)	-2	-1	0	1	2	3	4	5	6	7
Building	0%	0%	1%	16%	28%	36%	43%	48%	54%	58%
Content	0%	0%	0%	29%	48%	60%	69%	76%	81%	88%

5.6 Flood Losses – Building and Content Damages

Analysts calculated expected property losses associated with the flood scenarios using the USACE Generic Riverine DDFs specific to the characteristics and occupancy of a structure as shown in **Tables 5-9**. As this information contains the most current and best available data, analysts used these functions to evaluate direct physical damages for each designed storm event as shown in **Table 10**.

Table 10. Wayland Drive Drainage Improvements Project Building and Content Damage Costs

Designed Storm Event	Building Damages	Content Damages
2-Year	$537,755.94	$281,364.79
10-Year	$725,661.83	$370,703.57
25-Year	$2,670,279.11	$3,847,544.51
100-Year	$3,169,754.38	$4,971,046.27
2-Year After Mitigation	$397,153.01	$207,512.75
10-Year After Mitigation	$530,618.45	$268,256.54
25-Year After Mitigation	$719,598.54	$368,501.80
100-Year After Mitigation	$1,671,818.61	$1,855,778.84

5.7 Flood Losses – Displacement

The displacement cost consists of a one-time disruption cost along with a recurring monthly rental cost for the duration of the displacement. The total displacement cost is estimated by adding the disruption cost and the rent costs as expressed in the equation below:

$$Diplacement\ Cost = (Disruption\ Cost\ x\ ft^2) + (Rental\ Costx\ ft^2 x\ Displacement\ Time\ in\ Months)$$

Tables 11 and **12** show the values that were used for cost and number of days for each building category. Please see **Appendix E** additional FEMA Standard Values for displacement costs.

Table 11. Displacement Costs

HAZUS-MH MR3 Label	Rental Cost (2021) $/ft^2/month	Disruption Cost (2021) $/ft^2
RES1	0.9563	1.1528
COM3	1.9126	1.3362
COM4	1.9126	1.3362
COM5	2.3842	1.3362
REL1	1.4279	1.3362

Table 12. Displacement Function in Number of Days

Flood Depth (ft)	-2	-1	0	1	2	3	4	5	6	7
Displacement (days)	0	0	0	45	90	135	180	225	270	315

The rental costs and the disruption costs calculated in this analysis are summarized below in **Table 13**.

Table 13. Wayland Drive Drainage Improvements Displacement Costs

Designed Storm Event	Displacement Costs
2-Year	$59,223.97
10-Year	$86,202.26
25-Year	$339,119.62
100-Year	$447,191.52
2-Year After Mitigation	$45,738.70
10-Year After Mitigation	$67,495.60
25-Year After Mitigation	$138,463.80
100-Year After Mitigation	$246,262.72

6. TRANSPORTATION DISRUPTION - ECONOMIC IMPACT OF ROAD CLOSURES

In the context of emergency planning, disaster response, and disaster recovery, roads and bridges are often characterized as lifelines. This characterization reflects the importance that roads and bridges have on the functioning of modern society. Especially in a disaster, roads and bridges are often critical for disaster response and evacuation. Roads and bridges are subject to physical damages from natural disasters such as hurricanes and floods. More importantly, however, roads and bridges are subject to loss of function; that is, closure to traffic. Such closures often have significant negative impacts on affected communities. Closure of a road represents loss of a public service – the availability of a transportation route.

The economic impact of road closures is estimated form the number of vehicles per day using the route, the average delay or detour time, and the average value of people's time. The primary economic impact of road closures is loss of time.

There are four steps in estimating the direct economic impacts of road closures:

1. Estimate the functional downtime; that is, the repair time to restore normal traffic flow on the road.
2. Determine the average daily traffic count for the closed road or bridge.
3. Estimate the average delay or detour time arising because of the closure
4. Place a typical or average dollar value per person hour or per vehicle hour of delay or detour.

In this analysis, S. Reilly Road is the only route that is flooded significantly for all designed storms. Thus, we assumed conservatively that the repair time to restore normal traffic flow on the road was one day. From City of Fayetteville Annual Average Daily Traffic (AADT) Map, AADT for S Reilly Road was obtained. AADT for S Reilly Road in 2016 (the most recent year available) was 16000 trips per day. According to Google Maps, the average delay or detour time arising because of the closure on S. Reilly Road for all designed storm events is 11 minutes and the additional miles due to the closure is 6.7 miles. Inputting these values into FEMA BCA Toolkit 6.0, we obtained that the road closure costs **$156,035.00** during each designed storm events.

7. RESULTS

Table 14 shows the results of the analysis for each category of loss avoided, both before and after mitigation. Please see **Appendix F** for further detailed calculations for all the damages and loss values.

Table 14. BCA Toolkit Input Summary

Designed Storm Event	Building Damages	Content Damages	Displacement Costs	Road Outages
2-Year	$537,755.94	$281,364.79	$59,223.97	$ 156,035.00
10-Year	$725,661.83	$370,703.57	$86,202.26	$ 156,035.00
25-Year	$2,670,279.11	$3,847,544.51	$339,119.62	$ 156,035.00
100-Year	$3,169,754.38	$4,971,046.27	$447,191.52	$ 156,035.00
2-Year After Mitigation	$397,153.01	$207,512.75	$45,738.70	$ -
10-Year After Mitigation	$530,618.45	$268,256.54	$67,495.60	$ -
25-Year After Mitigation	$719,598.54	$368,501.80	$138,463.80	$ -
100-Year After Mitigation	$1,671,818.61	$1,855,778.84	$246,262.72	$ 156,035.00

The benefit-cost ratio for the proposed project is listed in **Table 15**. Costs provided in the determination of the BCR include maintenance costs over the project useful life of the mitigation project. The total project BCR is **2.38,** which demonstrates that the mitigation project is a cost-effective solution. The BCA Report is provided in Appendix A and the BCA Excel Spreadsheet is attached to the project application.

Table 15. Wayland Drive Drainage Improvements Benefit-Cost Ratio

Description	Benefits	Costs	BCR
Wayland Drive Drainage Improvements	$ 7,033,992	$3,568,362	1.97