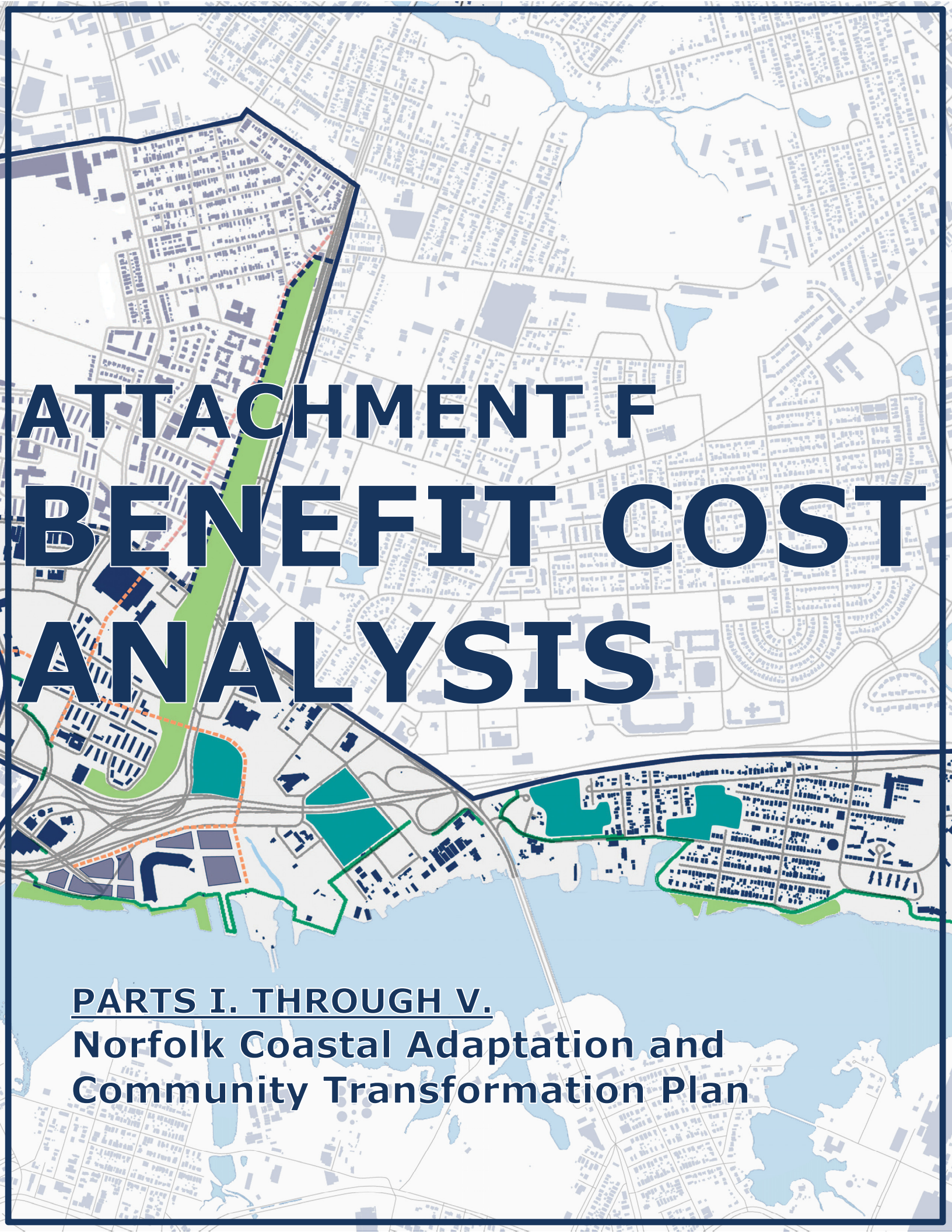

ATTACHMENT F
BENEFIT COST ANALYSIS

PARTS I. THROUGH V.

Norfolk Coastal Adaptation and Community Transformation Plan

Attachment F Benefit Cost Analysis

To facilitate the reader understanding, **Attachment F** is divided into five distinct sections plus an **Appendices**. Contents for **Sections I** through **III** are provided herein. Because **Section IV: BCA Methodologies** contains various sub-sections, another table of contents has been developed for this portion of the report and is provided in a separate document:

- **I: Overview** provides a summary of the purpose of the Benefit-Cost Analysis, the approach taken to conduct the analysis, and presents overarching results.
- **II: Project Description** provides a detailed project description of the Newton's Creek Watershed, Ohio Creek Watershed, and the Elizabeth River Shoreline Restoration. Though each of these projects can be viewed independently of one another, together they form the City of Norfolk Coastal Adaptation and Community Transformation Plan.
- **III: Existing Conditions** describes specific existing conditions of risks and vulnerabilities that will be reduced by the institution of each project. This includes disconnected neighborhoods, vulnerable populations, environmental conditions, cultural resources and critical assets, economic growth trends, and current risk context.
- **IV: Benefits Included in the Benefit Cost Ratio** provides a detailed approach for each benefit quantified in this analysis.
- **V: Qualitative Benefits** describes benefits not included in the benefit cost ratio (BCR), which are limited to the nine pages required by HUD.
- **Appendices**
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    - F-2: Sea Level Rise Memorandums
    - F-3: FEMA Flood Maps
    - F-4: Economic Loss Calculations and IMPLAN results
    - F-5: Norfolk IMPLAN Base Model
    - F-6: Overview of Stormwater Capital Improvement Projects, FY 2012 through FY 2016
    - F-7: Hazus Technical Manual Excerpts
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    - F-19: Comparable Facilities – Nassau County Pump Station Damage Assessment Summary (Hurricane Sandy, 2012)
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PART I
OVERVIEW

Overview

A comprehensive benefit cost analysis (BCA) must be completed for the Phase 2 submission to HUD's National Disaster Resilience Competition (NDRC.) This analysis must consider economic, environmental, social, and resiliency factors to ensure that project benefits outweigh the costs. Per the Notice of Funding Availability (NOFA) dated June 25, 2015, it is understood that the results of the BCA alone are not cause to reject or approve a proposal. HUD recognizes that a complete soundness of approach justification includes fundamental project elements such as feasibility, replicability, public desirability, meeting unmet needs, reducing risk, and improving resiliency. Over time the value of the project will increase as it prevents future losses in subsequent disaster incidents. This analysis for the City of Norfolk's Coastal Adaptation and Community Transformation Plan Phase 2 proposal follows a carefully considered process which includes direct project benefits as well as secondary impacts of those benefits.

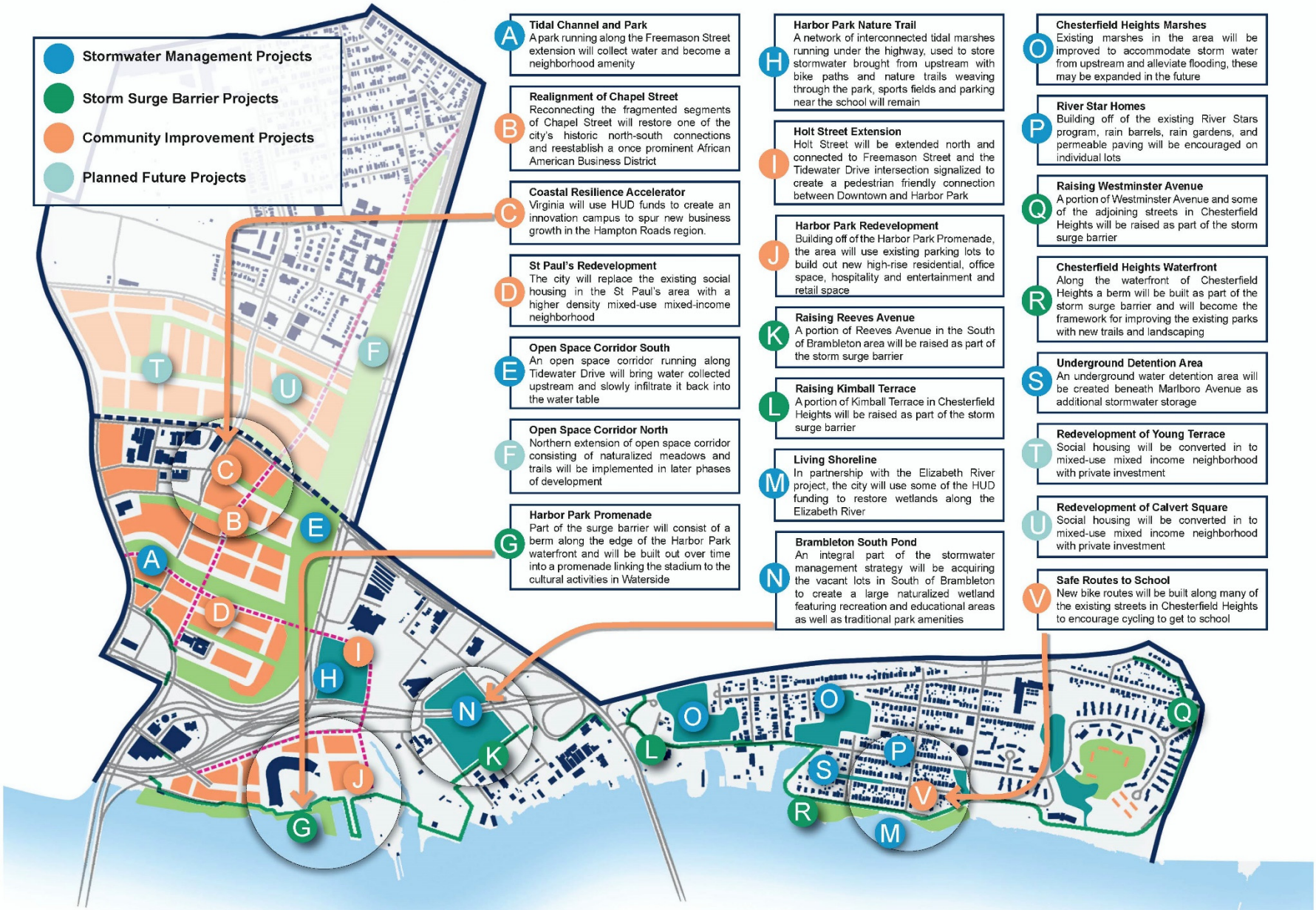
The Qualifying Disaster for Virginia's application is Hurricane Irene, which demonstrated that without mitigation, the City of Norfolk (indeed the Hampton Roads region) will continue to suffer physical, social and economic losses from future flooding. Losses experienced in Irene included structural and content damages to homes and businesses; loss of power, communication and transportation services; and inaccessibility due to stormwater flooding that was exacerbated by coastal storm surge. Future losses are expected to be even more significant as sea levels continue rise and coastal storms become more frequent and intense.
Virginia has developed a statewide approach to its coastal and inland stormwater challenges: "thRIVe: Resilience in Virginia" is a five-part approach to achieve resiliency-- guided by the National Preparedness System-- to 1) unite the region, 2) create coastal resilience, 3) strengthen vulnerable neighborhoods, 4) improve economic vitality, 5) and build water management solutions. The thRIVe plan's five lines of effort align with HUD's goal for the National Disaster Resilience Competition, as they are each designed to achieve a major critical objective, address unmet need, and provide replicable and scalable solutions to identified vulnerabilities within the Target Areas defined in this proposal.

The primary Target Area presented by the city is comprised of two watersheds: the Ohio Creek Watershed and the Newton's Creek Watershed. In each, a series of stormwater management techniques are combined with integrated coastal flood protection infrastructure and a living shoreline to create the greatest opportunity for a resilience response and recovery during future disaster events. Proposed project elements are described below and presented in the infographic on page I.3.

- Upper watershed green and blue stormwater management measures to be taken on both public and private land
- Re-alignment of streets and transportation systems to allow historic creek beds to fill during rain events, alleviating serious street flooding and allowing for the creation of "complete streets"
- An incentivized private property on-site retention and public education program that will allow runoff to be captured and detained for slow release post-storm
- The redevelopment of neighborhood areas where new or expanded wetlands and dry-day parks can absorb stormwater on rainy days
- Demolition of aged buildings that have added to area blight and whose spaces can provide new places for stormwater management activities and economic revitalization opportunities
- A coastal resiliency research, educational and workforce training center that will provide a hub for regional collaboration and innovation regarding water management issues and practices
- An integrated coastal flood protection system to hold back surge inundation into low-lying areas of the City
- The creation of new shoreline restoration areas that will provide a natural buffer for rising seas as well as healthier environment for native species of plants and animals in the area

Norfolk Coastal Adaptation and Community Transformation Plan

Key Intervention Sites for NDRC Application



A — Tidal Channel and Park
A park running along the Freemason Street extension will collect water and become a neighborhood amenity

B — Realignment of Chapel Street
Reconnecting the fragmented segments of Chapel Street will restore one of the city's historic north-south connections and reestablish a once prominent African American Business District

C — Coastal Resilience Accelerator
Virginia will use HUD funds to create an innovation campus to spur new business growth in the Hampton Roads region.

D — St Paul's Redevelopment
The city will replace the existing social housing in the St Paul's area with a higher density mixed-use mixed-income neighborhood

E — Open Space Corridor South
An open space corridor running along Tidewater Drive will bring water collected upstream and slowly infiltrate it back into the water table

F — Open Space Corridor North
Northern extension of open space corridor consisting of naturalized meadows and trails will be implemented in later phases of development

G — Harbor Park Promenade
Part of the surge barrier will consist of a berm along the edge of the Harbor Park waterfront and will be built out over time into a promenade linking the stadium to the cultural activities in Waterside

H — Harbor Park Nature Trail
A network of interconnected tidal marshes running under the highway, used to store stormwater brought from upstream with bike paths and nature trails weaving through the park, sports fields and parking near the school will remain

I — Holt Street Extension
Holt Street will be extended north and connected to Freemason Street and the Tidewater Drive intersection signalized to create a pedestrian friendly connection between Downtown and Harbor Park

J — Harbor Park Redevelopment
Building off of the Harbor Park Promenade, the area will use existing parking lots to build out new high-rise residential, office space, hospitality and entertainment and retail space

K — Raising Reeves Avenue
A portion of Reeves Avenue in the South of Brambleton area will be raised as part of the storm surge barrier

L — Raising Kimball Terrace
A portion of Kimball Terrace in Chesterfield Heights will be raised as part of the storm surge barrier

M — Living Shoreline
In partnership with the Elizabeth River project, the city will use some of the HUD funding to restore wetlands along the Elizabeth River

N — Brambleton South Pond
An integral part of the stormwater management strategy will be acquiring the vacant lots in South of Brambleton to create a large naturalized wetland featuring recreation and educational areas as well as traditional park amenities

O — Chesterfield Heights Marshes
Existing marshes in the area will be improved to accommodate storm water from upstream and alleviate flooding, these may be expanded in the future

P — River Star Homes
Building off of the existing River Stars program, rain barrels, rain gardens, and permeable paving will be encouraged on individual lots

Q — Raising Westminster Avenue
A portion of Westminster Avenue and some of the adjoining streets in Chesterfield Heights will be raised as part of the storm surge barrier

R — Chesterfield Heights Waterfront
Along the waterfront of Chesterfield Heights a berm will be built as part of the storm surge barrier and will become the framework for improving the existing parks with new trails and landscaping

S — Underground Detention Area
An underground water detention area will be created beneath Marlboro Avenue as additional stormwater storage

T — Redevelopment of Young Terrace
Social housing will be converted in to mixed-use mixed income neighborhood with private investment

U — Redevelopment of Calvert Square
Social housing will be converted in to mixed-use mixed income neighborhood with private investment

V — Safe Routes to School
New bike routes will be built along many of the existing streets in Chesterfield Heights to encourage cycling to get to school

The combination of these flood risk reduction techniques throughout each of the watershed Target Areas is expected to provide a comprehensive resiliency milieu that can be sustained, replicated, and expanded over time in the City and throughout the region.

These proposed activities, and their interdependent subparts, are described and analyzed in greater detail in **Attachment F II. Project Description**. While these activities can be implemented independently, all are required to achieve Norfolk's vision and to meet the Unmet Need described in **Exhibit B**, **Exhibit E, a**nd **Exhibit D** of the application.

As outlined in the Phase I application, the City of Norfolk in the larger Hampton Roads region is subject to the highest rate of relative sea level rise on the East Coast – the area has experienced a 14 inch rise since 1930.[1] The global sea level rise is 5 – 8 inches over the last century (Phase 1 Application, Exhibit D: Unmet Need, pg. 26). The Hampton Roads area is second to New Orleans for the largest population at risk from sea level rise (Phase 1 Application, Exhibit D: Need, pg. 26). Over the past several decades, Norfolk residents have received increased stresses due to the impacts of climate changes, such as sea level rise and more frequent and intense coastal storms. As discussed in the Hampton Roads Planning District Commission's 2013 report Coastal Resiliency: Adapting to Climate Change in Hampton Roads, sea level rise has significant effects on the region even when using varied and conservative modeling.[2] The threat of sea level rise, and the effects of climate change in the region, are very real threats.

Additionally, the Target Area has an unmet affordable housing need. Currently, within the St. Paul's Quadrant of the Target Area, there are over 618 public housing units that need to be rebuilt. The current public housing stock is unsatisfactory, and within the St. Paul's Area Plan, the City hopes to replace the public housing units one-for-one within the existing neighborhood or within nearby communities. The current affordable housing is inadequate, causes economic segregation within the St. Paul's Quadrant (and into the larger Target Area) and does not provide adequate protection against extreme flood events. Within the proposed Projects, affordable housing resilience will be addressed.

The Target Area also requires economic revitalization. Currently, the City is preparing for various efforts to revitalize, specifically though development of city-owned land in the St. Paul's Quadrant. Norfolk is currently soliciting for a Master Developer, who will assist the city in maximizing the city's real estate assets and economic development opportunities, creating non-competing land uses, a new tax base and emphasizing short and long term job creation in the Target Area and beyond.

Finally, to meet the needs of the populations within the Target Area, there must also be a focus on social cohesion. Norfolk's Mayor's Commission on Poverty Reduction proposed a plan entitled the Norfolk Plan to Reduce Poverty, which outlined the core values of the City to build a thriving future for all Norfolk residents by creating opportunities for pathways out of poverty, provide the tools and education needed to enter and succeed in those pathways, relying on citizens' motivation and a sense of personal responsibility, and invest in cost-effective and proven solutions. Recommendations included better and more available early childhood development programs, youth education and career pathways, adult workforce development, and neighborhood revitalization and support. This final recommendation utilizes strategies to stabilize stressed neighborhoods through community revitalization and economic development, develop mixed-income housing and mixed-use communities in distressed neighborhoods, and create policies to facilitate the de-concentration of poverty in Norfolk's public housing communities.

Because of the size and scale of the proposed City of Norfolk Coastal Adaptation and Community Transformation Plan, the city has developed an established phasing strategy. This phasing strategy will allow the city to effectively allocate the resources needed and efficiently integrate each portion of the project into the urban fabric of Norfolk as a whole.

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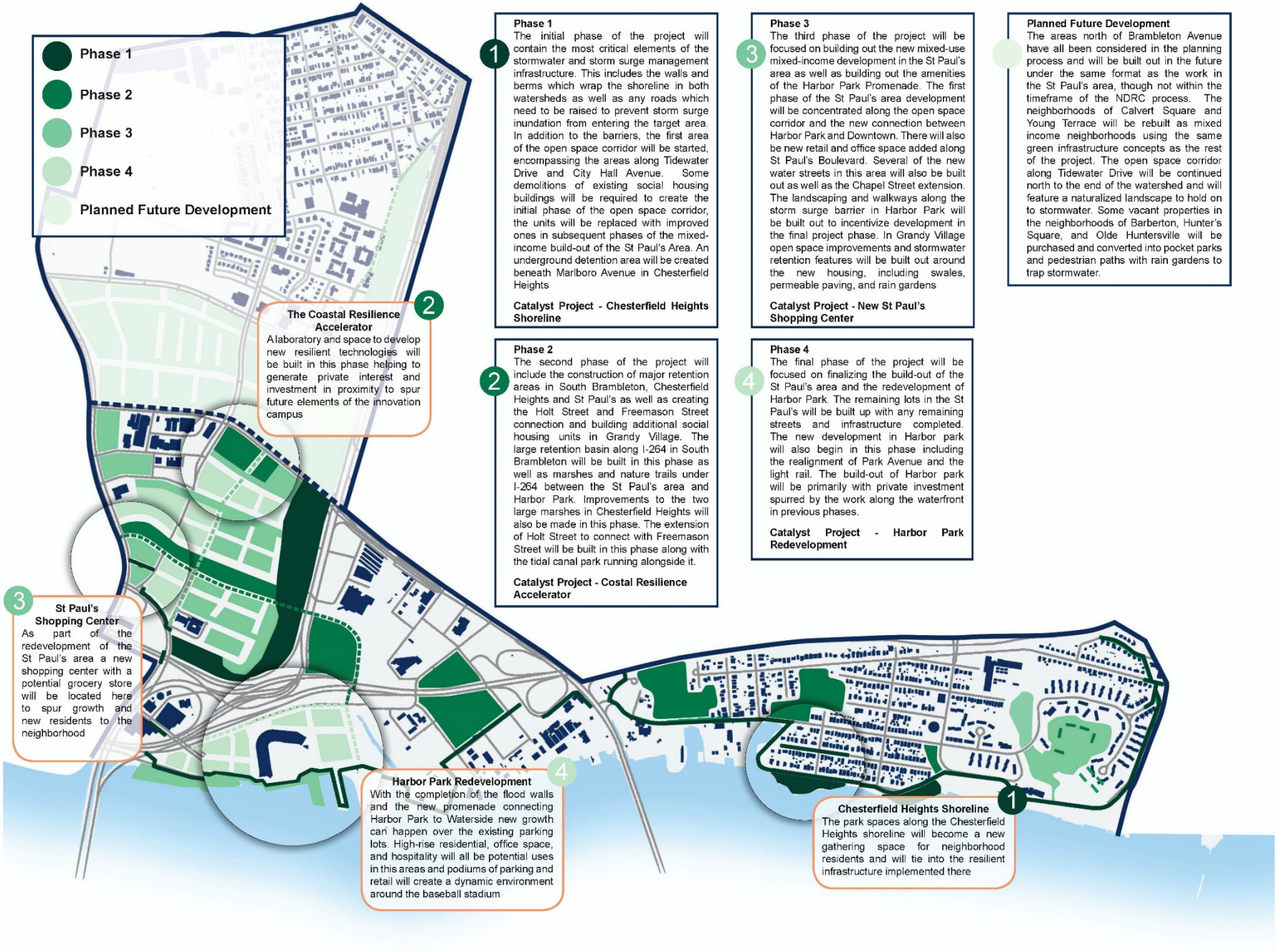
[1] *Atkinson, Ezer, and Smith, Sea Level Rise and Flooding Risk in Virginia, 2012 (http://nsglc.olemiss.edu/sglpj/vol5no2/2-atkinson.pdf)*
[2] *Coastal Resiliency: Adapting to Climate Change in Hampton Roads, HRPDC, 2013*

Norfolk Coastal Adaptation and Community Transformation Plan

Phasing Strategies



1 Phase 1

The initial phase of the project will contain the most critical elements of the stormwater and storm surge management infrastructure. This includes the walls and berms which wrap the shoreline in both watersheds as well as any roads which need to be raised to prevent storm surge inundation from entering the target area. In addition to the barriers, the first area of the open space corridor will be started, encompassing the areas along Tidewater Drive and City Hall Avenue. Some demolitions of existing social housing buildings will be required to create the initial phase of the open space corridor, the units will be replaced with improved ones in subsequent phases of the mixed-income build-out of the St Paul's Area. An underground detention area will be created beneath Marlboro Avenue in Chesterfield Heights

Catalyst Project - Chesterfield Heights Shoreline

2 Phase 2

The second phase of the project will include the construction of major retention areas in South Brambleton, Chesterfield Heights and St Paul's as well as creating the Holt Street and Freemason Street connection and building additional social housing units in Grandy Village. The large retention basin along I-264 in South Brambleton will be built in this phase as well as marshes and nature trails under I-264 between the St Paul's area and Harbor Park. Improvements to the two large marshes in Chesterfield Heights will also be made in this phase. The extension of Holt Street to connect with Freemason Street will be built in this phase along with the tidal canal park running alongside it.

Catalyst Project - Costal Resilience Accelerator

3 Phase 3

The third phase of the project will be focused on building out the new mixed-use mixed-income development in the St Paul's area as well as building out the amenities of the Harbor Park Promenade. The first phase of the St Paul's area development will be concentrated along the open space corridor and the new connection between Harbor Park and Downtown. There will also be new retail and office space added along St Paul's Boulevard. Several of the new water streets in this area will also be built out as well as the Chapel Street extension. The landscaping and walkways along the storm surge barrier in Harbor Park will be built out to incentivize development in the final project phase. In Grandy Village open space improvements and stormwater retention features will be built out around the new housing, including swales, permeable paving, and rain gardens

Catalyst Project - New St Paul's Shopping Center

4 Phase 4

The final phase of the project will be focused on finalizing the build-out of the St Paul's area and the redevelopment of Harbor Park. The remaining lots in the St Paul's will be built up with any remaining streets and infrastructure completed. The new development in Harbor park will also begin in this phase including the realignment of Park Avenue and the light rail. The build-out of Harbor park will be primarily with private investment spurred by the work along the waterfront in previous phases.

Catalyst Project - Harbor Park Redevelopment

Planned Future Development

The areas north of Brambleton Avenue have all been considered in the planning process and will be built out in the future under the same format as the work in the St Paul's area, though not within the timeframe of the NDRC process. The neighborhoods of Calvert Square and Young Terrace will be rebuilt as mixed income neighborhoods using the same green infrastructure concepts as the rest of the project. The open space corridor along Tidewater Drive will be continued north to the end of the watershed and will feature a naturalized landscape to hold on to stormwater. Some vacant properties in the neighborhoods of Barberton, Hunter's Square, and Olde Huntersville will be purchased and converted into pocket parks and pedestrian paths with rain gardens to trap stormwater.

In order to demonstrate the benefits expected from investment in the proposed Coastal Adaptation and Community Transformation Plan, analysts evaluated four categories of benefits: resiliency values such as direct physical damages and critical asset impacts; environmental benefits such as reduced carbon emissions and reduced stormwater runoff; social and recreational benefits including recreational and aesthetic values and mental stress and anxiety; and economic revitalization impacts realized by the project. Within each of these categories, losses avoided and benefits added by the project were considered. Principle sources of methodologies and data standards for the development of the BCA originated from entities such as the United States Army Corps of Engineers (USACE), the Federal Emergency Management Agency (FEMA), Earth Economics, as well as literary publishers and journals.

Quantified Results

The BCA for Norfolk's Coastal Adaptation and Community Transformation Plan considers both quantified and qualitative benefits in accordance with the NDRC NOFA Appendix H. The quantified benefits, which can be represented in monetary terms and are used to develop the benefit cost ratio (BCR) are broadly divided into Resiliency values and Inherent values.

Results are ultimately provided in three ways: annual benefits, net present value, and the BCR.

- **Annual Benefits:** Annual benefits are the avoided damages and added benefits per year expected over the useful life of the project. Annual losses avoided are presented as a function based on the annual chance of the damaging event occurring. For example, if benefits for a 1-percent annual chance event are $150,000 then the benefit is multiplied by .01, and $1,500 is the annual benefit.

- **Net Present Value:** In order to compare the future benefits to the current cost of a project, a discount rate, or coefficient, is applied over the life of the project to calculate the net present value of annual benefits. The present value coefficient used in this analysis is 13.80027 for a 50-year project useful life. The net present value is the benefit used in the benefit-cost ratio, and once all benefits are aggregated, the project net present value is the sum of the benefits minus the net present costs. Annual benefits and net present value are calculated for each value measure presented herein so that they may be incorporated into the benefit cost ratio.

- **Benefit Cost Ratio:** To evaluate cost effectiveness, a project's total net benefits are divided by the total project cost, resulting in a benefit cost ratio. A project is considered to be cost-effective when the ratio is greater than or equal to 1.0, indicating that the benefits are sufficient to justify the costs.

Costs incorporated into the BCA include all project life cycle costs, such as:

- Project capital investment costs
- Operations and maintenance costs over the project useful life
- Any costs associated with actions taken by the City or any governmental partner(s) have taken after the date of the Qualified Disaster, to enhance resilience. These costs are described in Exhibit G.

See Table I.1 below for a summary of the benefits presented herein, including a description of how each is derived. All benefits presented are directly related to the social, environmental, and economic resiliency metrics that will measure project success, as defined in Exhibit E, Soundness of Approach. A crosswalk is provided at the end of this section to review the methodologies used to calculate these benefits and the associated results, in addition to presenting an uncertainty analysis (Table I.4).

Table I.2 and associated figures below summarize the results of benefits that are appropriate to integrate into the benefit-cost ratio. As pages are counted for the description of additional benefits not incorporated into these

All proposed activities, as well as the application in total are cost beneficial with benefits of over one billion dollars, compared to a total estimated cost of over three hundred million dollars, including existing resiliency efforts and operations and maintenance costs, a ratio of 3.93.

Table I.1 Overview of Benefits Calculated and Included in the Benefit Cost Ratio

Benefit Category	Benefit Calculated	Description
Resiliency Benefits	Direct Physical Damages to Buildings, Contents, and Inventory	Analysts applied USACE depth-damage functions (DDFs) to vulnerable structures, critical/essential facilities, and modes of transportation in the benefitting area. The DDFs consider the type of structure/asset, structure or contents replacement value, and expected flood depth within the structure to determine the dollar value of contents or structure damage. Economic losses also use DDFs to evaluate the economic impact of natural disasters. Natural disasters threaten or cause direct impact to structures but can also seriously harm health, social, and economic resources, which lead to psychological distress. Methodologies to calculate expected losses avoided for Human Impacts are a product of flood depth and damage to people's homes.
	Essential Facility and Critical Infrastructure Service Loss	
	Human Impacts	
	Economic Losses	
Environmental Benefits	Provisioning Services	Environmental benefits are gained heavily from the implementation of the projects, which are designed to incorporate expansion of park spaces/wetlands, provide connectivity between neighborhoods and the waterfront, and offer aesthetically pleasing public gathering spaces.
	Regulating Services	
	Supporting Services	
	Cultural Services	
Social Value	Recreational Benefits	Social benefits are based on added recreational and community gathering space. There are health cost reductions and willingness to pay values associated with these amenities.
	Health Benefits	
	Aesthetic Benefits	
Economic Revitalization	Economic Revitalization	Economic gains are based on the addition of new retail and commercial space and expected job growth and gains as a result.

Table I.2 All Applicable Costs included in the Benefit Cost Analysis

Activity	Capital Costs*	Operations and Maintenance	Post-Irene Resiliency Actions	Total Costs
Newton's Creek	$132,227,737	$72,761,568	$11,170,052	$216,159,357
Ohio Creek	$79,327,374	$36,771,119	$11,170,052	$127,268,544
Elizabeth River	$9,778,341	$4,542,654	$0	$14,320,995
Total	$221,333,452	$114,075,341	$22,340,103	$357,748,896

**Capital costs are presented as net present value, as the capital costs are broken out over a 7 year implementation period*

Table I.3 Benefit Cost Analysis Results

Activity	Scenario	All Applicable Costs	Net Present Value of Benefits	Benefit-Cost Ratio
Newton's Creek	Low	$216,159,357	$519,913,259	2.40
	Medium	$216,159,357	$1,206,918,596	5.58
	High	$216,159,357	$1,637,324,992	7.57
Ohio Creek	Low	$127,268,544	$134,310,814	1.05
	Medium	$127,268,544	$189,502,191	1.48
	High	$127,268,544	$210,868,901	1.65
Elizabeth River	Low	$14,320,995	$434,649	0.03
	Medium	$14,320,995	$10,388,429	0.72
	High	$14,320,995	$12,348,992	0.86
Total	Low	$357,748,896	$654,658,722	1.82
	Medium	$357,748,896	$1,406,809,216	3.93
	High	$357,748,896	$1,860,542,885	5.20

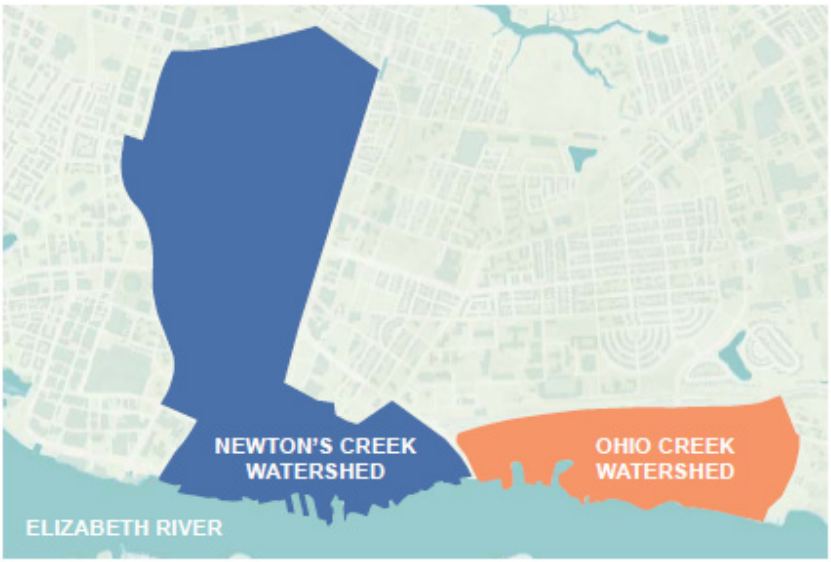
BENEFITS

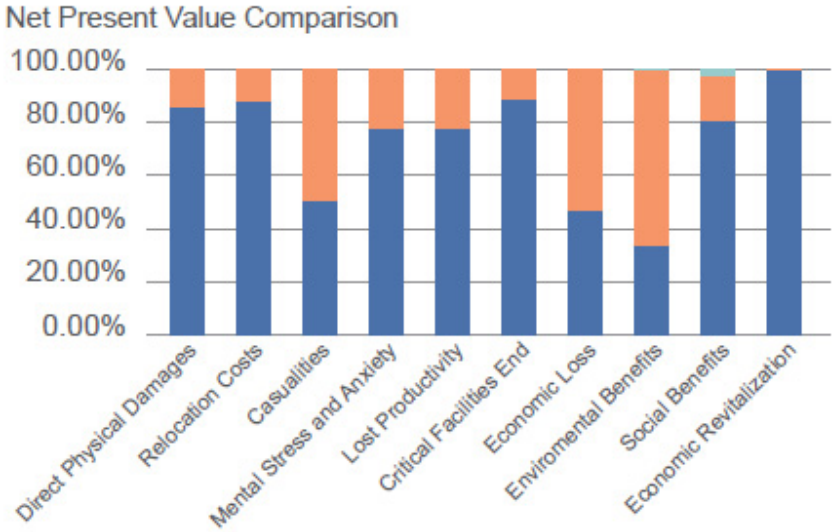
The results of the Benefit Cost Analysis for Norfolk's Coastal Adaptation and Community Transformation Plan application consider economic, environmental, social, and resiliency factors. Results are provided in three forms: annual benefits, net present value, and the BCR. In order to compare future benefits to current cost, a discount rate is applied over the life of the project to calculate the **net present value**, or NPV, from annual benefits. A project's total net benefits are divided by the total project cost, resulting in a **benefit cost ratio**, or BCR. A BCR greater than 1.0 is considered cost-effective.

$1.6 BILLION

NET PRESENT VALUE BENEFITS

BCR: 3.93





404 STRUCTURES **PROTECTED** WITHIN HISTORIC DISTRICT

+7 HISTORIC STRUCTURES PROTECTED

2,224 TREES **ADDED**

1,673 UNITS OF **WELL-BUILT & SAFE** AFFORDABLE HOUSING

226.7 **MILLION GALLONS** STORMWATER RUNOFF **REDUCED**

OVER 600 JOBS **GENERATED**

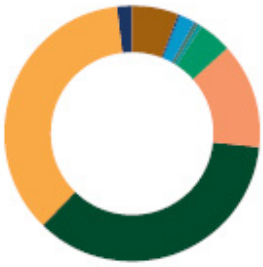
74 ACRES NATURAL COMMUNITY GATHERING SPACE **ADDED**

COMPARISON OF BENEFITS BY ACTIVITY (NPV)

Newton's Creek Watershed

5.66% Direct Physical Damages
0.21% Relocation Costs
0.32% Casualties
0.31% Mental Stress and Anxiety
0.19% Lost Productivity
5.19% Critical Facilities Loss
1.81% Economic Loss
2.71% Enviromental Benefits
26.3% Social Benefits
57.5% Economic Revitalization

Ohio Creek Watershed



6.09% Direct Physical Damages
0.19% Relocation Costs
2.02% Casualties
0.58% Mental Stress and Anxiety
0.35% Lost Productivity
4.36% Critical Facilities Loss
13.2% Economic Loss
35.5% Enviromental Benefits
36.0% Social Benefits
1.81% Economic Revitalization

Elizabeth River

2.00% Enviromental Benefits
98.0% Social Benefits

Table I.4 BCA Crosswalk

Costs and Benefits by Category	Page # in Factor Narratives of BCA Attachment	Qualitative Description of Effect and Rationale for Including in BCA	Quantitative Assessment (Explains basis and/or methodology for calculated Monetized Effect, including data sources, if applicable)	Monetized Effect (if applicable)	Uncertainty
Life Cycle Costs					
Norfolk's Coastal Adaptation and Community Transformation Plan	BCA Attachment F Appendix F-1. Project Costs	The project proposes to implement a series of stormwater management techniques, combined with integrated coastal flood protection infrastructure and a living shoreline to create the greatest opportunity for a resilience response and recovery during future disaster events. Additional project components proposed are further described in **Attachment F II. Project Description.** Operations and maintenance costs, as well as the costs of existing resiliency efforts in the Target Area are also considered to provide the most comprehensive cost of resiliency in the Target Areas.	Engineers compiled a detailed cost estimate based on labor, materials, and equipment necessary to complete the project and maintain permanent project features.	*See* Table I.2 All Applicable Costs included in the Benefit Cost Analysis: $357,748,896.	3 Medium uncertainty due to variation in the level of project design completeness.

Costs and Benefits by Category	Page # in Factor Narratives of BCA Attachment	Qualitative Description of Effect and Rationale for Including in BCA	Quantitative Assessment (Explains basis and/or methodology for calculated monetized effect, if applicable)	Monetized Effect (if applicable)	Uncertainty
Resiliency Values					
Direct Physical Damages (Buildings)	Attachment F IV. Benefits Included in the Benefit Cost Ratio, pages IV.1.19 through IV.1.26.	Direct physical damages are those that occur to residential, commercial, industrial, and public property that result from the action of storm surge and stormwater ponding (floodwater). These damages include real impacts to structures, which can be quantified.	A structure inventory was developed from Norfolk 2014 Real Estate data. Ground elevations for the structures were gathered from LiDAR, first floor elevations were estimated based on structure foundation type. Flood elevations were based on storm surge modeling for three sets of storm surge flood scenarios in addition to Hurricane Irene. Storm surge models include 2.5 feet of sea level rise based on projections by the Virginia Institute of Marine Science. Building Replacement Values (BRVs) were calculated using Hazus default values. Depth damage functions (DDFs) represent a relationship between the depth of floodwater in a structure and the percent of damage that can be attributed to the flooding. The DDFs from the USACE are applied	Newton's Creek: • Medium Scenario Annual Benefits: $1,153,001 • Medium Scenario Net Present Value: $15,911,751 Ohio Creek: • Medium Scenario Annual Benefits: $377,220 • Medium Scenario Net Present Value: $5,205,741 The Elizabeth River is not expected to produce benefits that are related to this category.	3 There is a high certainty for the methodology used to estimate direct physical damages to buildings from coastal storm surge; the methodology used for calculating this benefit has been approved by at least one federal agency. Further, LiDAR data was used to determine grade elevations, and conservative estimates for first floor elevations were incorporated, thus producing a conservative estimate of flood depths inside of the structures. Nevertheless, there is uncertainty in the

Costs and Benefits by Category	Page # in Factor Narratives of BCA Attachment	Qualitative Description of Effect and Rationale for Including in BCA	Quantitative Assessment (Explains basis and/or methodology for calculated monetized effect, if applicable)	Monetized Effect (if applicable)	Uncertainty
Resiliency Values					
			to estimate structure damages associated with each return period. The percent of structural damage is related to 1-foot depth increments which are multiplied by a structure replacement value to produce a physical loss value in dollars. See Part IV for additional data sources.		accuracy of the structure data gathered from Norfolk 2014 Real Estate data. For this reason, uncertainty level for this benefit is a 3.
Direct Physical Damages (Contents and Inventory)	Attachment F IV. Benefits Included in the Benefit Cost Ratio, page IV.1.19 through IV.1.26.	Contents and inventory damage is that which applies to personal property and material goods and services held by a business that are damaged during flood events. This value is quantifiable.	Damage to contents and inventory are estimated using a DDF associated with structure occupancy type. Contents and inventory DDFs from the USACE are applied to estimate damages associated with each return period. The percent of damage is related to 1-foot depth increments. See Part IV for additional data sources.	Newton's Creek: • Medium Scenario Annual Benefits: $3,799,988 • Medium Scenario Net Present Value: $52,440,859 Ohio Creek: • Medium Scenario Annual Benefits: $459,495 • Medium Scenario Net Present Value: $6,341,149 The Elizabeth River is	3 There is a high certainty for the methodology used to estimate direct physical damages to buildings from coastal storm surge; the methodology used for calculating this benefit has been approved by at least one federal agency. Further, LiDAR data was used to determine grade elevations, and conservative estimates for first floor elevations were incorporated, thus producing a conservative estimate

Costs and Benefits by Category	Page # in Factor Narratives of BCA Attachment	Qualitative Description of Effect and Rationale for Including in BCA	Quantitative Assessment (Explains basis and/or methodology for calculated monetized effect, if applicable)	Monetized Effect (if applicable)	Uncertainty
Resiliency Values					
				not expected to produce benefits that are related to this category.	of flood depths inside of the structures. Nevertheless, there is uncertainty in the accuracy of the structure data gathered from Norfolk 2014 Real Estate data. For this reason, uncertainty level for this benefit is a 3.
Essential Facility and Critical Infrastructure Service Loss	Attachment F IV. Benefits Included in the Benefit Cost Ratio, page IV.1.27.	Typical essential facilities whose functions are critical during natural disasters include hospitals, fire stations, EMS stations, police stations, and similar facilities. Critical infrastructure that are equally as necessary includes wastewater service, electrical power service, and transportation infrastructure. Interruption of these assets, services, and systems that serve the public can cascade and result in further economic, environmental, and societal losses. The value of service provided by essential facilities and critical infrastructure can be quantified and included as	Loss of service calculations are a function of service population, loss of function time, and value per capita of service. Analysts identified the number of type of essential and critical facilities that are vulnerable to flood impacts using local data from the City of Norfolk's Geographic Information System (GIS) department. Service populations for identified assets and facilities were estimated using the total population for the City of Norfolk. Loss of function time was estimated using local knowledge of emergency response and preparedness measures employed by the jurisdiction in a flood event. FEMA standard values were	Newton's Creek: • Medium Scenario Annual Benefits: $4,535,498 • Medium Scenario Net Present Value: $62,593,255 Ohio Creek: • Medium Scenario Annual Benefits: $598,008 • Medium Scenario Net Present Value: $8,252,954	2 There is a high certainty for the methodology used to estimate essential facility and critical infrastructure service loss as a result of storm surge; the methodology used for calculating this benefit has been approved by at least one federal agency. Uncertainties lie in the estimation of service populations for critical facilities. Service population

Costs and Benefits by Category	Page # in Factor Narratives of BCA Attachment	Qualitative Description of Effect and Rationale for Including in BCA	Quantitative Assessment (Explains basis and/or methodology for calculated monetized effect, if applicable)	Monetized Effect (if applicable)	Uncertainty
Resiliency Values					
		benefits within the benefit cost analysis in addition to any expected physical property damages.	used as the value of the service provided for each facility or system.	The Elizabeth River is not expected to produce benefits that are related to this category.	data was not readily available for some assets, therefore it was necessary to obtain a general estimate of service population based on total population and additional assets within Norfolk.
Fatalities	Attachment F IV. Benefits Included in the Benefit Cost Ratio, pages IV.35 through IV.42.	Fatalities are an unfortunate risk inherent to storm events. The proposed project provides benefit by reducing the potential for lost life during a storm event.	After an analysis of the impacts of the Qualified Disaster and various methodologies available for estimating the number of fatalities for a flood event, the estimation methodology selected is based upon a 2013 study conducted by Brno University. The methodology considers expected damage value, community preparedness, and warning features to estimate loss of life. FEMA standard life safety values were applied to the number of fatalities expected for each of the three flood scenarios assessed.	Full Target Area: • Annual Benefits: $553,939 • Net Present Value: $7,644,504	4 A standard FEMA value for the cost of a life was used, however there are multiple methods for determining the number of possible casualties. The method chosen for evaluation is considered the most conservative as it evaluates community characteristics that contribute to vulnerability. Nevertheless, there are many factors post-disaster that could increase or decrease potential casualties, including unpredictable

Costs and Benefits by Category	Page # in Factor Narratives of BCA Attachment	Qualitative Description of Effect and Rationale for Including in BCA	Quantitative Assessment (Explains basis and/or methodology for calculated monetized effect, if applicable)	Monetized Effect (if applicable)	Uncertainty
Resiliency Values					
					behaviors.
Relocation and Economic Loss of Function	Attachment F IV. Benefits Included in the Benefit Cost Ratio, pages IV.42 through IV. 46.	Relocation costs and economic loss of function (ELOF) are consequences of displacement that result from disaster impacts. Relocation costs are associated with moving a household or a business to a new location and resuming business or life in that new location. ELOF cost is associated with the interruption of a business or the removal of a piece of real estate from the market as a result of disaster impacts. Both costs can be derived as a function of displacement time. See economic loss for costs associated with ELOF.	Displacement time has been calculated by: 1. Identifying expected flood depths and structural damage expected to occur 2. Calculating building restoration time based on flood depths and structure damage identified 3. Assigning relocation and ELOF rates based on occupancy class and extent of damage 4. Using relocation and loss of function time values by occupancy and damage extent to calculate relocation expenses and ELOF time without benefit duplication. See Part IV. for data sources	Newton's Creek: • Medium Scenario Annual Benefits: $181,620 • Medium Scenario Net Present Value: $2,506,399 Ohio Creek: • Medium Scenario Annual Benefits: $25,421 • Medium Scenario Net Present Value: $350,817 The Elizabeth River is not expected to produce benefits that are related to this category.	2 High certainty; the methodology used for calculating this benefit has been approved by at least one federal agency. Further, analysis was completed based on USACE depth damage functions. There are uncertainties with regard to underground networks and flooding that could exacerbate loss. Further, LiDAR was used to determine grade elevations, with site checks in several areas. FEMA Hazus methods improve the analysis. Uncertainty in commercial owner occupancies are acknowledged, as well as post-disaster behavior of residents and businesses.

Costs and Benefits by Category	Page # in Factor Narratives of BCA Attachment	Qualitative Description of Effect and Rationale for Including in BCA	Quantitative Assessment (Explains basis and/or methodology for calculated monetized effect, if applicable)	Monetized Effect (if applicable)	Uncertainty
Resiliency Values					
Shelter Needs	Attachment F IV. Benefits Included in the Benefit cost Ratio, pages IV.47 through IV.52	After a disaster event, impacted individuals may need to shelter if they cannot access their homes due to flooding. Even though the home may not be damaged, people will be displaced if they are evacuated or cannot physically access their property by foot, vehicle, or transit due to flooded roadways and transit systems.	The FEMA Hazus methodology is used for this benefit. Short-term sheltering needs are based on displaced population, determined using flood depths. For this analysis, the displaced population is considered residential population located within the area where flood depth is equal to or greater than 12 inches. Population is estimated based on the percentage of residential square footage per building compared to the total residential square footage in the census block group. The number of displaced individuals is then modified by factors accounting for income and age. The cost for sheltering is captured in the relocation costs and is not given a separate monetary value to avoid duplication of benefits. See Part IV for data sources.	Newton's Creek: • 10% Annual Chance: 47 households, 113 people • 2% Annual Chance: 99 households, 242 people • 1% Annual Chance: 318 households, 774 people Ohio Creek: • 10% Annual Chance: 3 households, 8 people • 2% Annual Chance: 42 households, 101 people • 1% Annual Chance: 57 households, 139 people The Elizabeth River is not expected to produce benefits that are related to this category.	2 High certainty; the methodology used for calculating this benefit has been approved by at least one federal agency. The same considerations as other resiliency measures apply related to structure data and depth damage functions. Recent census data was used for population and demographics. Uncertainty lies in post-disaster behavior.

Costs and Benefits by Category	Page # in Factor Narratives of BCA Attachment	Qualitative Description of Effect and Rationale for Including in BCA	Quantitative Assessment (Explains basis and/or methodology for calculated monetized effect, if applicable)	Monetized Effect (if applicable)	Uncertainty
Resiliency Values					
Mental Stress and Anxiety	Attachment F IV. Benefits Included in the Benefit cost Ratio, pages IV.53 through IV.58	Natural disasters threaten or cause loss of health, social, and economic resources which may lead to psychological distress. Research indicates that individuals who experience a high number of stressors and property damage are more likely to experience symptoms of mental illness, Post-Traumatic Stress Disorder (PTSD), and higher levels of stress and anxiety. An increase in mental health issues after a disaster will increase mental health treatment costs. Such costs are captured here and are considered losses avoided by the project.	Benefits are based on a national standard cost of treatment per person by type of treatment (mild/moderate or severe), provided by FEMA. The FEMA standard value was normalized to 2015 values and applied to the number of residents that would be impacted by the three flood scenarios analyzed; however this number is adjusted by 41% based on FEMA estimates. The cost of mental health is estimated for 30 months, the amount of time literature has been able to estimate the prevalence of mental health impacts after a disaster. See Part IV for data sources.	Newton's Creek: • Medium Scenario Annual Benefits: $272,725 • Medium Scenario Net Present Value: $3,763,805 Ohio Creek: • Medium Scenario Annual Benefits: $79,284 • Medium Scenario Net Present Value: $1,094,174 The Elizabeth River is not expected to produce benefits that are related to this category.	3 Medium certainty; the methodology used for calculating this benefit has been approved by one federal agency. However, this method only considers the percent of the population that is expected to seek treatment post-disaster and is considered to be conservative for that reason. Further, the percent of the population expected to seek treatment is a natural figure, and not locally specific. Costs are also national and not locally specific. Coping tactics vary widely within a given population.
Economic Impacts Avoided	Attachment F IV. Benefits Included in the Benefit Cost Ratio, pages IV.64 through IV. 75.	Direct economic output refers to the value of industry production, which varies by industry. For example, the output of the	This methodology calculates lost economic output as a result of flood-damaged structures using the IMPLAN economic impact assessment	Newton's Creek: • Medium Scenario Annual Benefits: $1,583,332	3 This benefit has been calculated using a standard

Costs and Benefits by Category	Page # in Factor Narratives of BCA Attachment	Qualitative Description of Effect and Rationale for Including in BCA	Quantitative Assessment (Explains basis and/or methodology for calculated monetized effect, if applicable)	Monetized Effect (if applicable)	Uncertainty
Resiliency Values					
		service sector is measured in sales, hospital output is measured in the total service package that a patient receives during their entire length of stay, and output for non-profit organizations is based on the cost of production or the expenses that the organization must incur to operate. The industry output value is significant because it supports the understanding of the relationships of industries that comprise the overall economy within a geographic region. Measuring change in industry output as a result of some stimulus or impact is considered one of the most efficient and straightforward methods to evaluate the relationships between industries in any given economy. Moreover, it allows one to witness the reverberating effects of natural disasters on that economy.	software. This analysis uses lost economic output by industry and input-output modeling software to calculate the direct effects of output loss within an industry, as well as the effects that loss has on supporting industries and spending patterns in the economy (also known as indirect effects). See Part IV for data sources.	• Medium Scenario Net Present Value: $21,851,167 Ohio Creek: • Medium Scenario Annual Benefits: $1,812,950 • Medium Scenario Net Present Value: $25,020,068 The Elizabeth River is not expected to produce benefits that are related to this category.	methodology from City level data from IMPLAN. Uncertainty is due to the use of multiple conversion calculations associated with use of City-level data. Moreover, the results are considered a conservative estimate as economic impacts measured are limited to the Virginia Beach – Norfolk-Newport News MSA.

Costs and Benefits by Category	Page # in Factor Narratives of BCA Attachment	Qualitative Description of Effect and Rationale for Including in BCA	Quantitative Assessment (Explains basis and/or methodology for calculated monetized effect, if applicable)	Monetized Effect (if applicable)	Uncertainty
Environmental Value					
Environmental Value	Attachment F IV. Benefits Included in the Benefit-Cost Ratio, pages IV.2.2 through IV.2.32.	Benefits provided by ecosystem goods and service and green infrastructure 9GI) can be valued using the economic valuation theory, which relies on people's willingness to pay for a good or service. Under the umbrella of willingness to pay theory are numerous valuation methods including contingent valuation, hedonic pricing, and travel cost. Other methods used to value environmental benefits include factor income, replacement cost, avoided cost, and market price. For this analysis, the benefits of ecosystem goods and services are calculated through value, or benefit transfer. The transfer refers to the application of derived values from the original study site to the goods and services provided by the project site. Benefit transfer has become popular to value the ecosystem services of natural capital, as it allows for timely and cost-effective analyses.	The benefits of ecosystem goods and services of natural capital and GI are valued using different approaches. FEMA values ecosystem goods and services based on the square footage of different types of vegetative areas (green open space, wetlands, and riparian), and the Green Infrastructure Guide values the environmental benefits of GI. It was determined that, for certain ecosystem services, it was possible to calculate benefits using both methods. When this occurs, a combination of benefits is calculated, and the combined benefits are included in the benefit cost ratio as low, medium, and high value scenarios. Data sources and a more detailed description of the approach are provided in Section IV.	Newton's Creek: • Medium Scenario Annual Benefits: $2,294,418 • Medium Scenario Net Present Value: $32,739,631 Ohio Creek: • Medium Scenario Annual Benefits: $2,620,337 • Medium Scenario Net Present Value: $67,165,782 Elizabeth River: • Medium Scenario Annual Benefits: $14,539 • Medium Scenario Net Present Value: $207,460	2 Values used in calculating this benefit are provided by federal and published sources. Further certainty in the results is accomplished by combining both approaches.

Costs and Benefits by Category	Page # in Factor Narratives of BCA Attachment	Qualitative Description of Effect and Rationale for Including in BCA	Quantitative Assessment (Explains basis and/or methodology for calculated monetized effect, if applicable)	Monetized Effect (if applicable)	Uncertainty
Social Value					
Recreational Benefits	Attachment F IV. Benefits Included in the Benefit Cost Ratio, pages IV.3.3 through IV.3.10.	The proposed project will add new and improved park space, bicycle and pedestrian trails, and community gathering and recreation spaces and amenities, which will give residents and visitors opportunities to participate in activity such as walking, jogging, bicycling, and playground use. There are two benefits related to recreation that may be quantified: 1) increased outdoor recreation, and 2) health benefits related to increased activity due to the availability of new recreation space.	There are two methods that can be used to quantify recreational benefits: Earth Economics of FEMA. Earth Economics uses participation rates based on statewide recreation activity, collected through an Outdoors Demand Survey, to estimate benefits in the Target Area. FEMA quantified recreational benefits based on the square footage of added or improved recreational space. Both methods and results are included in the benefit-cost ratio as a range of benefits. See Part IV for more detail on the approach and data sources.	Newton's Creek: • Medium Scenario Annual Benefits: $16,322,534 • Medium Scenario Net Present Value: $225,263,139 Ohio Creek: • Medium Scenario Annual Benefits: $3,408,428 • Medium Scenario Net Present Value: $47,038,856 Elizabeth River: • Medium Scenario Annual Benefits: $724,989 • Medium Scenario	2 This benefit was calculated using standard federal methodology and other published resources. Further certainty in the results is accomplished by combining both approaches. However, uncertainty lies in the fact that benefits are based on a conceptualized scenario for project programming, based on public outreach and feasibility. The final design will determine the extent of benefits here.

Costs and Benefits by Category	Page # in Factor Narratives of BCA Attachment	Qualitative Description of Effect and Rationale for Including in BCA	Quantitative Assessment (Explains basis and/or methodology for calculated monetized effect, if applicable)	Monetized Effect (if applicable)	Uncertainty
Social Value					
				Net Present Value: $746,035,912	
Health Benefits	Attachment F IV. Benefits Included in the Benefit Cost Ratio, pages IV.3.11through IV.3.13.	Generally, those who are physically active live longer and are at lower risk for heart disease, stroke, type 2 diabetes, depression, some cancers, and obesity. Access to outdoor recreation has been found to increase the rate of exercise by the surrounding population, therefore improving overall health in the area. Improved health is related to reduced health care costs and increases in work productivity. The benefits valued here are avoided health care costs of medical bills and compensation payments due to an increase in physical activity, as well as lost productivity	The total number of residents in the Target Area is adjusted based on the percent of population that meets physical fitness guidelines in the state of Virginia. The resulting number is then increased based on the expected increase related to added recreation space. Health care cost savings per capita per year are then applied to the increased number of residents meeting physical fitness guidelines to determine avoided health care costs due to increased physical activity. To provide low, medium, and high estimated benefits and to account for	Newton's Creek: • Medium Scenario Annual Benefits: $1,605,227 • Medium Scenario Net Present Value: $17,614,037 Ohio Creek: • Medium Scenario Annual Benefits: $328,917 • Medium Scenario Net Present Value: $4,539,294 The Elizabeth River is not expected to produce benefits that are related to this category.	3 There is medium certainty for this benefit; it was calculated using published resources. Uncertainty lies in the use of population projections to estimate low, medium, and high expected benefits for this category. Furthermore, benefits are based on a conceptualized scenario for project programming, based on public outreach and feasibility. The final design will determine the extent of benefits here.

Costs and Benefits by Category	Page # in Factor Narratives of BCA Attachment	Qualitative Description of Effect and Rationale for Including in BCA	Quantitative Assessment (Explains basis and/or methodology for calculated monetized effect, if applicable)	Monetized Effect (if applicable)	Uncertainty
Social Value					
		costs.	population growth, benefits are calculated for the projected population at certain points in time.		
Aesthetic Benefits	Attachment F IV. Benefits Included in the Benefit Cost Ratio, pages IV.3.14 through IV.3.19.	Norfolk's proposed project will provide a litany of benefits that will render the Target Areas more appealing to existing and future residents and businesses, in turn resulting in a positive effect for residents and the local economy. Attractive views and reduction of flood risk are just two contributing factors to this positive benefit that can be quantified.	There are two methods that can be used to quantify such benefits: FEMA calculates aesthetic benefit based on the square footage of added space that may be considered an aesthetic amenity; while Earth Economics provides an approach that evaluates potential impacts to property values. Impacts to property values considered include the location of property near well-maintained green spaces and attractive views, in addition to the reduction in perceived risk of flooding. Property value benefits are	Newton's Creek: • Medium Scenario Annual Benefits: $11,746,597 • Medium Scenario Net Present Value: $74,057,969 Ohio Creek: • Medium Scenario Annual Benefits: $2,476,862 • Medium Scenario Net Present Value: $16,571,290 Elizabeth River: • Medium Scenario Annual Benefits:	3 This benefit was calculated using standard federal methodology, however uncertainty exists due to the fact that no similar studies evaluating the economic benefits of adding aesthetic amenities and reducing flood risk exist for the area. The studies that were utilized are considered to be comparable. Benefits are based on a conceptualized scenario for project programming, based on public outreach and feasibility. The final design will determine the extent

Costs and Benefits by Category	Page # in Factor Narratives of BCA Attachment	Qualitative Description of Effect and Rationale for Including in BCA	Quantitative Assessment (Explains basis and/or methodology for calculated monetized effect, if applicable)	Monetized Effect (if applicable)	Uncertainty
Social Value					
			presented as high, medium, and low scenarios, and are expected to incorporate considerations presented in FEMA's aesthetic benefit methodology. Therefore, the Earth Economics benefit values are those that are incorporated into the benefit cost ratio so that a duplication of benefits is avoided.	$27,849 • Medium Scenario Net Present Value: $175,576	of benefits here.

Costs and Benefits by Category	Page # in Factor Narratives of BCA Attachment	Qualitative Description of Effect and Rationale for Including in BCA	Quantitative Assessment (Explains basis and/or methodology for calculated monetized effect, if applicable)	Monetized Effect (if applicable)	Uncertainty
Economic Revitalization					
Economic Revitalization	Attachment F IV. Benefits Included in the Benefit Cost Ratio, pages IV.4.1 through IV.4.7.	The proposed project consists of several economic revitalization efforts targeted towards various locations within the Target Area. These efforts include the following: 1) Redevelopment of public housing sites to create additional residential, retail, office, and hospitality opportunities; 2) Creation of an Acceleration Center that will partner with education organizations to focus revolutionary water management solutions and workforce training for the water management industry. The economic benefits of	Output and employment compensation benefits can be quantified per square foot using standardized data (based on FEMA's Hazus software methodology which uses national output per square foot data) to estimate economic losses and employment/output ratios to estimate economic and employment losses using IMPLAN data. IMPLAN data from 2013 was available to analysts and provided City-level output and employment compensation by industry. The methodology relates industries from IMPLAN to structure use and calculates average	Newton's Creek: • Medium Scenario Annual Benefits: $88,522,969 • Medium Scenario Net Present Value: $692,040,640 Ohio Creek: • Medium Scenario Annual Benefits: $248,350 • Medium Scenario Net Present Value: $3,427,409 The Elizabeth River is not expected to produce benefits that are related to this	3 Local IMPLAN data was used to calculate this benefit based on a conceptualized scenario for project programming, based on public outreach and feasibility. The final design will determine the extent of benefits here.

Costs and Benefits by Category	Page # in Factor Narratives of BCA Attachment	Qualitative Description of Effect and Rationale for Including in BCA	Quantitative Assessment (Explains basis and/or methodology for calculated monetized effect, if applicable)	Monetized Effect (if applicable)	Uncertainty
Economic Revitalization					
		the aforementioned efforts can be measured by anticipated added economic output and employment compensation for those industries.	IMPLAN output/employment compensation for the industry. The total square footage throughout the City was calculated and the output and employment compensation per square foot was determined. Benefits are presented for high, medium, and low density revitalization scenarios. See Part IV for data sources	category.	

Costs and Benefits by Category	Page # in Factor Narratives of BCA Attachment	Qualitative Description of Effect and Rationale for Including in BCA	Quantitative Assessment (Explains basis and/or methodology for calculated monetized effect, if applicable)	Monetized Effect (if applicable)	Uncertainty
Qualitative Benefits					
Affordable Housing	Attachment F V. Qualitative Benefits, page V.3	Several public housing projects are located within the Target Area; units within these projects are subject to frequent flooding that damages structures and contents. Recurrent damage to such units has rendered the area blighted, and some residential areas have been vacated. Studies estimate that building 100 affordable housing units for families through housing tax credit programs can support as many as 30 new jobs in the local economy. Moreover, the availability of affordable housing attracts employers to the area and could also increase the amount of disposable income to be	If families within affordable households are required to spend a smaller percentage of their income on housing, assumptions can be made that these populations would be able to allocate these resources more heavily in disaster response, action, and recovery. Therefore, by protecting affordable housing from future flood events, the Target Area can preserve the economic benefits that affordable housing provides, encourage and retain current and future LMI employers, and increase disposable income expenditures in the local economy.	Not Applicable	The lack of existing research methodologies on this subject limits the ability to quantify the benefits of affordable housing that will be both protected and generated by the proposed project. However, it is clear that the loss of affordable housing due to a future flood event would greatly impact the populations within the Target Area. A portion of these benefits are recognized in the Economic Impact benefits.

Costs and Benefits by Category	Page # in Factor Narratives of BCA Attachment	Qualitative Description of Effect and Rationale for Including in BCA	Quantitative Assessment (Explains basis and/or methodology for calculated monetized effect, if applicable)	Monetized Effect (if applicable)	Uncertainty
Qualitative Benefits					
		reinvested into the local economy. Many employers have reported that a lack of affordable housing makes it more difficult – and thus more costly – to recruit and retain employees.			
Stormwater Management	Attachment F V. Qualitative Benefits, page V.3	Most of Norfolk collects stormwater from streets and surrounding areas in a dedicated stormwater drainage system. The stormwater network in the project areas is designed to collect rainwater runoff and route it towards the Elizabeth River. During extreme flood events, the outfalls of these systems are closed to prevent tidal waters from backing up into the system up through the inlets causing flooding in city streets	Analysts calculated the total volume water for the 20% annual chance, 24-hour rain event and compared this volume to two rain-driven flooding scenarios: estimated flood depths given blockage of the stormwater system (depression storage), and estimated flood depths given failure of stormwater storage and removal systems with the proposed flood walls in place.	Not Applicable	Based on the model, flooding from the scenario is expected to concentrate in low lying areas, but also against the coast, damaging assets most vulnerable to coastal flood events. Therefore, benefits of the project that are related to stormwater flood reductions, such as direct physical damages, relocation, economic impacts, and critical facilities, are already realized.

Costs and Benefits by Category	Page # in Factor Narratives of BCA Attachment	Qualitative Description of Effect and Rationale for Including in BCA	Quantitative Assessment (Explains basis and/or methodology for calculated monetized effect, if applicable)	Monetized Effect (if applicable)	Uncertainty
Qualitative Benefits					
		and surrounding areas. Analysts used GIS to determine the potential areas of stormwater inundation of the Target Area and ran models to estimate depression storage and the level of stormwater ponding.			
Workforce Benefits	Attachment F V. Qualitative Benefits, page V.5	The proposed Acceleration Center - a nexus for technological, organizational and conceptual innovation around identified regional resilience issues – will provide a workforce training program in the water management industries.	Workforce training programs create opportunities for individuals to obtain experience that will land them a well-paying job in the future. Thus, such programs are considered future investments in a particular industry.	Not Applicable	Although the Center expects to employ 5 FTE staff in year 1, the number of industry workers trained and exported from this initiative is unknown at this time. Therefore no quantitative benefits could be derived from the amenity.
Historic Preservation	Attachment F V. Qualitative Benefits, page V.5 through V.7	The proposed Target Area contains a number of historic structures that would benefit directly from the installation of the	Benefits associated with protecting historic and cultural resources include the protection of high property values,	Not Applicable	The benefit that is provided by the presence of historic and cultural resources is captured elsewhere within this

Costs and Benefits by Category	Page # in Factor Narratives of BCA Attachment	Qualitative Description of Effect and Rationale for Including in BCA	Quantitative Assessment (Explains basis and/or methodology for calculated monetized effect, if applicable)	Monetized Effect (if applicable)	Uncertainty
Qualitative Benefits					
		protection measures. Though the building/content replacement value of these structures is not inherently higher when compared to non-historic buildings; the social, cultural, and historic loss of these structures would have a much greater impact on the community as a whole.	monetary values of the number of visits and ticket sales, and nonmarket values of such resources such as the desire to conserve and preserve historical resources for future generations.		analysis. Nevertheless, it is important to note that the abundance of historical structures in the Target Area would have an impact on the community if they were impacted by a flood event.
Water Quality Benefits	Attachment F V. Qualitative Benefits, page V.7 through V.8.	Reduction in stormwater treatment needs inherently provides water quality benefits in the form of TMDLs. TMDLs represent the total amounts of pollution that a water body can receive and still meet EPA standards for water quality.	The Virginia Department of Environmental Quality submits the "Reduction of Toxics in State Waters Report" to several House Committees each year in January. From the January 2015 report's Appendix I-3 "State of the Elizabeth River Scorecard 2014", we read: "The Eastern Branch [of the Elizabeth	Not Applicable	Although it is known that the Elizabeth River is currently polluted, there is no clear way to ascertain a value for overall water quality at this time, such as Total Maximum Daily Loads (TMDLs) that are expected to be reduced though these projects. Reduced costs for stormwater treatment are being included as benefits in the quantitative portion of this

Costs and Benefits by Category	Page # in Factor Narratives of BCA Attachment	Qualitative Description of Effect and Rationale for Including in BCA	Quantitative Assessment (Explains basis and/or methodology for calculated monetized effect, if applicable)	Monetized Effect (if applicable)	Uncertainty
Qualitative Benefits					
			River] earns a D, indicating urgent need behind a new plan for this branch. Scientists found disturbingly high levels of bacteria in Broad Creek and Indian River tributaries and extremely low dissolved oxygen in Broad Creek. The Elizabeth River Project has just completed a draft comprehensive strategy for community-wide efforts to improve the Eastern Branch, with a priority focus on Broad Creek and Indian River." (page 3).		analysis.
Urban Heat Island Mitigation	Attachment F V. Qualitative Benefits, page V.8	Urban areas are more vulnerable to the effects of temperature increase and precipitation pattern changes because of the heating and cooling	In a 2014 study, Norfolk ranked fifth in the nation as having the fastest growing overnight urban heat island with temperatures heating in the city faster than	Not Applicable	The uncertainty of quantifying this benefit is too great, as it involves knowing the degree to which heat will be reduced in the locality; thus this benefit is

Costs and Benefits by Category	Page # in Factor Narratives of BCA Attachment	Qualitative Description of Effect and Rationale for Including in BCA	Quantitative Assessment (Explains basis and/or methodology for calculated monetized effect, if applicable)	Monetized Effect (if applicable)	Uncertainty
Qualitative Benefits					
		processes of building roofs and cars, as well as the emission of greenhouse gases. The City of Norfolk is vulnerable to the Urban Heat Island (UHI) effect, as it maintains a relatively dense urban environment to the surrounding regions and contains a large amount of impervious paved surfaces that trap and absorb heat. Research has indicated that the installation of green space, such as rain gardens, bio-retention features, and permeable pavements, cause a reduction in temperature variations; therefore it can be assumed that the proposed project will reduce the UHI effect in Norfolk.	in rural areas. The proposed Target Area will contribute towards reducing UHI effects by planting trees, expanding park spaces, installing bio-retention features, incorporating rain gardens into existing landscapes, and installing permeable pavement throughout.		considered qualitative.
Emergency and Recovery Efforts	Attachment F V. Qualitative Benefits,	After Hurricane Irene, flooded roadways	The protection of these areas from	Not Applicable	This reduction in the need for and cost of

Costs and Benefits by Category	Page # in Factor Narratives of BCA Attachment	Qualitative Description of Effect and Rationale for Including in BCA	Quantitative Assessment (Explains basis and/or methodology for calculated monetized effect, if applicable)	Monetized Effect (if applicable)	Uncertainty
Qualitative Benefits					
	page V.9	and out-of-service transportation services impeded travel throughout the Target Area. Although no lives were lost due to this situation, flooded roads could in the future prevent effective emergency response vehicles such as police cars, ambulances or firefighting equipment from reaching victims in time.	flooding will serve to reduce emergency response times and give adequate access to crews that typically deal with fallen trees, downed power lines or other disaster incidents. Flood risk reduction will also favorably impact post-disaster recovery efforts, allowing residents and property owners to return from evacuation safely in order to address possible damages and begin the return to “blue skies” life.		emergency services is not able to be quantified at this time, however, due to a lack of data from previous flood events.
Injuries	Attachment F V. Qualitative Benefits, page V.9	Injuries are an unfortunate inherent risk associated with natural hazard events. According to the CDC, injuries sustained in New York City within the first week of Hurricane Sandy recovery were from evacuation, cleanup,	The same CDC study states that Twenty-five % of people with an injury in New York City received treatment from a hospital, emergency department (ED), or doctor’s office, though this varied by household. It is possible to attribute	Not Applicable	Injuries that may be experienced during and immediately after a future flood event have not been quantified in the Benefit Cost Analysis due to lack of data from past storms. Although it would have been possible to apply knowledge of

Costs and Benefits by Category	Page # in Factor Narratives of BCA Attachment	Qualitative Description of Effect and Rationale for Including in BCA	Quantitative Assessment (Explains basis and/or methodology for calculated monetized effect, if applicable)	Monetized Effect (if applicable)	Uncertainty
Qualitative Benefits					
		or repair of a damaged/destroyed home. The most common injuries were arm/hand cuts, followed by back strain/sprain, and leg cuts. Such injuries are associated with medical treatment and costs that may be quantified to include as a benefit.	this percentage to the Norfolk area, however there is a lack of injury data related to Norfolk and the qualifying disaster.		Hurricane Sandy injuries to Norfolk, the level of uncertainty in such an analysis warranted exclusion of such benefits from the Benefit-Cost Ratio.
Regional Benefits	Attachment F V. Qualitative Benefits, page V.9	Naval activities, the Virginia Port Authority, and other water-based industries in the area such as ship building and ship repair facilities provide considerable employment; the ability for these employees to get to and from work each day is paramount to the region's economic success. The protection afforded by the proposed projects will positively impact the	There are no known considerations for base relocation and closures (BARC) for the Hampton Roads area, however such closures would certainly have an impact on the economy and response efforts.	Not Applicable	This benefit is unquantifiable at this time with regard to the Target Area, as the measurable impact of flooding is greater than the project areas.

Costs and Benefits by Category	Page # in Factor Narratives of BCA Attachment	Qualitative Description of Effect and Rationale for Including in BCA	Quantitative Assessment (Explains basis and/or methodology for calculated monetized effect, if applicable)	Monetized Effect (if applicable)	Uncertainty
Qualitative Benefits					
		lives of these employees, in turn helping to maintain a steady productivity in the region.			
Light Rail Infrastructure	Attachment F V. Qualitative Benefits, page V.9 through V.10.	Norfolk's light rail system is part of a larger plan to develop a multi-modal transportation network to sustain Norfolk's position as the business, cultural, educational, and medical center of Hampton Roads. During the Hurricane Irene event, light rail transportation was suspended Saturday, August 27th and was scheduled to resume approximately 35 hours later at 11 am on Sunday, August 28th.	Work week ridership for the first six months of operation averaged 4,650 a day – exceeding the original projection of 2,900 trips per day. Norfolk has already experienced over $1.2 billion in investment along the 7.4 mile light rail alignment since it was announced. The Tide light rail system ridership is significantly dependent on the system as nearly half of all trips on the system are home based work trips. Loss of service impacts as a result of flooding have large impacts on the community as it affects people's	Not Applicable	If it was assumed that the light rail received would receive similar impacts as the roadway systems during natural hazard impacts, which is likely considering the tracks' proximity to the water, the analysts believe significant impacts could be experienced. The proposed project will provide benefits to transportation infrastructure including the light rail system by protecting these assets against future natural hazard impacts related to storm surge and flooding thereby reducing shocks and stresses on the community.

Costs and Benefits by Category	Page # in Factor Narratives of BCA Attachment	Qualitative Description of Effect and Rationale for Including in BCA	Quantitative Assessment (Explains basis and/or methodology for calculated monetized effect, if applicable)	Monetized Effect (if applicable)	Uncertainty
Qualitative Benefits					
			ability to get to and from work. It can be assumed under the scenario which incorporates SLR, stated above and within the BCA results, the light rail system if impacted could be out of service for an extended period of time.		

PART II
PROJECT DESCRIPTION

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Project Area, Objectives, and Alternatives Considered

Project Area

The Target Area includes the southern Norfolk neighborhoods of Tidewater Gardens, South Brambleton, Harbor Park, St. Paul's Area and Chesterfield Heights. In the context of this application, the neighborhoods will be broken into two watersheds: the Ohio Creek Watershed and the Newton's Creek Watershed.

The Target Area contains a total population of 11,840 persons according to the US Census Bureau. Of this population, approximately 86% households meet the low to moderate income ("LMI") requirements for the Commonwealth of Virginia (FY 2015 HUD LMISD (HUD Median Income for Fiscal Year 2014)). LMI is generally defined as cash-income of 140% of the median income for Moderate Income, and 80% of the median income for Low Income.[1] The Target Area is comprised of twelve US Census block groups, with a combined median income of $25,350 per household, an income level that is only 48% of the national median household income.[2] The median household income for the City of Norfolk is $44,474.

The Target Area includes the following census tracts: 35.01, 41, 42, 46, 47, 48, and 49. Ohio Creek Watershed contains census tracts (whole or partial) 46 and 47. Newton's Creek Watershed contains census tracts (whole or partial) 35.01, 41, 42, 47, 48, and 49. Within the Target Area census block groups, 43.2% of households live below the poverty line. Based upon HUD American Community Survey (ACS) data, 86% of households within the Target Area meet the standards for LMI. It should be noted that the ACS data used to determine LMI status is 2006-2010 Survey data, whereas income and poverty data is based upon 2013 ACS data. Norfolk is confident in the information, however, as it is the most up-to-date data available for each metric.

The Target Area contains 23 critical assets. These include 3 elementary schools, a middle school, a pre-school, an electrical substation, a fire station, 4 recreational centers, and various other critical infrastructure. The Newton's Creek Watershed also contains seven historic buildings, all of which are listed on the National Register of Historic Places.[3] In addition, the historic African-American district located within the St. Paul's Area, on Church Street, is culturally important and in need of improvement to increase connection and access to the surrounding area. The Ohio Creek Watershed houses Chesterfield Heights, a designated national historic district on the National Register of Historic Places containing 404 structures.[4]

Figure II.1 Existing Conditions of the Target Area

[1] *http://portal.hud.gov/hudportal/HUD?src=/program_offices/comm_planning/communitydevelopment/rulesandregs/memoranda/lmidef84*
[2] *http://factfinder.census.gov/faces/nav/jsf/pages/community_facts.xhtml*
[3] *http://www.nps.gov/nr/research/*
[4] *http://www.nps.gov/nr//listings/20030620.htm*

Proposal Objectives

The primary proposal objectives are those goals described in the Phase-1 application. They are 1) uniting the region; 2) economic vitality; 3) building resilience; 4) neighborhood connectivity; and 5) innovative water management. The goal of providing innovative water management is the fundamental driver that makes the other objectives possible. The City of Norfolk suffers from increasing vulnerability to flooding which has been increasingly disruptive to regional transportation connectivity and is undermining commercial and military activities. In recent years, there has been increasing unwillingness to invest in a region that floods with growing frequency. In this way, the recurrent flooding is seen as an underlying threat to regional economic vitality. Figure 2 below indicates the current existing 1% annual chance flood conditions in the City of Norfolk with no SLR. The analysis performed for the City of Norfolk's Coastal Adaptation and Community Transformation *Plan* utilizes modeling with 2.5 feet of SLR in order to project the potential consequences into the future. This will be discussed further in Part 5.

Figure II.2 Estimated Flooding at the 1% Annual Chance Event of the Target Area

Alternatives Considered

Several alternatives were considered for the Target Area.

No Action

If the present conditions were allowed to persist without any action, the vulnerable areas would remain vulnerable to coastal flooding and continued stormwater flooding. Without taking action to protect the region, residents would have no resilience to flooding and the conditions would worsen over time due to sea level rise and subsidence. Moreover, the region would not benefit from the ancillary benefits provided by the recommended projects.

River Barrier

One alternative to the proposed shoreline defenses against coastal flooding would be to construct a barrier at the mouth of the Eastern branch of the Elizabeth River. Such a barrier would be very effective at preventing coastal surge flooding for neighborhoods along the entire river. However, the barrier would be very expensive

and would require expensive navigation gates for industrial shipping. Moreover, the barrier and gate would create significant impediments to tidal flushing and environmental health of the river. Finally, the barrier would only remedy the coastal flooding and would not solve all of the rainfall induced flooding. Additional actions would be required in addition to the gate. Thus, the cost of the barrier and gate was considered excessive compared to the limited benefits obtained.

Elevated Houses

One alternative to preventing flooding is to adapt the community to accommodate frequent flooding. To avoid property damage to residential structures, the buildings could be individually elevated above the expected flood elevation. This would provide each resident with a safe and dry location during flood events. The limitations were determined to be high cost for elevation of all properties and failure to address other regional problems such as poor connectivity. For instance, even with elevated houses, flooding on local roadways would prevent access by emergency services, impede commuting, and disrupt regular daily activities. Thus, this approach was removed from further consideration.

Recommended Action

The proposed action integrates coastal and stormwater flood management in a holistic manner while simultaneously generating social and environmental benefits for the neighborhoods. The proposed action is innovative and produced the desired outcomes for protecting LMI homes, increasing neighborhood connectivity, providing opportunities for new economic activity, and increasing the overall resiliency of the neighborhoods. Furthermore, the recommended actions are scalable, feasible, and replicable throughout Norfolk and the Hampton Roads Region.

Project Summaries

Project Summaries

The City of Norfolk has developed a Coastal Adaptation and Community Transformation Plan which seeks to substantially improve conditions at several locations along the Eastern Branch of the Elizabeth River. The project is partitioned into two components; modifications within the Ohio Creek Watershed and a largescale renovation of the Newton's Creek Watershed. While the overall strategy is the same – to use innovative storm water management to nurture healthy and resilient neighborhoods – the two project components require different tactics to achieve the same strategy in response to the unique characteristics of each neighborhood. Figure 3 indicates the resulting land uses and outcome once the projects have been completed within the Target Area.

Within the Ohio Creek Watershed are two thriving neighborhoods, the historic Chesterfield Heights neighborhood and Grandy Village, both of which have a cohesive community personality. Thus, the water management tactics deployed in these neighborhoods must be integrated into the existing landscape while maintaining the character of place and the location of existing road networks. The strategies identified offer the advantage of a small scale, replicable and community oriented approach to resiliency at a neighborhood scale. As neighborhood streets are improved with green stormwater techniques, new permeable bicycle and sidewalk connections will be constructed that will provide recreational benefits as well as safe routes to school and other community facilities. Bike lanes and new pedestrian walkways are designed in the proposed project, which will increase neighborhood connectivity and integration into the other areas of Norfolk.

In contrast, the Newton's Creek Watershed contains several areas that are ideal for a more comprehensive renewal. In this area, the South Brambleton neighborhood is a mix of industrial waterfront activities, a few apartments, and many vacant lots. The Harbor Park area is an under-utilized waterfront location that contains extensive gravel parking lots which function as infrequently used overflow parking for the Tides Ball Park and an Amtrak passenger rail station. The St. Paul's Area, which includes Tidewater Gardens and Calvert Square, is comprised of isolated HUD housing developments from the 1960s which have reached the end of its design life and contains many aging apartment buildings in need of demolition and replacement. Thus, the tactics envisioned for the Newton's Creek Watershed can take advantage of extensive areas that can be completely transformed to create an innovative water management foundation upon which a new, resilient community will be built with housing for all income levels and to strengthen the local economy.

Project Useful Life

The project useful life is 50 years, based upon FEMA Standard Values for infrastructure projects.

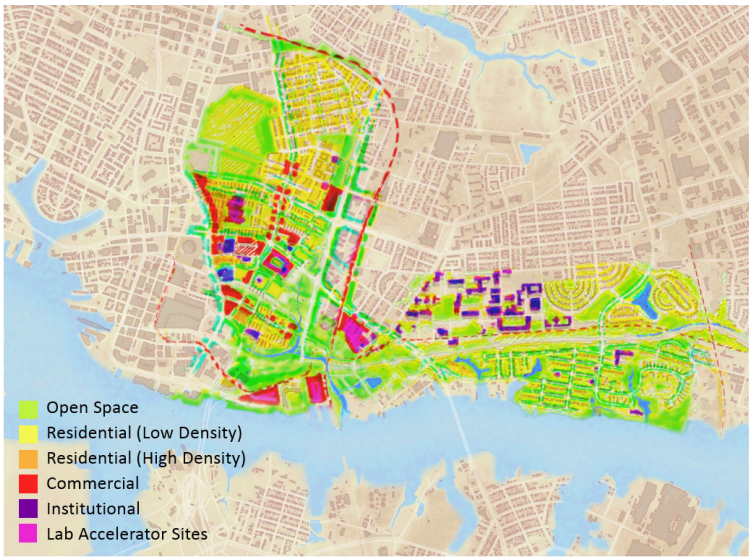

Figure II.3 Resulting Target Area

Ohio Creek Watershed Transformation Project

Ohio Creek Watershed

A large portion of this activity is to protect residential housing from nuisance flooding and future coastal inundation. During Hurricane Irene, coastal storm surge pushed up the Elizabeth River and into the few remaining low-lying areas that were the original Ohio Creek, and from there, the water slowly inundated the neighborhood. During these kinds of hurricanes, nor'easters, and even high tides, water from the Elizabeth River also moves backward up the stormwater drainage system and consequently prevents rainfall from draining out of the neighborhood. During especially high surges, the water from the river can back up the system far enough to flow out onto streets and sidewalks. Even during normal tide conditions in the river, the very old stormwater system is too small to convey run-off to the river during many rainfall events. As a consequence, the neighborhood streets and sidewalks flood frequently. There are only two roadways from which residents can enter and leave the neighborhood, one of which is submerged during nuisance flood events. As a result, the residents are cut off from the rest of the city. To remedy this situation, two water management tactics are proposed. First, fortify the shoreline so that high water levels in the river do not enter the neighborhood or the stormwater system. Second, capture rainfall across the watershed to slow its flow into the stormwater system and provide additional storage for rainwater so that the water doesn't pond in the streets. Third, introduce a living shoreline feature to minimize erosion and increase environmental wellness. Moreover, the City of Norfolk proposes to use these water management activities as opportunities to improve the neighborhood by improving neighborhood connectivity, adding natural habitat, and increasing resilience to future flooding.

Typically, urban areas are structured according to the desired location of buildings and street layout, only after which stormwater considerations are fit within the constraints of the urban landscape. However, the City of Norfolk proposes an innovative approach to invert that paradigm and instead organize the stormwater infrastructure first. In the St. Paul's Area, the city proposes to take advantage of the fact that the existing HUD project housing has outlived its useful life and must be demolished. Norfolk proposes to level the neighborhood and to develop a new neighborhood organized around stormwater management. The innovative proposal is to first construct a system of surface water storage and then fit the neighborhood within and around the stormwater features.

Coastal Fortification

The 100-year coastal surge along this part of the Elizabeth River is approximately 8ft at present day sea levels. However according to NOAA's intermediate SLR forecast, the combined effects of sea level rise and subsidence may amount to as much as a 2.5 ft increase over the next fifty years. In order to provide a resilient defense against future surge and waves, future coastal defenses should be based upon a 100-year coastal surge of 11 ft.

To ameliorate the most significant vulnerability for the communities in this watershed, the Kimble Terrace road will be elevated from its current elevation to 11 ft, and a new, higher bridge will be constructed. This road raising serves two functions: the first is to prevent water from flowing over the road and into the upland area, and the second is to maintain passable and safe egress in and out of the adjacent neighborhoods during times of high tide and coastal flooding. To further mitigate vulnerability to coastal flooding, the two drainage outfalls under Kimball Terrace (west of Chesterfield Heights) will be fitted with tide gates that can be closed during high water conditions in the Elizabeth River. This will prevent coastal surge from flowing into the marsh areas and inundating the neighborhood as happened during Hurricane Irene.

To increase resilience to future events, a flood protection berm is proposed along the shoreline that will stretch from Kimball Terrace Drive on the west of Chesterfield Heights to the east side of the Grandy Village, and inland along the eastern perimeter of the Grandy Village neighborhood. Figure 4 indicates the proposed shoreline protection measures. The berm only needs to be 2 to 3 ft above prevailing grade in order to provide protection against the future 100-year coastal flood. The berm is envisioned to contain a robust sheet pile core with an exterior of soil which will be vegetated with grasses and indigenous plants. If desired by the community, a walking path of pervious pavement, exercise equipment, benches, and picnic tables can be placed on the river front berm to provide a recreational amenity. In this way, the flood protection feature will be visually integrated into the existing landscape. At several locations along the river front, there is inadequate space to provide a properly sloped berm, so a vertical flood wall is proposed on the river side at these locations, with a

graded landscape feature on the inland side. Along the shoreline, several stormwater pipes discharge into the river; these will be fitted with one-way check values to prevent high river stages from pushing water backward up the stormwater conveyance system.

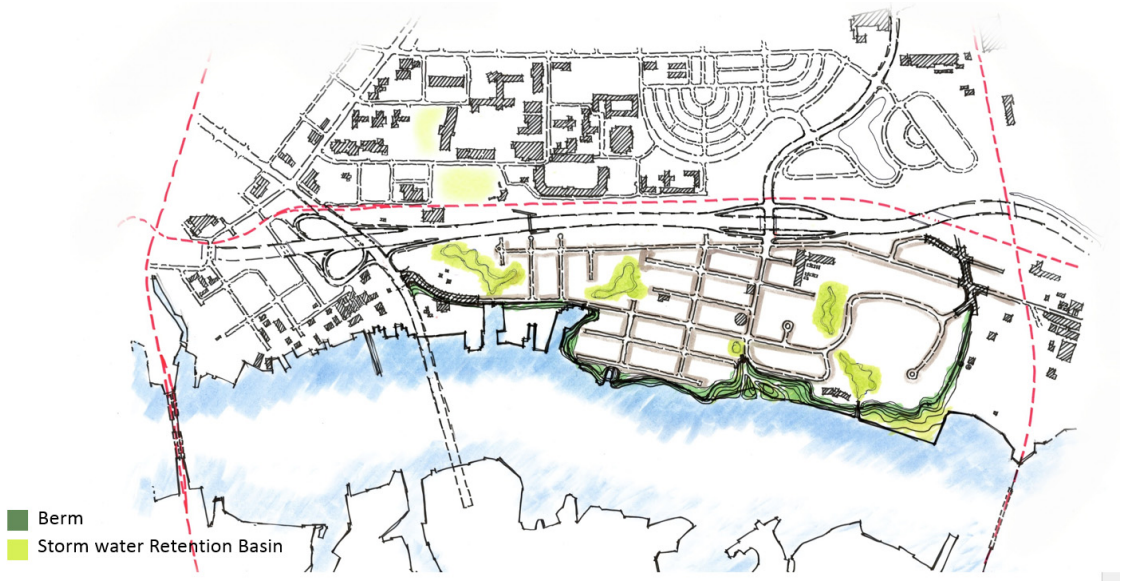

Figure II.4 Ohio Creek Shoreline Proposed Coastal Flood Protection

On the river side of the flood protection berm, a robust living shoreline will be created. The slope of the berm and the elevation of the rock breakwater and vegetation of the shoreline construction will be carefully integrated so that as sea levels rise, the natural vegetation will be able to adapt by moving up the properly graded river bank. This presence of the rock, soil, and vegetation will function to attenuate wave energy and prevent erosion of the shoreline during coastal flooding events. In this way, the combined, multiple layers of defense from the berm and the living shoreline, will afford greater protection in concert than either feature could provide by itself. In addition to contributing to the robustness of the shoreline flood protection system, the marsh vegetation will provide important habitat along this reach of the river which will benefit local faunae and recreational fishing which is popular in the community.

Figure II.5 Ohio Creek Watershed Vision Plan

Finally, to seal off the perimeter of the watershed, several roads on the northeast of Grandy Village will be raised to an elevation of 11 ft so that coastal surge cannot enter the neighborhood overland from the east. Thus, with these minor adjustments to the perimeter topography and landscape, the neighborhood can be made more resilient to both present and future 100-year coastal flooding, maintain critical access to the neighborhood during times of emergency, and keep numerous homes will be kept out of harm's way.

Summary of Coastal Fortification

PLACEHOLDER FOR FINAL FIGURES… Consider table or visual

Length of Elevated Roads = 3000 linear feet

Length of Coastal Berm = 5000 linear feet

Length of Flood Wall = 2100 linear feet

Number of Tide Gates = 2

Number of Check Valves on Stormwater Outfall = ____

Acres of Living Shore Line created = _____

Homes protected from 100-year coastal flooding = _____

Innovative Stormwater Management

By nature of preventing coastal surge and high tides from backing up the storm water system, the coastal fortification described above will provide significant improvement of the ability for the system to drain during low-intensity rain events. However, the very old stormwater infrastructure remains significantly undersized, with much smaller diameter pipes than would be used today. The small pipes limit the capacity to convey large water volumes from the intense summer thunderstorms that can cause nuisance flooding. Nuisance flooding can be reduced by capturing and slowing down the water so that it doesn't all try to go down the small pipes at the same time. To further mitigate the vulnerability to street and neighborhood flooding, several tactics are proposed to attenuate the intensity of stormwater runoff within the neighborhood.

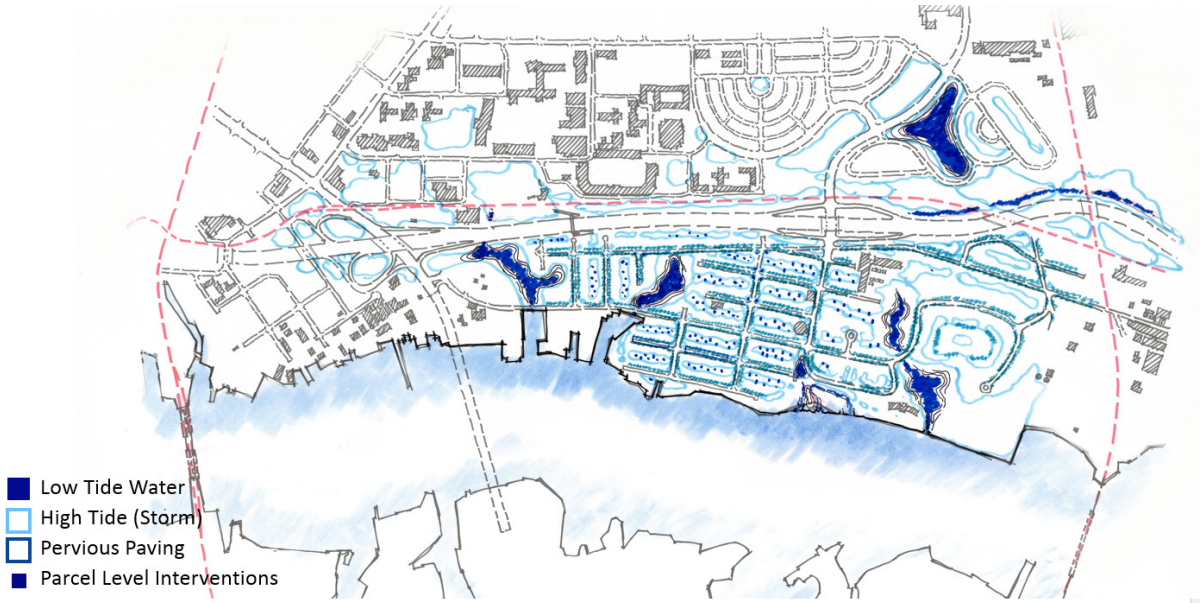

Figure II.6 Ohio Creek Proposed Stormwater Management

Flooding is reduced by capturing and temporarily retaining water in barrels, rain gardens, open areas, and parks. The City of Norfolk proposes to implement an innovative, dispersed stormwater collection program using a combination of rain barrels and rain gardens at each residential parcel within the watershed. The flow in roof gutters and downspouts will be redirected into a storage device which has a capacity to accommodate the 10-year rainfall volume and discharge it slowly from an outlet on the bottom of the device. When each parcel temporarily stores the water that falls on their own property and releases it slowly into the communal drainage, the initial pulse of stormwater into the system is attenuated, which helps to prevent the undersized system from being overwhelmed and backing up into the streets. Residents can use a rain barrel and save some of the water for watering lawns and garden during dry periods. Alternately, residents can capture the rain in a decorative rain garden in which vegetable or ornamental flowers are planted. As part of the stormwater collection program and in order to bring about a community-wide sense of responsibility for personal environmental impacts, the City intends to encourage all residents of the watershed to participate. This program incorporates, builds upon and refines community-chosen designs that have been developed and engineered by Hampton University, Old Dominion University and Wetlands Watch. Public outreach and education materials and events about stormwater, flooding and water quality will be offered, building upon and incorporating best strategies and lessons learned from the successful Ripple Effect Water Literacy Project piloted in New Orleans after Katrina and the innovative Elizabeth River Project: River Stars Program. The City will incentivize participation in the actual on-site retention activities through the use of discounted city fees.

Flooding is also mitigated by reducing the amount of impervious surfaces in the neighborhood so that rainfall can infiltrate into the soil rather than entering the stormwater drainage system. The City proposes to retrofit existing streets with pervious pavement, bio-swales and rain gardens, as well as permeable bike paths to manage stormwater collection in parts of the neighborhood. Many of the neighborhood streets have street parking along one or both sides of the street which is currently impervious material. The City proposes to replace the impervious paving with pervious paving under all of the parking areas to allow infiltration along the street curbs (see Figure 6 above). In addition, at many street intersections, “green” decorative planters will be constructed in the sidewalks that contain flowers and ornamental plants but will also contain water storage capacity in undergrown gravel cisterns. Throughout the neighborhood, a number of bio-swales and rain gardens will be created to capture and detain rainwater in an aesthetically pleasing manner. Finally, large cisterns will be placed underneath two of the largest streets in the watershed to detain stormwater runoff. The sub-grade storage will receive water from the surface streets and release it slowly into the existing stormwater system.

In addition to the innovative parcel scale and street level stormwater detention, the proposed project includes increased capacity and improvement of several large storm water retention areas, which will simultaneously increase wetland habitat. Three marsh retention areas on the west side of the watershed are expected to provide a total of 1.7 million cubic feet of rainwater storage, and will be connected to and integrated with the wetlands and park areas in the design for a holistic stormwater management and treatment system. The passage of stormwater through the marshes will remove phosphorus and nitrogen thereby helping the city to meet its TMDL targets. Finally, there are several parcels imperiled by low elevation and proximity to flooded areas. The City proposes to acquire these properties and turn them into multi-purposed open park space and recreational amenities where residents can gather during dry days, but where additional storm water will be detained during rainfall events. Figure 7 indicates new park spaces to be added to the area. The sum of parcel scale, street scale, and large scale detention will be adequate to accommodate the 10-year rainfall and prevent most nuisance flooding of streets, sidewalks, and homes.

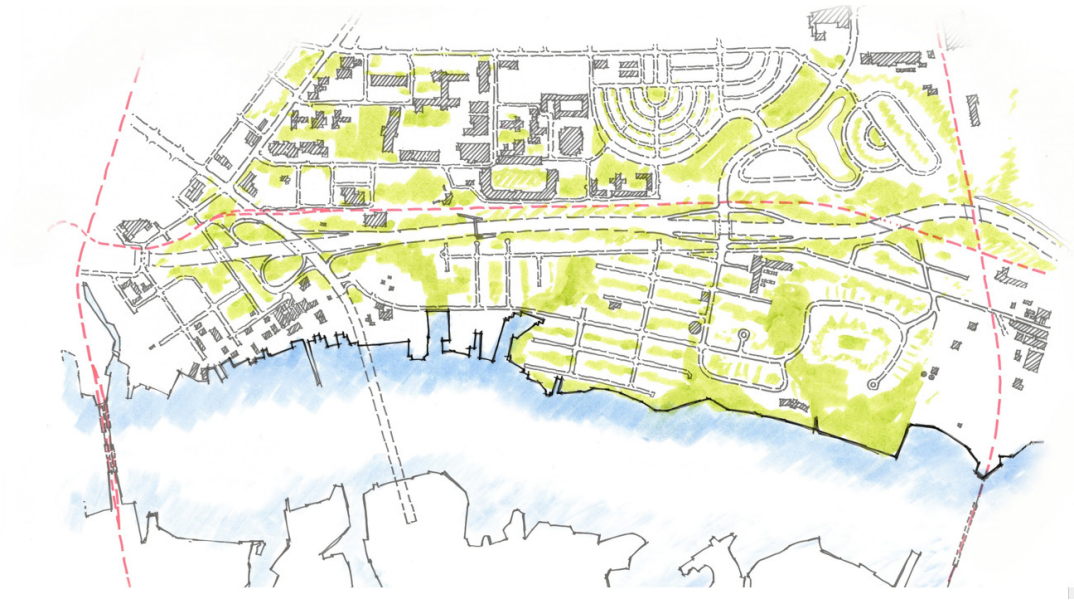

Figure II.7 Ohio Creek Proposed Open Space Network

Because tidal gates and check values will block the discharge of stormwater during coastal flooding and high tide, stormwater will be stored inside the berm in the marsh areas. Despite the increased capacity of stormwater retention, the storage is limited. For many rain events, the stormwater will exceed the storage capacity of the system before the river stage subsides and the gates can be opened to release the stormwater into the river. Thus, several large pumps are proposed to discharge rainwater over the coastal berm and into the river. These pumps help to ensure that the rainfall within the Ohio Creek Watershed can be adequately managed.

Summary of Stormwater Management

PLACEHOLDER FOR FINAL FIGURES… Consider table or visual

Anticipated number of residential rain barrels and rain gardens = ___ (= number of parcels)

Number of Green water storage cisterns at street intersections = ____

Area of new rain gardens for water storage = 6,840 square feet

Area of pervious street paving = 77,725 square feet

Storage capacity of green street scape and sub-grade cisterns = 36,000 cubic feet per rain event

Number of pumps for moving stormwater over the coastal berm = ____

At-risk properties transformed into water storage parks = _____

Wetlands protected and enhanced = 658,000 square feet

Community Amenities

All of these strategies offer the advantage of a small scale, replicable and community oriented approach to resiliency at a neighborhood scale. The communities of Chesterfield Heights and Grandy Village contain school facilities and a Community Center. As neighborhood streets are improved with green stormwater techniques, new permeable bicycle and sidewalk connections will be constructed that will provide recreational benefits as well as safe routes to school and other community facilities. Bike lanes and new pedestrian walkways are designed in the proposed project, which will increase neighborhood connectivity and help improve social cohesion. Figure 8 indicates the various connections made through this effort supplying safe bike routes and integration into other areas of the city.

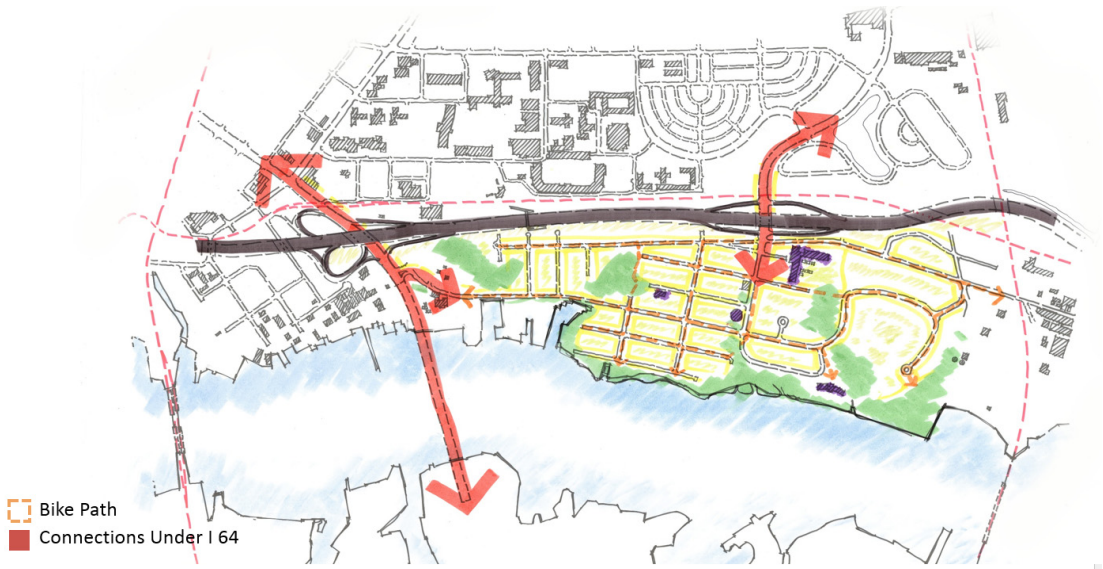

Figure II.8 Ohio Creek Proposed Network Connectivity

Along the waterfront, the berm can be utilized as community open space with a promenade as a central feature. Along the promenade, benches and exercise stations provide additional public benefit. Additional multi-purpose open space and recreational amenities will be provided with the acquisition of several parcels imperiled by low elevation and proximity to flooded areas so that these can be turned into multi-purposed open space and recreational amenities.

Summary of Community Amenities

PLACEHOLDER FOR FINAL FIGURES… Consider table or visual

Length of bike path = ___

Wetlands increased and protected =

Living Shoreline habitat =

Increased park areas = ____

Newton’s Creek Watershed Transformation Project

Newton's Creek Watershed

The Newton's Creek Watershed is experiencing the same flooding dynamics as in the Ohio Creek Watershed described previously. Consequently, many of the same water management measures are proposed for the Newton's Creek Watershed. However, one significant difference between the watersheds is that the land use types are more diverse in the Newton's Creek Watershed, which permits some additional options for large scale stormwater management as well as community and economic development which are not possible in the Ohio Creek Watershed.

There are three distinct neighborhoods within the Newton's Creek Watershed, each with its own character, challenges, and unique opportunities. The South Brambleton neighborhood is a mix of industrial waterfront activities, a few apartments, and many vacant lots. The Harbor Park area is an underutilized waterfront location that contains extensive impervious parking lots and many gravel parking lots which function as infrequently used overflow parking for the Tides Baseball Park. The St. Paul's Area is an isolated HUD housing development from the 1960's which has reached the end of its design life and contains many aging apartment buildings in need of demolition and replacement. Thus, the flood reduction techniques envisioned for the Newton's Creek watershed can take advantage of extensive areas that can be completely transformed to create an innovative water management foundation upon which a new, resilient community can be built. The tactics proposed throughout the Newton's Creek Watershed are coastal fortification, construction of green spaces, wetlands, and water streets for stormwater management, as well as design and the start of construction of new neighborhoods with enhanced connectivity and opportunities for economic development. Outdated public housing located in flood-prone areas will be replaced with mixed-income, mixed-use neighborhood landscape. Importantly, the redevelopment can only take place once the coastal and stormwater flooding has been mitigated.

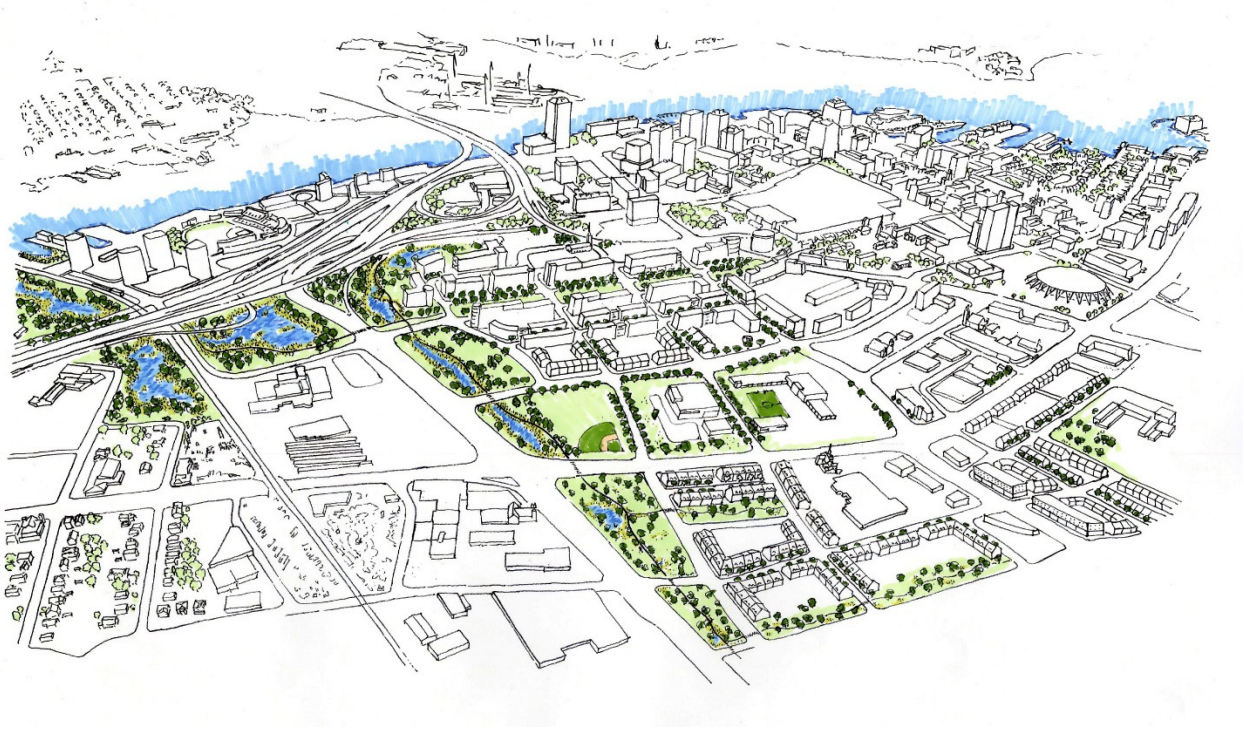

Figure II.9 Newton's Creek Watershed Vision Plan

Coastal Fortification

As described for the Ohio Creek Watershed, the estimated future coastal surge elevation along this part of the Elizabeth River is approximately 11 ft. All proposed actions are needed to protect the inland regions from this level of coastal flooding. A continuous line of coastal protection is proposed along the entirety of the shoreline in this region, the character of the coastal protection will vary according to differences in land use goals across the watershed. Starting in the east, the South Brambleton neighborhood has industrial activities along the coast which require access to the river. Thus, the coastal protection in this area will be placed behind the industry and will be an integration of a low earthen berm and raised roads to create a continuous topographic feature at an elevation of 11 ft. To the west of the industrial sites, the elevated road will connect to a vertical flood wall which will encompass an important electrical sub-station. The entire electrical supply to the city of Norfolk passes through this site, thus energy resilience is significantly enhanced by protecting the Reeves Electrical Substation site within the coastal fortification. To the west of the electrical sub-station is a water channel which is the vestigial remnant of Newton's Creek. All stormwater runoff from the entire watershed drains through this channel into the Elizabeth River, thus this channel is very important to the overall stormwater management of the whole watershed. The coastal fortification will continue across the channel and tie into the elevated Norfolk-Southern railroad right of way on the west bank of the channel. This portion of the shoreline barrier will include a tidal gate that can be closed during high tides and coastal surge to prevent water moving from the Elizabeth River up the channel and into the upper watershed.

The Harbor Park area starts on the west side of the Norfolk-Southern line, where the coastal protection will take the form of an earthen berm with a solid sheet pile core, similar to the one proposed in the Ohio Creek Watershed. There will be an 8 ft. wide concrete walking/bicycle path running the length of the berm. Once protected, the existing waterfront will become valuable waterfront real estate that will be transformed into attractive, waterside commercial spaces and additional waterfront recreational areas. There are stormwater outfalls along the river in Harbor Park on which one-way check valves will be installed to prevent back flow when the river elevation is high. Similar to the living shoreline described above for the Ohio Creek, watershed, breakwaters and marsh vegetation will be installed along the Harbor Park shoreline to provide wave attenuation, erosion control, increased natural habitat, and an adaptive living shoreline that accommodates sea level rise over time.

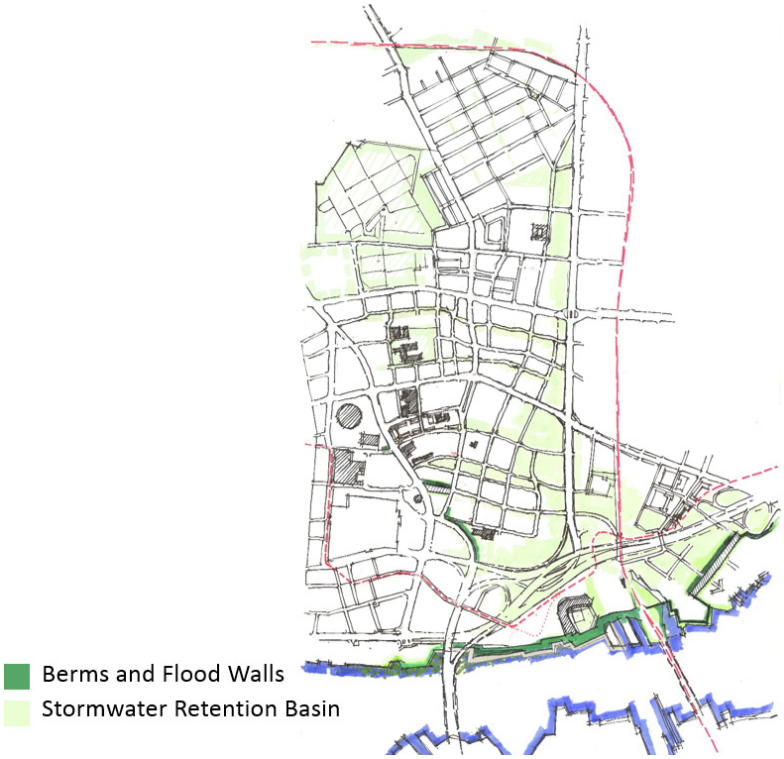

Figure II.10 Newton's Creek Proposed Coastal Resiliency Improvements

Stormwater Management

Many locations within the Newton's Creek Watershed suffer from nuisance stormwater flooding. Some components of the drainage system in this area are older, undersized pipes and there is not adequate stormwater storage within the watershed. Thus, when there is more water than the drainage system can convey, the water ponds on low-lying roads and areas within the neighborhoods. One of the primary chokepoints in draining the system are the undersized culverts that convey the water under Holt Avenue and under the Norfolk-Southern rail line to the outflow channel on the east side of the rail line. The culverts are small and they are located below mean sea level such that even high tides push water back up the system and prevent rainfall from draining out to the river. Figure 10 provides a visual of the existing flood issue using modeled storm events. The proposed solution to remedy the stormwater flooding in the Newton's Creek watershed is to take advantage of the proposed coastal barrier and tide gates to prevent backflow, improve some of the main system components, and to greatly increase the available stormwater storage in the watershed.

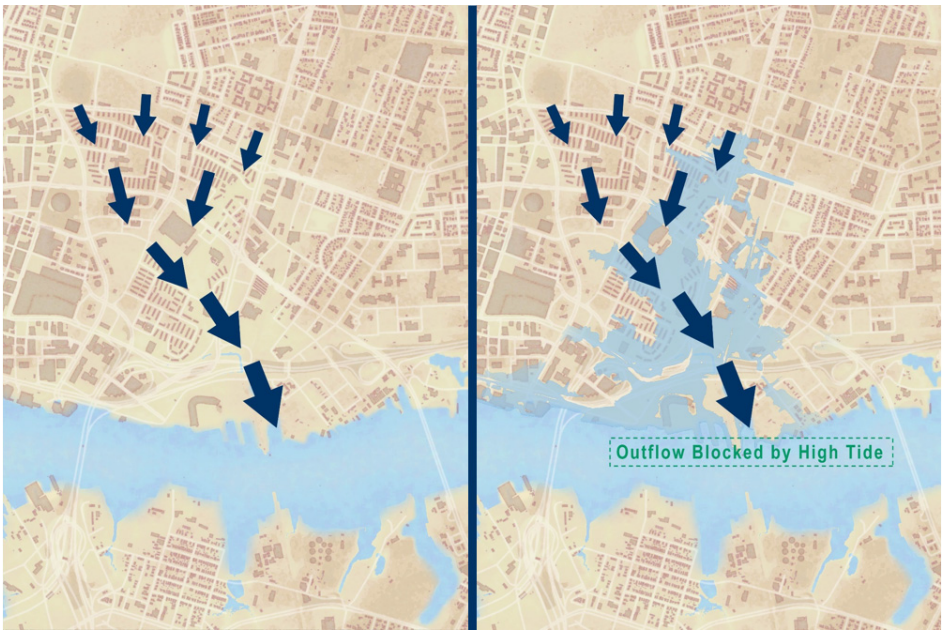

Figure II.11 Newton's Creek Watershed Holt Avenue Back-Up

First, the proposed tide gate at the mouth of the outflow channel next to the Norfolk-Southern rail line provides an opportunity for stormwater storage to be disconnected from the river. Several large pumps are proposed for placement just inside the mouth of the channel so that when the tide gate is closed, the pumps can expel water from the channel and effectively empty the storm water system prior to a rain fall event. To increase the available storage on the bottom of the watershed, an auxiliary storage area is proposed adjacent to the outflow channel. The City proposes to convert several, city-owned, vacant lots in the South Brambleton area to water storage. These lots are in the area northwest of the industrial regions and will be excavated to produce a large storage area that will be connected to the main outflow channel by a large underground culvert. In this way, stormwater draining from the upper watershed can accumulate in the pre-emptied channel and to the new South Brambleton storage pond via the underground culvert. The large pumps which can be used to drain the stormwater system before a storm can also be used to continue moving storm water over the berm and into the river during and after a storm. The pumping capacity will be designed to accommodate the 25-year rainfall volume and thus prevent nuisance flooding up to the 4% chance rainfall event. Once the river stage attenuates to normal elevations, the tide gate can be opened, allowing the accumulated stormwater from up the watershed to drain naturally into the river.

Second, to increase the efficacy of the stormwater system to move water down the watershed to the primary storage areas, the City proposes to improve and increase the capacity of the culverts under Holt Avenue and the Norfolk-Southern line. Upgrading this feature will allow the system to more efficiently move stormwater out of the St. Paul's Area and into storage in the South Brambleton area. The lower storage areas and pumps provide the primary capacity for the watershed to mitigate stormwater flooding.

Typically, urban areas are structured according to the desired location of buildings and street layout, only after which stormwater considerations are fit within the constraints of the urban landscape. However, the City of Norfolk proposes an innovative approach to invert that paradigm and instead organize the stormwater infrastructure first. In the St. Paul's Area, the city proposes to take advantage of the fact that the existing HUD project housing has outlived its useful life and must be demolished. Norfolk proposes to demolish the Tidewater Gardens complex (77 structures) and to develop a new neighborhood organized around stormwater management. The innovative proposal is to first construct a system of surface water storage and then fit the neighborhood within and around the stormwater features. The main stormwater features will be a series of open green spaces aligned with the original Newton's Creek channel, which is the lowest topography in the area and the area most prone to flooding. The sequence of green spaces will be designed to collect and hold rainwater and will be linked together with low weirs to control the flow of water between the areas. During a rain event, all neighborhood drainage will flow into these green areas, and like cascading pools, the collected storm water will flow from one pool to the next down the length of the watershed before finally passing through the newly upgraded culverts under Holt Street and into either of the primary detention areas (if the river is high) or through the outfall channel and directly into the river (if the river is low). The sequence of greenspaces will also be underlain by a large culvert into which water can drain under moderate to small rainfall events via inlets within each greenspace. When the culvert fills during large rainfall events, then the green spaces will store the excess water and deliver it down gradient over the connecting weirs. The proposed system offers substantially more resilience to stormwater flooding than a traditional curb and gutter stormwater system. In addition, the linked sequence of green spaces can function as an amenity which can be landscaped with ornamental plants and flower gardens, and can function as parks and playgrounds during dry weather. Figure 11 below indicates the envisioned stormwater management systems for the Newton's Creek Watershed.

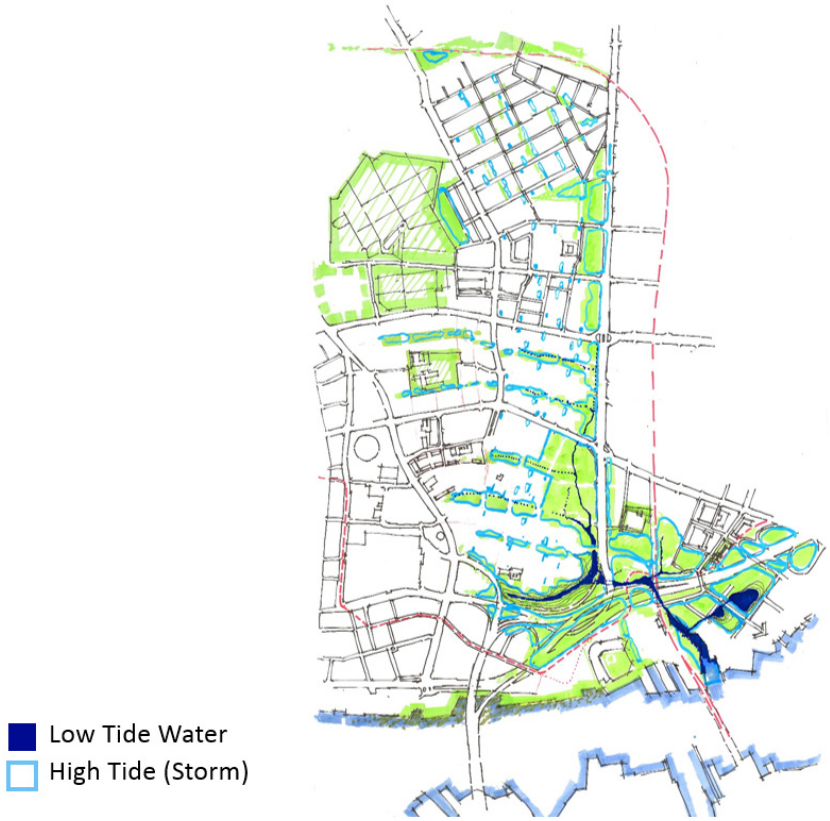

Figure II.12 Newton's Creek Proposed Stormwater Management

After the surface water network has been established, the innovative neighborhood development will proceed with a realignment of green streets and water streets that connect to each other and to the individual green spaces. Figure 12 provides a visual of the existing street network to the newly proposed road network which integrates these greenspaces into the fabric of the road system. The function of the green and water streets is similar to the main green spaces; an area along the street alignment will be dedicated to holding water and slowly conveying it down to the main green spaces. When it rains, rather than letting rain collect in the street or into traditional curb and gutter, there will be pervious soil and plants, such as a bioswale, that will have a lower elevation than the street and sidewalk. Thus, rainwater will gather in the bioswales rather than on the street or sidewalk. The bioswales will convey some of the water to the main green spaces of the surface water collection system, while the remainder will infiltrate into the soil without impeding day-to-day life for residents and businesses. For some of the main streets, the bioswales will be quite deep and take on the appearance of a canal during heavy rain. Depending upon aesthetic decisions, the streets can be designed to retain some water during dry times or they be designed to fully drain and thus be vegetated during dry times. Thus, the neighborhood can have a mix of water streets or green streets to provide a diversity of beautiful streetscapes as an additional benefit to the robust and resilient water management program.

Figure II.13 Newton's Creek Current Roadway Network and Newly Proposed Network

Once the green and water streets are organized for maximum effective storm water drainage, new mixed-income and multi-use neighborhoods can be implemented without the risk of frequent flooding. Moreover, the development can include wide walking areas and parks which can be integrated with the bioswales and canal-like features along the streets. The City is intent on integrating green infrastructure, on-site water retention and mixed-use, mixed income housing restrictions on all new development in the renovated portions of the community, and will implement changes to zoning and building codes to accomplish these important

objectives, especially as outlined in its PlaNorfolk 2030 comprehensive plan. Note that both the use of primary storage low in the watershed and the distributed “water-first” approach in urban planning are innovative ideas for the City of Norfolk. The outcome of this innovative approach to water management provides resilience against nuisance flooding and opportunities for economic investment, commercial development, and community renewal within an attractive area protected from coastal flooding.

Summary of Expected Amenities

- 57.3 acres of new park space
- 67.4 acres of improved park space with stormwater management technology
- 45,500 linear feet of permeable walkways and bike paths
- 1,192 additional trees planted throughout the Newton’s Creek Target Area
- 4,946 linear feet of improved and protected shoreline
- 25.8 acres of new wetland habitat

Community Amenities

The innovative stormwater management solutions in the Newton’s Creek watershed will create the framework and the incentives to revitalize several communities and create new incentives to spur growth in the adjacent downtown. The open space corridor running north – south along Tidewater Drive will serve the dual purpose of collecting water from the higher ground in the neighborhoods to the north and allowing it to slowly infiltrate and move to larger water bodies to the south, as well as creating a new network of parks and trails connecting residents to the downtown and Harbor Park. The connections and the park spaces created will give new multimodal transportation options and bring access to quality natural open spaces for many residents in the city. New road connections will be made between the downtown area, St. Paul’s Area, Harbor Park, and South Brambleton. Figure 13 identifies the new connections made with other portions of the city by the institution of the proposed projects. This critical connectivity is presently missing in the area. Historic Church Street (an important African American business district) will also be carefully re-developed as a main thoroughfare in the neighborhood, in accordance with community input.

Figure II.14 Newton's Creek Connectivity Improvements

The St. Paul's Area, which is currently underserved by park spaces, will gain access to large multi-use, attractive open spaces containing sports fields, water features and nature trails. These open spaces will offer safe walking and bike routes to work, school, and to the public transit systems currently operating in the city. The combination of permeable paving surfaces and the water features will create pathways for water to slowly enter the ground, preventing pooling during minor rains and the severe flooding currently experienced in these areas during significant storm events.

The landscape around these water features will concentrate on using native species and creating new protected refuge areas for wildlife. The open space network being created will restore the area's natural and historic hydrology as well as the area's local plants and wildlife to the place where they have been lost.

The creation of this new hydrological and open space network in the St. Paul's Area will be used to spur private investment that can replace existing dilapidated public housing buildings with mixed-use mixed-income buildings. The proximity of the neighborhood to downtown Norfolk demands a higher density of residential units than is currently occupying the site. Downtown Norfolk represents a large, regional employment center, and by increasing the density in the adjacent neighborhoods, the city can bring people closer to their work and keep more of the city's income flowing back into local businesses. By creating a higher density mixed-income neighborhood the city will be able to maintain the same number of low and moderate income units in the area while improving the quality of those units and the surrounding environment.

Coastal Resilience Accelerator

Another amenity proposed for the Newton's Creek watershed area is the creation of a new Coastal Resilience Accelerator hub ("Accelerator") to research, educate, and promote holistic and innovative water management practices. In alignment with the Hampton Roads area's strategic initiative to "thrive with water", the Accelerator will serve as a nexus for technological, organizational and conceptual innovation around regional resiliency

issues including increased flooding, economic vitality and equity of opportunity. Figure 14 identifies the potential location of the new Coastal Resilience Accelerator site with identified future expansion locations.

Figure II.15 Newton's Creek Coastal Resilience Accelerator Potential Locations

This center fits within Norfolk's long-term initiative to become a hub for such innovation by leveraging regional assets - military expertise, local universities and medical schools, as well as its location as the gateway to the Chesapeake Bay. The Accelerator center will facilitate research and entrepreneurship in emerging 21st century sectors to provide "new solutions to new problems" as part of the wider effort to RE.Invent Hampton Roads (RE.Invent).

The Coastal Resilience Accelerator has eight objectives:

1. *Acceleration of Water Management Solutions:* The Accelerator will concentrate on the development and evolution of business that contribute to regional resilience by providing innovative water management solutions.

2. *Acceleration of Incorporation of Resilient Principles in Existing Systems:* The Accelerator will act as the center for resilience thinking accessible to all of the cities across the region. A prime focus will be identifying those sectors, projects and actions that most quickly build the region's ability to move forward following disruptions—key areas will include business continuity and recovery, critical infrastructure recovery, reduction of burden on emergency management, building neighborhood cohesion and Naval Station Norfolk operational continuity.

3. *Workforce Development Accelerator:* Facilitating ongoing local efforts to ensure a workforce capable of filling the needs of a growing water innovation sector, the Accelerator will assist Opportunities Inc.,

Tidewater Community College, Old Dominion University and other educational institutions to ensure alignment of high quality low-cost training opportunities that quickly move unemployed, underemployed and recent veterans into living wage jobs.

4. *Regional Leadership and Planning:* The region has already established itself as a national leader in their focus on adaptation to sea level rise through the Old Dominion University Pilot, the ODU Mitigation and Adaptation Research Institute, Virginia Institute of Marine Science at William and Mary and the adaptive work of local nonprofits including Wetlands Watch, Lafayette River Partnership, the Elizabeth River Project and others. Through work with the Rockefeller Foundation, Hampton Roads communities became aware of a best practice that is known as "Dutch Dialogue" which allowed communities to work with Dutch urban designers, engineers, landscape architects, planners, academics, and government officials to engage with American counterparts to explore creative solutions and holistic concepts for flood risk reduction, (green and gray) infrastructure with multiple benefits, resiliency, and smart redevelopment. As a result of the Dutch Dialogue, the cities of Hampton and Norfolk have committed to work together to advance common challenges of increased flooding due to increasing precipitation and sea level rise. Through the Hampton Roads Planning District Commission, the regional City Managers are exploring new leadership mechanisms to drive this work in the future. The Accelerator will support and advance this work where appropriate and where value is added.

5. *Research and Evaluation Accelerator:* Working with universities and private organizations including Old Dominion University, Resilience Corporation, Indra, Virginia Tech and others the Accelerator will support the innovation and market readiness of resilience building strategies.

6. *Accelerate change through Pre-K-12th Grade Educational Opportunities:* The Accelerator will assist in developing a partnership between educational institutions including local public school districts, Old Dominion University, Norfolk State University, Hampton University, and Tidewater Community College to create and implement programs that educate students about climate change, sea level rise and its impact on the region. Programs will emphasize real life impacts and mitigating activities that can allow citizens to thrive in a coastal environment including: hazard identification, the role of the environment in mitigating impacts, the importance of strong social networks in a high-risk environment, and the role of science, mathematics, technology and innovation in creating solutions to system level challenges.

7. *Entrepreneurial Ecosystem:* Focusing on water resilience, accelerate the timeline between research to product and product to market to increase regional economic vitality.

8. *Financing and Capital Market Innovation:* Working with 100 Resilient Cities Platform Partners including SwissRe, Re.Bound, Social Finances and others, create innovative financing to ensure the region's ability to implement needed resilient projects. Innovations may include catastrophe bonds, tax increment financing (TIFs) and innovations to capture disaggregated cost savings from mitigation interventions.

Recognizing the significant threat posed to Virginia's coastal communities by climate change, the Governor signed Executive Order 19, convening the Governor's Climate Change and Resiliency Update Commission. Hampton Roads is the most vulnerable region on the East Coast (second to New Orleans), and without action the area's economic, environmental, military, and cultural assets could be severely impaired. Virginia has the opportunity to be a leader in finding creative ways to mitigate climate change and adapt to the effects of climate change that have already been seen here in the Commonwealth.

Norfolk intends to leverage public property for the location of the hub, with three potential locations within Newton's Creek Watershed that will have access to improved recreational and housing options and proper transportation access.

Holt Street

To further enhance the connections between the St. Paul's Area and the adjacent neighborhoods, Holt St, which currently runs from Harbor Park to the south, under I-264 and intersects with Tidewater Drive, will be extended further north so that the intersection at Tidewater Drive can be signalized and can run through the St. Paul's Area to align with Freemason Street. This new connection will allow vehicular and pedestrian traffic to move through the neighborhood and establish a new tie between Harbor Park and downtown Norfolk. To enhance the pedestrian and cyclist experience along this route, a new system of pathways will be implemented under I-264, wrapping around the water features being added in this area. This bike and pedestrian path will not only connect Harbor Park to the downtown area but will also tie in to the system running east to South Brambleton, Chesterfield Heights and Norfolk State University.

In Harbor Park the storm surge barrier will, over time, become the framework to build a new waterfront promenade tying into the Tides baseball stadium and the existing waterside development. Linking the museums, hotels, and entertainment venues currently housed in waterside to the stadium will benefit both areas economically and will help to attract more private investment to Norfolk's waterfront. The flood protection afforded by the storm surge barrier will also increase the value of the land around the stadium, creating new opportunities for private investment in office, residential and hospitality space. The addition of new residents, workers, and visitors to the area will help to bring new vitality to downtown Norfolk and to the city's waterfront. The area is already served by both public transit and Norfolk's Amtrak station, making it an attractive transit oriented development site.

Holt Street Graphic

Elizabeth River Shoreline Restoration Project

Elizabeth River Shoreline Restoration

Shorelines have traditionally been stabilized using hardened structures such as bulkheads, revetments, and concrete seawalls. These structures ironically can contribute to erosion, and provide little habitat for estuarine species that improve water quality and absorb stormwater. As part of the proposed activities in the Ohio Creek and Newton's Creek Watersheds, the City of Norfolk proposes to construct robust living shorelines along the bank of the Elizabeth River in the Target Area. Figure 15 below illustrates some examples of living shorelines.

The living shoreline (sometimes called a constructed wetland) design includes: Riparian, Wetland, and Sill zones. These are placed parallel to the shore, from upland to river. The shoreline will be carefully graded to provide the appropriate slope conditions in each zone, and will account for plant species to migrate with rising sea levels. Riparian area (the most upland zone) will integrate with berm sections and allow for heavy shrubbery and grass to grow. The wetland (the intertidal zone) allows for tidal grasses such as cordgrass (*spartina alterniflora*) to take root in soils that are inundated during high tide. These grasses cause the accumulation of sediment over time, creating habitat for successive species of high marsh grasses and mollusks. The Sill safe guards the shoreline from erosion due to wave energy.

Wetlands act like a sponge, soaking up stormwater and dampening storm surges. By trapping polluted runoff, wetlands help slow of the flow of nutrients, sediment and chemical contaminants into rivers, streams and the Chesapeake Bay.[5]

Photo Credits: Low Country Open Land Trust (left) Chesapeake Bay Trust (Right)

Figure II.16 Examples of Living Shorelines with Protective Sills (oyster shell, left, stone, right)

Normally a south-facing shoreline without major issues concerning fetch like the Chesterfield Heights and Harbor Park shore would not require a protective sill. However, since this shoreline experiences frequent boat wakes from the passing barges in the nearby shipping lane, a marsh toe sill was included in our design.

The wetlands are designed to meet the proposed marsh toe sill at midtide so that the marsh grass and other plants will be sustained. As sea level rises in future years, the midtide elevation will also rise. The designed wetland that lies below midtide has a greater chance of becoming a mud flat as the marsh grasses retreat upland. The mud flat is still healthy and beneficial to the ecosystem, so the design accommodates for sea level rise as well as providing continuous benefits to the neighborhoods.

When combined with a shoreline berm, a robust living shoreline can increase the durability and effectiveness of the flood protection structure. The slope of the berm and the elevation of the rock breakwater and vegetation of the shoreline construction can be carefully integrated so that as sea levels rise, the natural vegetation will be able to adapt by moving up the properly graded river bank. This presence of the rock, soil, and vegetation will function to attenuate wave energy and prevent erosion of the shoreline during coastal flooding events. In this

[5] *Chesapeake Bay Foundation http://www.chesapeakebay.net/issues/issue/wetlands*

way, the combined, multiple layers of defense from the berm and the living shoreline, will afford greater protection in concert than either feature could provide by itself. Several storm water outfalls coincide with the designed living shorelines. By taking discharge capacity into account, it is necessary to protect this area from storm water spilling at a higher discharge rate and potentially ruining the integrity of the proposed living shoreline. Integrating stone around the outfall opening will provide outlet protection by reducing the flow rate of storm water flows. Recycled concrete or existing stone debris on site can be used to reduce cost. The design proposes 2,200 linear feet of living shoreline in the Ohio Creek Watershed, and --- linear feet in Newton's creek, totaling a full acre of new wetland creation.

Figure II.17 Living Shoreline Areas in Chesterfield Heights Neighborhood, Ohio Creek Watershed

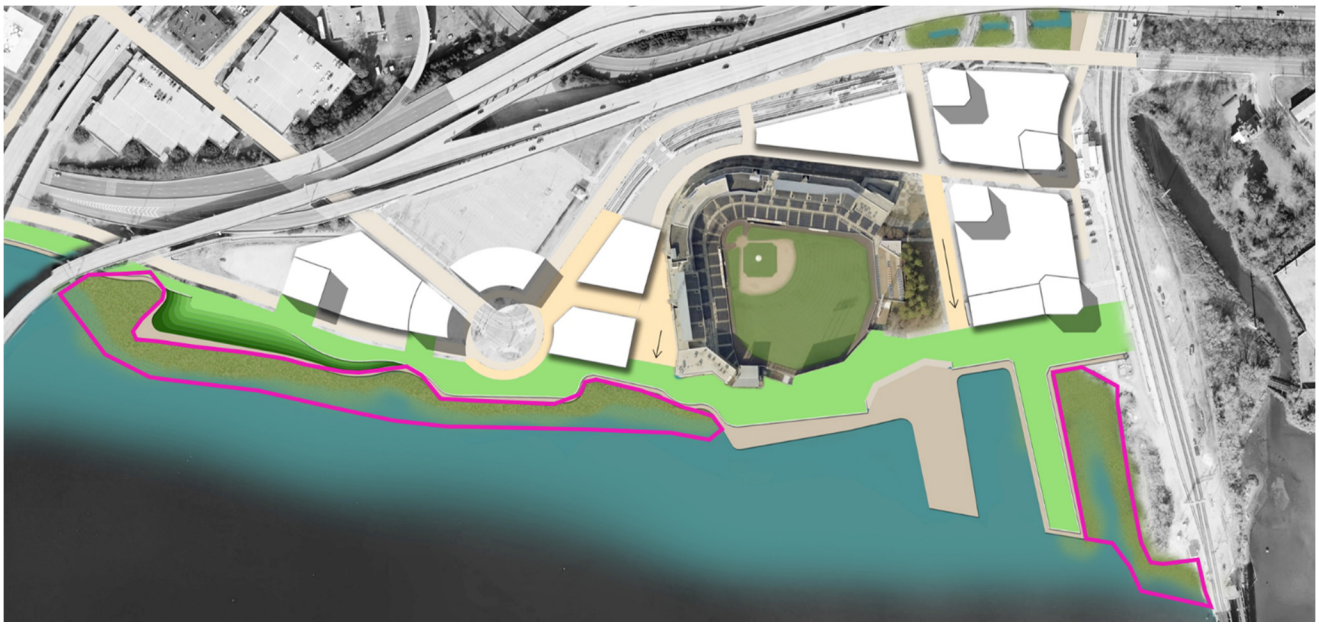

Figure II.18 Living Shoreline Areas at Harbor Park, Newton's Creek Watershed

Design Philosophy

Design Philosophy

Combined Resiliency Actions

The primary goal of the Target Area designs are to develop a system in which both coastal and precipitation events can be mitigated to the highest degree feasible. As such, the measures proposed in each area advises a holistic system of water retention and detention. In preliminary designs, pervious pavement, bio-swales, rain gardens, above ground stormwater storage, wetland expansion, and open park spaces, as well as permeable bike paths will manage stormwater impacts in a collective and collaborative manner while the identified floodwall, berm, and roadway elevations will ensure protection from coastal surge impacts. The conceptual designs for both watersheds propose to maximize water storage volumes in the space available, while integrating these features into the local environment as an amenity rather than a requirement.

Coastal Resiliency and Flood Protection

The proposed design within each of the Target Area considers a coastal protection system that will incorporate permanent engineered features while also integrating the natural landscape into the design. Because the City of Norfolk relies heavily on the use of its waterfronts by both visitors and residents to stimulate activity in the Target Area, preservation of existing waterfront access and the addition of new pedestrian friendly riverside features was important in each prevention measure's design. The demand for visual corridors and anticipated waterfront zoning provided strict guidance in identifying both locations and prevention feature proposals primarily due to the need to maintain unobstructed views. Although a combinations of berms, floodwalls, and road elevations are being proposed, these features will be incorporated into the fabric of the waterfront through landscaped promenades, attractive commercial areas, and integrated park spaces. These proposed project elements will be important in maintaining the community's visual and physical connectivity to the waterfront, as well as the prevention of damages and loss within the area due to flooding.

Additionally, the overall project design of both Target Area will focus heavily on the integration of bioretention features and coastal surge water management upgrades into the community. The increased capacity and improvement of multiple storm water retention areas and increased wetland habitat areas have been unified into the design of the Ohio Creek Watershed. Because this area has an established infrastructure, the project design will work to integrate many of these new improvements into the existing systems creating a holistic stormwater management and treatment system. One of the primary ways the project design is working around the existing street grids is by removing the current roadways and replacing these roads with permeable pavements. This method will not only allow for the current infrastructure to remain but also allow for water to infiltrate into the soils ultimately providing a higher degree of protection in the area.

Because the scope of the project in the Newton's Creek Watershed provides a much greater level of flexibility with regard to the installation of new infrastructure and design, the project has indicated that the approach should largely focus on the re-establishment of the historic Newton's Creek streambed. Flooding is common in this watershed not only because of low elevations near the water but also due to the quick urbanization of the area. Figure 18 displays the existing conditions of both the Newton's Creek Watershed and Ohio Creek Watershed and the historic streambeds.

Figure II.19 Target Area Existing Conditions and Historic Streambed

The Newton's Creek design will include the development of park spaces, natural bioswales, daylighting stream areas, and instituting rain gardens along the streambed to allow for flooding to occur in the area without directly affecting any residents or businesses. The City of Norfolk will also convert multiple city-owned parcels into water retention features serving duel purposes as both a stormwater collection area and public amenity. The Newton's Creek Watershed proposal also focuses heavily on the relocation and redevelopment of neighborhoods prone to flooding, as well as readjusting the existing street grid. This portion of the project would not only provide more opportunity to incorporate upgraded stormwater features but also allow the city to begin re-envisioning the area as a whole.

The protection features proposed will be designed to provide protection at the 1-percent annual chance still water elevation plus 2.5 feet (30 inches) of sea level rise. This elevation is estimated at +10.1 to +10.6 feet (NAVD88). This level of protection is based on two contributing factors: the 1-percent annual chance surge still water level at a level of elevation between 7.6 and 8.1 feet NAVD88 and an allowance for sea level rise (SLR) for the high projection of ranges in 2060.

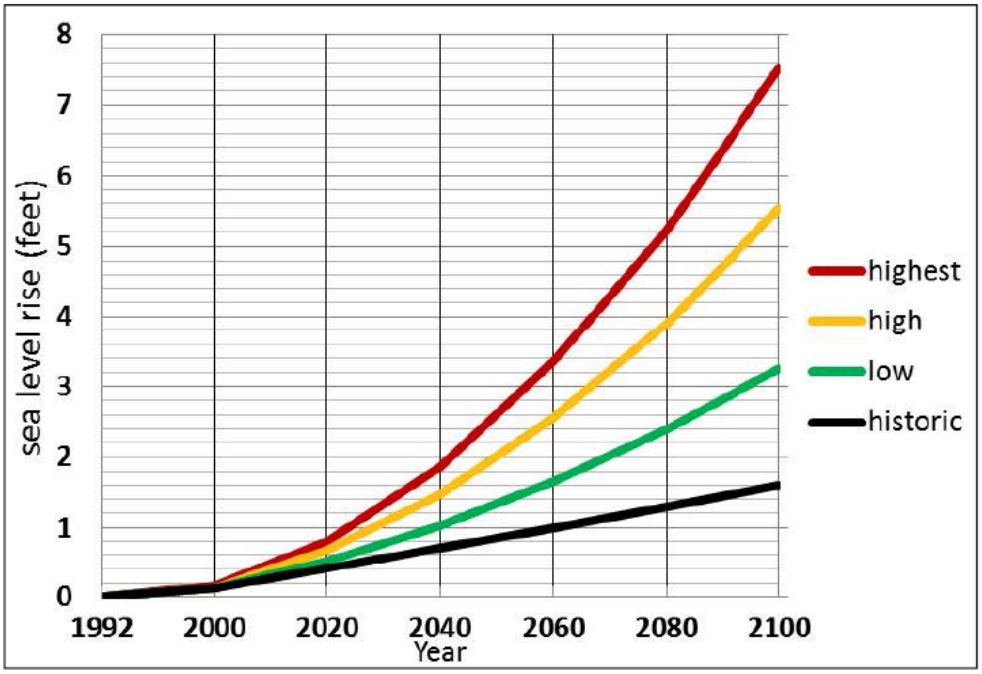

Figure II.20 Sea Level Rise Projections, Norfolk, VA

Source: Mitchell, M., et. al. (2013). Recurrent Flooding Study for Tidewater Virginia. Gloucester, VA: Virginia Institute of Marine Science.

Stormwater Flood Protection

As a best management practice, it is also important to consider the implementation of stormwater flood protection measures in the proposed Target Area designs. This is particularly important in the case of the City of Norfolk due to the fact that a major portion of both designs involve the employment of a coastal floodwall and berm system. Typically, in coastal regions, elevations tend to slope downward as they near the water. This means that in areas where there is a high level of impermeable surface, precipitation and stormwater tends to flow towards these lower elevations. If a coastal protection system is put into place that does not take into account this consideration during a severe enough precipitation event, the measure could be deemed useless as water will begin to build-up behind the system and flood nearby structures. To mitigate this risk, both project designs have incorporated a series of pump stations on the landward side of the proposed floodwall to assist in pumping stored rainwater over the floodwall back into the Elizabeth River.

An additional concern that must be factored into the proposed designs is the backup and overloading of existing stormwater management systems. In storm events, it is the intent of the City of Norfolk management infrastructure to convey all gathered stormwater through the existing pipes to a number of outfalls directly into the receiving waters, such as the Elizabeth River. During a high tide event such as a storm surge, water from the river can backflow through the stormwater outfalls into the system seriously impeding the outflow capacity. This prevention of outflow essentially causes a bathtub effect within low lying areas where water will continue to build eventually causing flooding in roadways and possibly structures. Therefore, these outfalls must have a closure mechanism to account for anticipated surge. This consideration has been incorporated into the Ohio Creek Watershed area where this problem has been experienced and documented before.

Additional Benefits

Although there is a heavy focus on each of the project's resiliency benefits; the additional social, recreational, environmental, and economic benefits cannot be overstated. Within this BCA report, the proposed project designs are evaluated for affordable housing benefits, new employment opportunities, economic revitalization, community connectedness, added value to quality of life, reductions in undesirable factors, historic preservation, and expected health improvements. All of these considerations are integrated into one overarching design philosophy; to make Norfolk a more resilient and sustainable city.

Schedule and Cost Estimates

Capital Cost Estimates

Project Schedules

Operation & Maintenance Costs

Feasibility of Proposed Projects

Feasibility of Proposed Projects

The activities proposed here are achievable and will be effective at meeting the goals established in the Phase 1 application.

While there are many innovative components to the proposed holistic approach of integrating coastal and stormwater flooding, the individual components are standard practice. The methods for estimating storm surge risk and for computing stormwater volumes have been well validated in the engineering community and result in dependable design of the berm heights and pumping volumes. The construction of the berms and pump stations are straightforward and the sites are accessible by traditional construction equipment. The terraforming and landscaping of the green spaces and bioswales are likewise standard practice. One challenge will be the variable depth to groundwater within the Target Area which will impact the excavation depth and storage capacity of the green spaces. Fortunately, the strategy of the plan provides amble flexibility to adjust the areal extent and depths of the individual storage areas. The proposed retrofit of green water collection, pervious pavement, and sub grade water storage in the Ohio Creek Watershed have been implemented previously and have been demonstrated to work. Additional components of the proposed activities such as demolition of obsolete properties, construction of parks, and bike paths do not present any concerns. The City of Norfolk has an extensive GIS database which will be used to locate all subsurface utilities for coordination and avoidance during construction.

During construction, there will be challenges from working in heavily congested areas and in areas with space constraints (such as under I-264), but these can be handled with careful planning and attention to safety.

The cost estimates have carefully considered all of the direct projects costs and have included some contingency to account for some uncertainties such as unknown sub-surface soil conditions. It is expected that the project can be implemented for the estimated costs. Several regions require conversion of landuse from typical residential lots into water storage sites, and fortunately, the City already owns most of the desired sites.

Finally, success of the project is helped by the continual public involvement and stakeholder engagement that Norfolk and others have pursued over a number of years. In the St. Paul's Area, there have been multiple community meetings and a renovation plan has already been published which has been well received by the neighborhood. According to City officials, many residents are excited for the project to begin. In the Chesterfield Heights neighborhood, a coalition of university students has previously explored the concepts of parcel-scale stormwater detention with the community. There is acceptance and interest by the community in participating in these resiliency activities. Additionally, continuous efforts from organizations like the Norfolk Redevelopment and Housing Authority have spurred interest in the redevelopment and renovation of many of the targeted areas. Thus, with substantial community support and in the absence of unidentified technical roadblocks, the proposed activities are feasible and viable for the requested sums.

Project Risks to Implementation

Despite careful planning and the support of an optimistic community, there are several risks that may impede progress on implementing the proposed activities. First, there may be permitting obstacles that are as yet unidentified. Possible permitting impediments may involve construction of the living shoreline on the river bottom, concerns about the tide gates impacting tidal flushing, riparian impacts of the coastal berm, and water quality in the bioswales and urbane green spaces. There may also be significant time that will need to be dedicated to environmental impact studies.

Second, there may be complications from uncooperative property owners adjacent to the proposed activities. For instance, it may be difficult to coordinate construction activities with Norfolk-Southern or with Dominion Electric power, both of whom are important stakeholders and whose permission will be required to implement the coastal berm. Additionally, the city plans to acquire some private property which may be imperiled if the City encounters an unwilling seller.

Other risks include coordinating construction activities in a busy and congested area with automobile and pedestrian traffic. This may be especially vexing in the area under I-264 and Tidewater Drive. Finally, there is uncertainty regarding the subsurface soil conditions along the Elizabeth River. This may have an impact on the penetration depth of piles for the shoreline berm.

Publicly Funded Resiliency Actions Post-Irene

Publicly Funded Resiliency Actions Post-Irene

Irene spurred a renewed interest in sea level rise (SLR) in Norfolk and City leadership responded with increased involvement in state and regional opportunities to assess and incorporate SLR into planning growth and resiliency actions. Norfolk also invested or committed to the following post-Irene resiliency actions either through grants or City revenues, totaling almost $30 million.

1. Development and implementation of the 2015 Dutch Dialogues: Through their Dutch connection (see **Exhibit G** narrative) the City spent time and travel costs over a period of several years to bring about the June 2015 Dutch Dialogues event, which was a regional, state and international multi-day design workshop to create innovative resilience solutions to regional flooding issues. Toward this effort, the City spent around $100,000 in in-kind, logistics, and staff time expenses. If the City were to pay for time and travel expenses of all Dutch experts who came for free, it would be additional $250,000 as estimated by the Dutch Embassy. This consensus became the basis for the Phase 1 NDRC projects and application.
2. In 2013 the Mayor's Commission on Poverty Reduction was charged with examining the causes and impacts of poverty in Norfolk, and with developing a plan to reduce poverty for future generations. Recommendations to reduce and de-concentrate poverty carry an implementation cost of $3.9 million; some of the actions include addressing flooding in poor neighborhoods.
3. In 2014 Norfolk was selected as one of the first 33 cities to participate in the Foundation's "100 Resilient Cities" program, which allowed the City to hire its first Chief Resiliency Officer and to pursue a portfolio of resiliency measures in programs, projects and policies. 100 Resilient Cities committed to a $1 million grant over two years in support of this effort. The City committed additional $187,866 over the same period.
4. Funding for the National Fish and Wildlife Foundation Sandy Grant for the development of a Green Infrastructure Plan and Network for the Lafayette River Watershed (project budget of $4.64 M) was accepted by the City Council in August 2015. The City approved the use of $257,343 in City funding as project match.
5. Norfolk is presently conducting a review of all City codes to analyze deficiencies and find areas for strengthening construction and zoning against flooding hazards. They are rewriting the zoning code ordinance which will be guided by a resilience framework being developed in cooperation with 100 Resilient Cities, the American Planning Association, the Urban Land Institute and others for sea level rise adaptation. Estimated cost of this effort is $564,715; this work is expected to be completed in 2017.
6. The US Army Corps of Engineers will be constructing a 2015/2016 Beach Nourishment Project; initial cost is estimated at $18.4 million. The City's initial cost share will be $5.5 million. Estimated 9-year period re-nourishment costs are $7.5 million, with the City's matching share (29%) of $2.2 million. The main purpose of this project is to reduce coastal storm damage by extending the berm of the beach for wave attenuation during storms. City funding is approved; project start date is 2016.
7. New funds aimed at economic and community revitalization: the City's approved FY 2016 budget embraces the creation of several unique programs that will be entirely capitalized with Community Development Block Grant (CDBG) funds and other federal resources. The investment in these programs in FY 2016 will be a total of $2 million for revitalization and reinvestment of catalytic redevelopment sites and neighborhood commercial districts, assistance to small businesses and women minority-owned businesses. This also includes the Norfolk Innovation fund – focused on providing financing for firms in the fields of technology, sustainability and resiliency, healthcare, entrepreneurship.
8. Norfolk has created a citywide flooding reserve account funded by Storm Water Fees that was increased in 2013 by an additional $1.00. Each fiscal year this reserve account brings in approx. $1,315,200 for neighborhood flood reduction, storm water quality improvement, storm water facilities improvement, and maintenance of waterfront structures (such as bulkheads).

For the fiscal years post-Irene (FY 2013, 2014, 2015 and FY 2016) the City has allocated a total of $14,000,000 as follows:

Neighborhood flood reduction	$5,800,000
Storm water quality improvement	$3,800,000
Stormwater facilities improvement	$2,400,000
Stormwater waterfront structures	$2,000,000

Projects included in these activities are listed in the appendices of the BCA report.

Grandy Village

The Grandy Village part of the proposed project includes the demolition of older public housing units and the construction of 70 new apartments, a 1500 sq. ft. community office, associated infrastructure, and a new roadway for the entire community connecting Kimball Terrace and Wiley Drive, as well as stormwater measures (expansion of bio-retention area and manufactured water quality inlets, grass swales) and open spaces.

The residential units will be spread across 12 new buildings totaling 88,982 sq. ft., featuring a mix of Garden and Townhouse styles ranging from 1 to 4 bedrooms. The seventy units will replace obsolete units built in the early 1950's that lacked central heat and air conditioning as well as other standard amenities that are common in apartments today such as dish washers, hook ups for washers and dryers, energy efficient appliances and more spacious apartments.

The Norfolk Redevelopment & Housing Authority (NRHA) will integrate these properties into the surrounding neighborhoods, using landscape plantings and amenities such as playgrounds, playing field space and proper lighting to enhance the quality of resident's lives. The Grandy Phase VI project will integrate similar features such as residential units overlooking the Elizabeth River to the south of the property. Landscape design includes the provision of grading and stormwater conveyance away from buildings, sod, seeding and planting beds in all disturbed areas, buffer yards, streetscape, parking and foundation plantings. Existing wetlands and tidal areas on the property will be preserved or enhanced. Water conservation practices will be achieved through drought tolerant plantings and limited irrigation.

Outdoor common areas for the residents will be located at the center of the main project area. An open field (approximately 41,000 sq. ft.) of usable gathering and play space is allocated for this amenity. The gathering area will be situated with residential units surrounding the space. Adjacent to the gathering space, a playground will be constructed to the southeast, easily accessible by the residents via proposed sidewalk connections. Proposed sidewalks also tie into the existing neighborhood sidewalks that branch out to the city sidewalks and nearby commercial centers.

PART III
EXISTING CONDITIONS

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Existing Conditions

Norfolk is the historic, urban, financial, and cultural core of the Hampton Roads metropolitan area, named for the large natural harbor of the same name located at the mouth of Chesapeake Bay. The city is partially bordered to the south and west by the Elizabeth River and to the north by the Chesapeake Bay. It also shares land borders with the independent cities of Chesapeake and Portsmouth to the south and Virginia Beach to the east.

The Target Area of this NDRC Application are two watersheds to the east of Downtown Norfolk: the Newton's Creek Watershed and Ohio Creek Watershed, with particular emphasis on the waterfront neighborhoods of St. Paul's Quadrant, Harbor Park, South Brambleton, and Chesterfield Heights, as shown in Figure III.1 and

Figure *III.2* below.

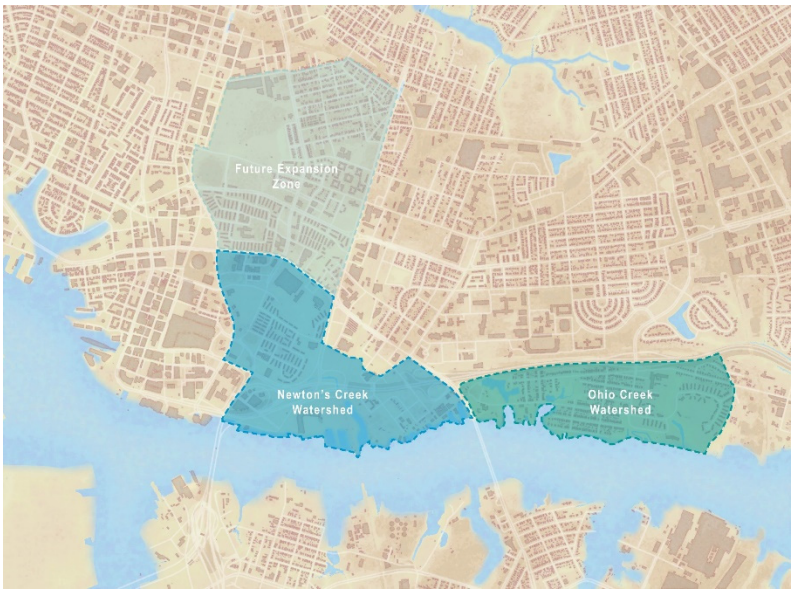


Figure III.1 Target Area Watersheds

Figure III.2 Target Area Neighborhoods

Vulnerable Populations

Vulnerable Populations

Certain populations are particularly vulnerable during disasters due to social, economic, and educational factors that can exacerbate disaster recovery and resilience. In the Target Area, vulnerable populations include seniors, children, those with disabilities, non-English proficient residents, and low- to moderate- income (LMI) residents.

Social Vulnerability

Seniors and young children are especially vulnerable during disasters, as they often depend on family care and may also be more susceptible to the stress of disasters.

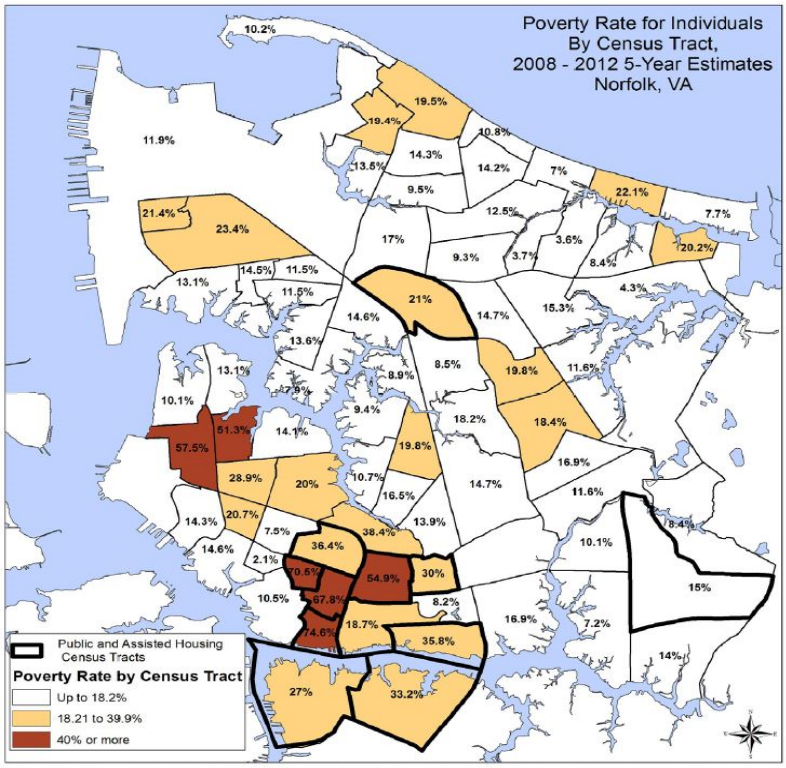
In the Mayor's 2014 "Plan to Reduce Poverty," the following statistics are cited for the City:

"Norfolk's poverty level has historically been nearly double Virginia's overall average. The U.S. Census Bureau reported that from 2008–2012, 18.2 % of individuals (27.7% of children) in Norfolk experienced poverty, versus 11.1% of individuals (14.6% of children) across the state as a whole. Compared to neighboring Hampton Roads localities, Norfolk has a high poverty rate. While poverty is a significant problem across the region, it is especially concentrated in the city of Norfolk." (page 8)

"In Norfolk, poverty and race are linked, with high levels of poverty among minorities. A given Norfolk resident experiencing poverty is most likely to be black: 58% of the city's 40,000 individuals living in poverty are black, constituting 24% of all blacks living in Norfolk. Although they constitute a much smaller %age of Norfolk's population, other minority groups—such as Native Americans—experience disproportionately high poverty rates." (page 10)

In the Target Area, 12% of the population in the Ohio Creek Watershed is over the age of 65 and 12% is under the age of 5, and 7% of the population in the Newton's Creek Watershed is over the age of 65 and 13% is under the age of 5.

Dependent population generally require dedicated assistance from caretakers or emergency personnel during and after disasters. Some people may physically lack the ability to evacuate themselves. Hearing or visually impaired persons or those with cognitive issues may not be able to respond to evacuation and emergency instructions in a timely manner. Those with mental challenges can become overwhelmed and have lasting traumatic impacts from the disruption of daily routine, changes in transportation options, and costs associated with recovery.



Note: Citywide poverty rate is 18.2% (ACS 2008-2012). Map is labelled with census tract number and poverty rate.
Source: US Census Bureau, American Community Survey, 5 year estimates, 2008-2012, Norfolk, Virginia

Figure III.3 Poverty by Census Tract in Norfolk

Economic Vulnerability

An estimated 86% of the Target Area population is considered low to moderate income (LMI). HUD defines a family of four earning $56,700 or less as low income in the Virginia Beach-Norfolk-Newport News Metropolitan area.[1]

Low income households face increased challenges in post disaster situations, as they have fewer financial resources to recover after

[1] *HUD User. http://www.huduser.gov/portal/datasets/il/il2015/2015summary.odn*

disasters. Furthermore, these households have fewer options for transportation and accommodation during or after disasters, and are less able to manage with lost income if they are unable to travel to work or their workplace is also impacted.

Analysts used the US Census Bureau-based Longitudinal Employer-Household Dynamics (LEHD) Origin-Destination Employment Statistics (LODES) dataset to estimate the number of jobs currently available in the Target Area, the earnings and demographic data of workers, and the general location of residences of those workers.

Based on the LODES analysis, 97% of the jobs in the Target Area are held by people living outside and commuting to the Target Area. Transportation links are critical for this population as they travel from areas such as Virginia Beach, other areas of Norfolk, Chesapeake, Portsmouth, Hampton City, Newport News, and Suffolk into the Target Area every day for work.

- 32% of the jobs in the Target Area earn less than $1,250 a month.
- 38.4% of the jobs in the Target Area are held by those with a high school degree or less.
- 46.5% of the outflowing jobs make less than $1,250 a month while only 37.4% of the inflowing jobs make $1,250 or less. Of the interior flow, 69% makes less than $1,250 a month.

A majority (58%) of Norfolk's housing units are renter occupied, and 29% of households are considered severely rent-burdened, paying greater than 50% of their income towards housing costs.[2] Despite Norfolk's ongoing efforts to reduce this burden (see Affordable Housing below), there continues to be an urgent need for affordable housing in the area.

Educational Vulnerability

"Norfolk adults living in poverty, in large part, do not have the education required for most job openings within the city or the region: only 2.7% of Norfolk citizens with a bachelor's degree or higher are unemployed, compared to 9.8% of residents with some college or an associate's degree, 11.7% of high school graduates, and 17.8% of persons with less than a high school education."[3]

Residents with low English proficiency may also not be able to access up to date emergency communications and may struggle to respond to evacuation measures. Residents with limited education have more limited job opportunities, typically earn lower incomes, and may have less access to clear information about hazards and preparedness.

Approximately 10% of the residents in the Target Area have low English proficiency, and 15% of residents have less than a high school education.[4]

Mental Stress and Anxiety

Vulnerable populations are at higher risk of mental health impacts after a disaster event, as they often have lower physical health and social or economic resources.[5] Literature indicates that mental health issues can impact work productivity, therefore vulnerable populations are more susceptible to decreased work productivity post-event. The American Red Cross estimates that 30 to 40 % of an impacted population will need mental health assistance post-disaster.[6] Studies by the World Health Organization in 16 countries indicate that persons with chronic mental health issues will have 25-% lower lifetime earnings.

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[2] *100 Resilient Cities Norfolk SWOT Analysis, July 2015*
[3] *Mayor's 2014 "Norfolk Plan to Reduce Poverty," pp. 14*
[4] *US Census Bureau, American Community Survey 5-year estimates*
[5] *Galea S, Tracy M, Norris F, and S.F. Coffey. 2008. Financial and social circumstances and the incidence and course of PTSD in Mississippi during the first two years after Hurricane Katrina. Journal of Traumatic Stress. 21:357–368. [PubMed: 18720399]*
[6] *Welker, Catherine. 2011. American Red Cross Liaison Officer to FEMA Headquarters Disaster Services. Personal correspondence, December 6.*

Environmental Conditions

Environmental Conditions

The Hampton Roads region, initially settled over 400 years ago, is located to the south and the west of Chesapeake Bay's mouth in the southeast corner of Virginia. The southern part of this region includes the urbanized cities of Portsmouth, Virginia Beach, Chesapeake, and Norfolk, the urban core of "the Southside." Norfolk is surrounded by several different water bodies, including the Elizabeth River, James River and Chesapeake Bay, and their main tributaries. As the City is low-lying, nearly all of the City is less than 15 feet above sea level.[7] The Target Area is comprised of 1.8 square miles, extending eastward of downtown Norfolk, and is located on the northern shoreline of the Eastern Branch of the Elizabeth River. This area includes lowlands and coastal formations, as well as areas of wetlands.

Air Quality

The Clean Air Act, which was last amended in 1990, requires EPA to set National Ambient Air Quality Standards (NAAQS) for pollutants considered harmful to public health and the environment. There are two types of national ambient air quality standards: Primary standards provide public health protection, and Secondary standards provide protection against decreased visibility and damage to animals, crops, vegetation, and buildings. EPA has set National Ambient Air Quality Standards for six principal pollutants, which are called criteria pollutants.[8]

Each year, the Virginia Department of Environmental Quality Office of Air Quality Monitoring releases a report of air quality levels around the state. This report outlines the results of testing for criteria pollutants. The latest report (2013) will be discussed in this section. One of the testing areas in the state for criteria pollutants is Norfolk. Criteria pollutants are particle pollution (PM2.5 and PM10) carbon monoxide, sulfur dioxide, nitrogen dioxide, ozone, and lead.

PM2.5, PM10, carbon monoxide, sulfur dioxide, and nitrogen dioxide levels in Norfolk were below Primary and Secondary National Ambient Air Quality Standards (NAAQS) in 2013. Ozone and lead air quality standards for Norfolk are not given. Nevertheless, for the period from 2011- 2013, only the counties of Fairfax and Arlington exceeded the ozone air quality standards in the state. The City of Norfolk is a "Maintenance Area" for ozone which means that it had formerly not attained the standard, but is now recognized by EPA as meeting the NAAQS. A maintenance area must have an approved "maintenance plan" to meet and maintain air quality standards. Lead levels were below the Primary and Secondary NAAQS for the 4 testing sites in Virginia outside Norfolk.[9]

In early 2015, the General Assembly of Virginia was in talks to join the Regional Greenhouse Gas Initiative that establishes a regional CO2 electric power sector cap and trade program as well as the Commonwealth Resilience Fund, a revolving fund to serve as a consistent revenue stream to assist counties, cities, and towns in the Hampton Roads region with the implementation of efforts to combat sea level rise and recurrent flooding. The bill also provides economic development assistance for families, businesses, and localities in Southwest Virginia to offset negative economic impacts associated with reduced fossil fuel production.[10] The bill will be considered in the next session. On January 27, 2015 Norfolk passed Resolution No. 1609 supporting this legislation, requesting that the Commonwealth participate in the regional greenhouse gas initiative for the protection of coastal flooding, due to an increase in recurrent flooding in the city.

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[7] *Briefing Book Tidewater District Norfolk. pp. 15.*
[8] *United States Environmental Protection Agency. National Ambient Air Quality Standards (NAAQS). http://www.epa.gov/ttn/naaqs/criteria.html*
[9] *Commonwealth of Virginia Department of Environmental Quality. Virginia Ambien Air Monitoring 2013 Data Report. http://www.deq.virginia.gov/Portals/0/DEQ/Air/AirMonitoring/Annual_Report_2013.pdf*
[10] *Virginia's Legislative Information System. HB 2205 Regional Greenhouse Gas Initiative; Commonwealth Resilience Fund established. http://lis.virginia.gov/cgi-bin/legp604.exe?151+sum+HB2205*

Water Quality

Norfolk's Department of Utilities is the second largest waterworks in the Commonwealth of Virginia. As a regional water purveyor, Norfolk provides top quality drinking water to 850,000 customers in Norfolk, Virginia Beach, parts of Chesapeake, and to the US Navy. In addition to water, the Department of Utilities also provides wastewater collection service to approximately 240,000 residents in Norfolk.[11]

The City of Norfolk obtains its raw (untreated) water from eight reservoirs, two rivers and four deep wells. From these sources, raw water is pumped to one of the Department of Utilities' two water treatment plants, where it is filtered and disinfected. The City meets or exceeds EPA standards for all regulated substances, and is well below the national level for secondary and unregulated but monitored substances, according to its 2015 Water Quality Report.

From the Dutch Dialogues Briefing Book (page 22):

"Norfolk's existing municipal separate storm sewer system (MS4) is managed by the Norfolk Public Works Stormwater Division. This system consists of 349 miles of pipe, 137 miles of ditches, 13 storm water ponds, and 10 storm water pump stations. The newest portions of the system have been sized to accommodate a 10-year storm event while portions constructed before the 1950s have capacity for a 2-year storm. Extra capacity is needed to handle the additional backwater flows caused by storm surges or high tide, which may occur concurrently. This could be accomplished by either increasing the capacities of most of the storm drain piping or by a number of retention strategies throughout the City.

Although much of the storm drain system design was intended to accommodate 2-year (50% annual probability of occurrence) or 10-year (10% annual probability of occurrence events) design events, those systems were designed for tail water elevations as had been measured at the Sewells Point tide gauge. As part of the Fugro Atlantic flooding studies, tide gauges were installed in many of the principle drainages within the City. The gauge measurements indicate that with the exception of the drainages on the northern perimeter of the city that empty into Chesapeake Bay, the water level elevations in the watersheds are higher than those measured at Sewells Point. While the differences between those water level elevations and the water level elevation at Sewells Point depend on many factors, in general the water level elevations in the drainages throughout most of Norfolk are 0.5-ft +/-0.2 ft above the water levels at Sewells Point.

While those differences are small, the landscape is flat. The lack of gradient implies that the small difference in tailwater elevation increases the annual % probability of occurrence of a specific water level within the drainages. A 0.5-ft difference (above that measured at Sewells Point) approximately doubles the annual probability of occurrence. Thus a system intended to serve a 2-year flood event (50% annual probability of occurrence) is in reality capable of serving a 1-year design event (100% annual probability of occurrence). Similarly, a system intended to serve a 10-year flood event (10% annual probability of occurrence) is in reality capable of serving a 5-year design event (20% annual probability of occurrence). While Norfolk has made significant investments to expand and improve its storm water infrastructure, the age and size of the systems, coupled with limited available funding resources, has created a significant backlog of high priority storm water projects."

Wastewater treatment plants for the City's effluent are operated by the Hampton Roads Sanitation District, although the wastewater system is maintained by the City's Division of Wastewater, Department of Utilities.

Brownfields and Contaminated Sites

As a strategic harbor, Norfolk has a legacy of industrial contamination that reflects its long history of naval operations, shipbuilding, and maritime trade. Environmental toxins are linked to numerous environmental and health risks. According to the EPA, contaminated sediments are a significant environmental problem, impairing the use of many water bodies and often contributing to the over 3,200 fish consumption advisories that have been issued nationwide. Volatile chemicals in buried wastes and/or contaminated groundwater can emit vapors that may migrate through subsurface solids and into air spaces of overlying buildings. Volatile organic

[11] *On 9-21-15: http://www.norfolk.gov/utilities/*

compounds such as those used in paints, solvents, disinfectants and stored fuels can cause cancer in animals; some are suspected or known to cause cancer in humans.[12]

According to the Virginia Department of Environmental Quality, there are 880 registered petroleum storage tanks and 1100 registered petroleum releases (64 of them open) in Norfolk.[13] There are 5 sites in the City which have completed the (Brownfield) Voluntary Remediation Program and 6 which are planned sites for the program as of June 2015.[14] There are two superfund sites on the US EPA's National Priorities List located within Norfolk. The National Priorities List (NPL) is the list of national priorities among the known releases or threatened releases of hazardous substances, pollutants, or contaminants throughout the United States. No superfund sites are located in the Target Area, although sites have been identified by the EPA as pollutants including the Sewells Point Naval Complex and the Naval Amphibious Base Little Creek.

The Norfolk Naval Base – Sewells Point Naval Complex site had contamination of concern in the following media types: groundwater, sediment, soil, subsurface soil, surface soil, and surface water. Some of the contaminants of concern include Base Neutral Acids, Dioxins/Dibenzofurans, Inorganics, Metals, PAH, PCBs, Pesticides, and VOCs. In 2010, physical construction of the remedies was completed. The site has not undergone post-construction, therefore, full remediation has not been achieved at the site.[15]

The second site is the Naval Amphibious Base Little Creek, located in the Tidewater region of Virginia, near the mouth of the Chesapeake Bay. Wastes that have been generated and disposed at the Little Creek facility include: pesticides, paints, solvents, inorganics, heavy metals, polychlorinated biphenyls, mixed municipal wastes, nickel plating baths, chromic acid, silver cyanide, copper cyanide, lacquer, lacquer stripper, per-chloro-ethylene sludge, soap, dyes, and degreasers. The most updated information from the US EPA is from 2012 and states that the site is still under cleanup.[16]

Chemical Storage Facilities

There are no Chemical Storage Facilities located in the Target Area.

Environmentally Sensitive Areas

The National Oceanic and Atmospheric Administration (NOAA) Office of Response and Restoration maintains Environmental Sensitivity Index maps which characterize coastal environments and wildlife based on their sensitivity to spilled oil. These maps are useful for understanding environmental sensitivity in a coastal region such as Norfolk. Figure 4 shows the map as it looks currently for the City. The red lines represent highly sensitive salt and brackish water marshes in sheltered tidal flats. This type of ecosystem is found in the Lafayette River and Little Creek, in the northern section of the city.

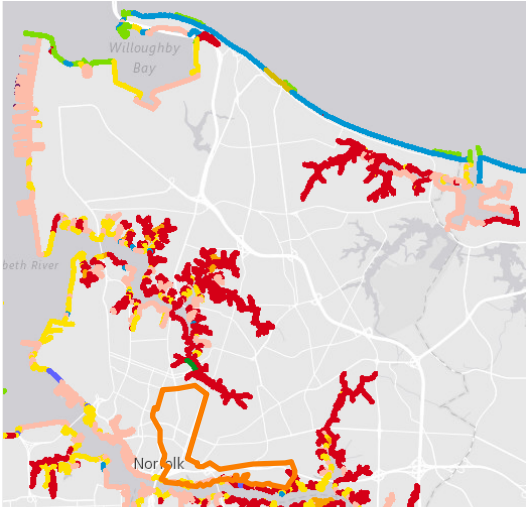

Figure III.4 Sensitive Environment Areas in Norfolk (Target Area outlined in orange)

Marshes are defined as wetlands frequently or continually inundated with water, and characterized by emergent soft-stemmed vegetation adapted to saturated soil conditions. Tidal marshes serve many important functions. They provide vital food and habitat for clams, crabs, and juvenile fish, as well as offering shelter and nesting sites for several species of migratory waterfowl.[17] The tidal marshes in Norfolk serve as habitat for threatened and endangered species including the Great egret, Peregrine falcon, Yellow crowned night heron, Green sea turtle, Kemps Ridley sea turtle, Leatherback sea

[12] EPA Chemicals and Toxics Resources: http://www2.epa.gov/learn-issues/chemicals-and-toxics-resources
[13] http://www.deq.virginia.gov/Programs/LandProtectionRevitalization/PetroleumProgram/FilesForms.aspx#petdbf
[14] http://www.deq.virginia.gov/Programs/LandProtectionRevitalization/RemediationProgram/VoluntaryRemediationProgram/PublicInformation.aspx
[15] http://cumulis.epa.gov/supercpad/cursites/csitinfo.cfm?id=0302858
[16] http://www.epa.gov/reg3hwmd/npl/VA5170022482.htm
[17] http://water.epa.gov/type/wetlands/marsh.cfm

turtle, Loggerhead sea turtle, and Atlantic sturgeon.[18] Tidal marshes also buffer stormy seas, slow shoreline erosion, and are able to absorb excess nutrients before they reach the oceans and estuaries. Therefore, this sensitive ecosystem is vital to the control of flooding in Norfolk.

In conjunction with these proposed projects, the Elizabeth River Project organization adopted their "Eastern Branch Environmental Restoration Strategy" in November of 2014[19], and is now gathering resources to implement the living shoreline restoration along the river in the Target Area of Harbor Park (Newton's Creek Watershed.) From its strategy (page 4): "The City of Norfolk and Elizabeth River Project are exploring the potential for restoring almost a mile of under-used, degraded, but highly visible waterfront just east of downtown at the mouth of the Eastern Branch, in the vicinity of Harbor Park stadium. This site has the potential to jump-start interest in the larger restoration of the Eastern Branch and demonstrate many aspects of this plan, from public outreach to habitat restoration and water quality improvements."

Land Use

Since Jamestown was settled in 1607, the region developed an economy that is based on its ties to the water. The natural shelter provided by protected harbors with deep water access has attracted commercial shipping activities, as well as national military activity.[20]

The downtown has a broad range of higher intensity uses; traditional character is present throughout the Target Area with a grid street pattern, smaller lots, and variety of uses within close proximity to one another.[21]

Before the Civil War the area was home to scattered farms and plantations. Post-Civil War and into the 19th century, the city expanded into the Harbor Park, Paul's Area, and South Brambleton areas. Expansion into Chesterfield Heights began in 1904 when the community was platted and the first development began in 1914.[22] Prior to man-made alteration, the shoreline consisted of numerous creeks and tributaries of the Eastern Branch, as well as wetlands. Harbor Park during the early history of the city was low lying wetlands with a large tributary of the Elizabeth River running north towards Tidewater Drive,[23] and development in the St. Paul's Area was built on former creek beds. Many of the tributaries and creeks were filled over the past 150 years with debris from fires and storms that devastated the city or to eradicate mosquitos following outbreaks of yellow fever in the 1850s. Now, 10-12% of the city is composed of filled lands,[24] the former creeks and wetlands are the lowest lying areas of the city today and have the most severe flooding. The predominant land uses in the Target Area are residential, industrial, and commercial, as shown in Figure III.5 below.

The St. Paul's Area is bounded by the Norfolk Southern Railroad on the north, Tidewater Drive on the east, I-264 on the south, and Monticello Ave. on the west. Most of the area was originally drainage and tributaries of the former Newton's Creek. By the 1920's, all of the tributaries, creeks, and wetlands within the St. Paul's Area had been filled. The area has had many uses over the history or Norfolk, and since the 1950's the area has mostly been low income housing, warehouses, commercial development, and vacant land.

Harbor Park is bounded by I-264 on the north and west, Norfolk Southern Rail Road on the east, and the waterfront on the south. The entire area used to belong to Newton's Creek before 1900 when most of these former water areas were filled in. The area flourished as the City's location for rail terminal and yards, warehousing, and other high intensity development, but such uses declined in the mid-twentieth century, coincident with the construction of I-264 in the 1950's and 1960's which further isolated the waterfront. In recent years, the Harbor Park baseball stadium and light rail station have been built here.

South Brambleton is bordered by the Elizabeth River to the south, Norfolk Southern Railroad on the west, and Route 168 (East Brambleton Ave./Campostella Avenue) on the north and east. Currently, the South

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[18] *http://geoplatform.maps.arcgis.com/home/webmap/viewer.html?webmap=6c427fb5d07745368ac8a22738659775*
[19] *http://media.wix.com/ugd/8de0fd_2142235a562444d9858ca4e1b5d25a11.pdf on 9-22-15*
[20] *Briefing Book Tidewater District. Page 8.*
[21] *PlaNorfolk. pp. 46.*
[22] *Briefing Book Tidewater District.*
[23] *Briefing Book Tidewater District. pp. 35.*
[24] *Briefing Book Tidewater District Norfolk. pp. 16.*

Brambleton shoreline is dominated by industrial uses. These areas present a challenge to the city as it must protect the shoreline and continue functionality of current land uses.

Chesterfield Heights is bounded by the Campostella Road Bridge to the west, I-264 on the north, the Elizabeth River on the south, and a second rail line to the east. Chesterfield Heights has primarily 1920's residential single family homes on the northern shore of the Elizabeth River, a tidal estuary with impaired water.[25] The outlet of the former Ohio Creek Watershed is west of the neighborhood and degraded wetlands are present in this portion of the neighborhood.[26] Flooding in the low-lying areas in the west restricts residential access to and from this direction during storms.

For these reasons, the selected Target Area serves as a perfect template for Norfolk to demonstrate the success of the proposed solutions. This area is unique in many ways and the variation of both the populations and land uses contained within will provide an enormous opportunity to determine the framework for replicability across the city as a whole.

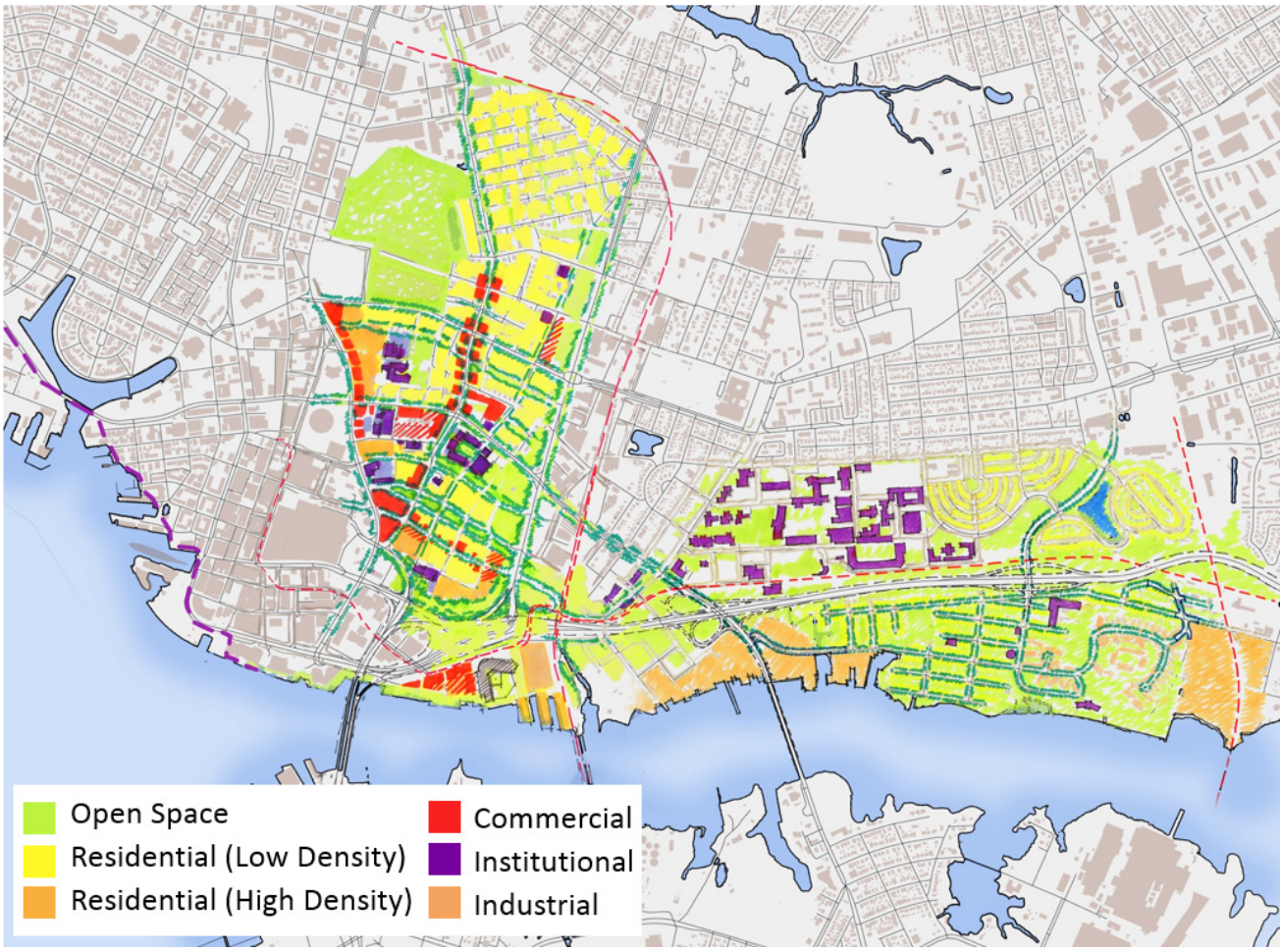

Figure III.5 Primary Land Uses in the Target Area

[25] *Dutch Dialogues Briefing Book. pp. 60.*
[26] *Dutch Dialogue Virginia: Life at Sea Level. August 17, 2015. pp. 8.*

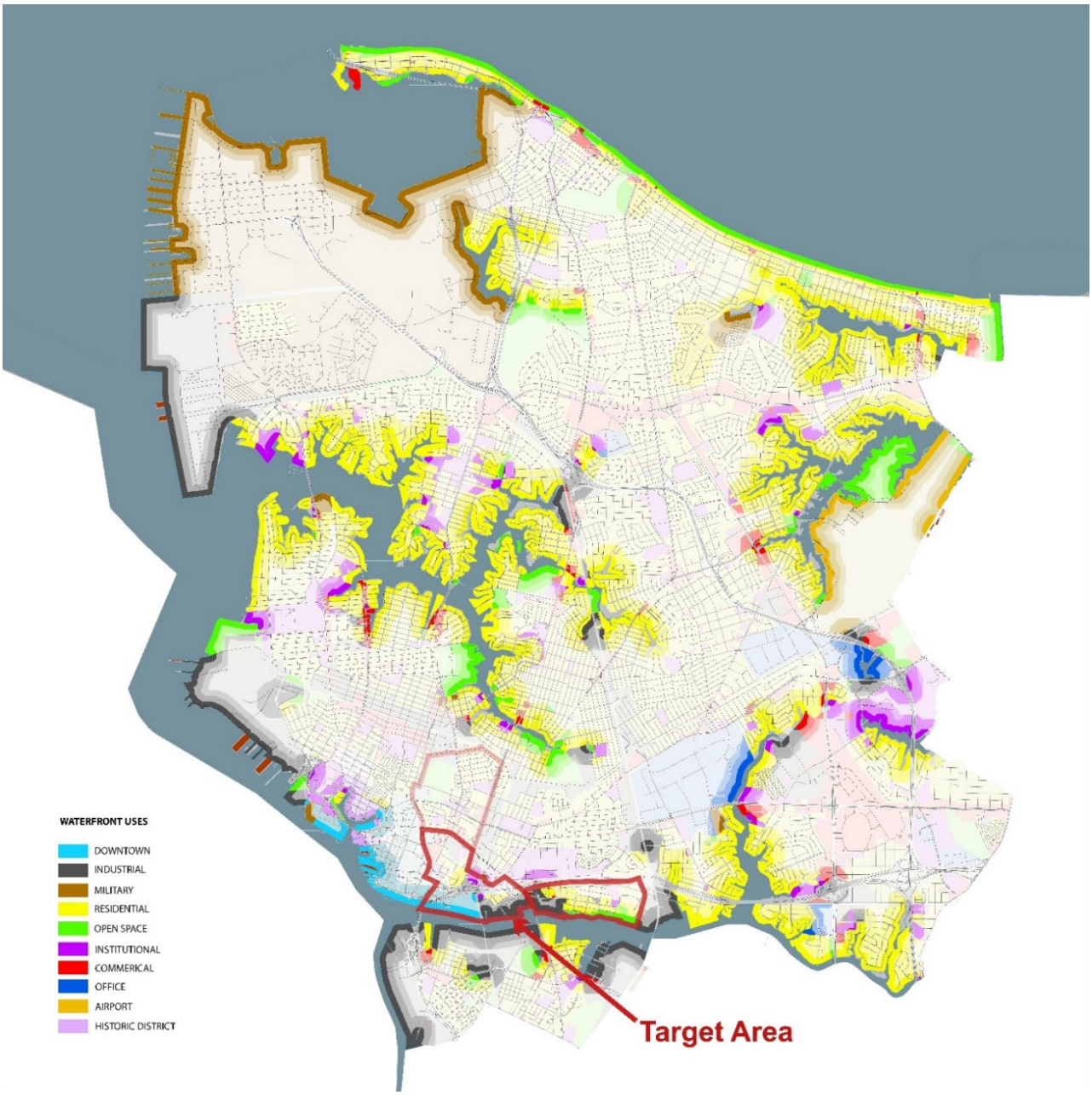

Figure III.6 Coastal Land Uses in the Target Area

MILITARY

OPEN SPACE

DOWNTOWN

RESIDENTIAL

OFFICE

HISTORIC DISTRICT

INDUSTRIAL

AIRPORT

Public, Cultural, and Natural Resources

Cultural Resources and Critical Assets

The historic character of Norfolk is exemplified in its vibrant downtown which is home to roadways lined with historic commercial and industrial buildings, the Attucks Theatre, numerous historic and culturally significant churches, and the local historic district of East Freemason.[27] In fact, the neighborhoods surrounding downtown Norfolk include four of the city's five historic districts.[28] The Chesterfield Heights neighborhood was added to the National Historic Register in 2003, and has 404 buildings contributing to its status as a National Historic District. The protection of historical and cultural resources from the force of nature will ensure a resilient tourism industry contributing to the resiliency of the overall economy. Figure III.7 below identifies the landmarks and cultural assets of the Target Area.

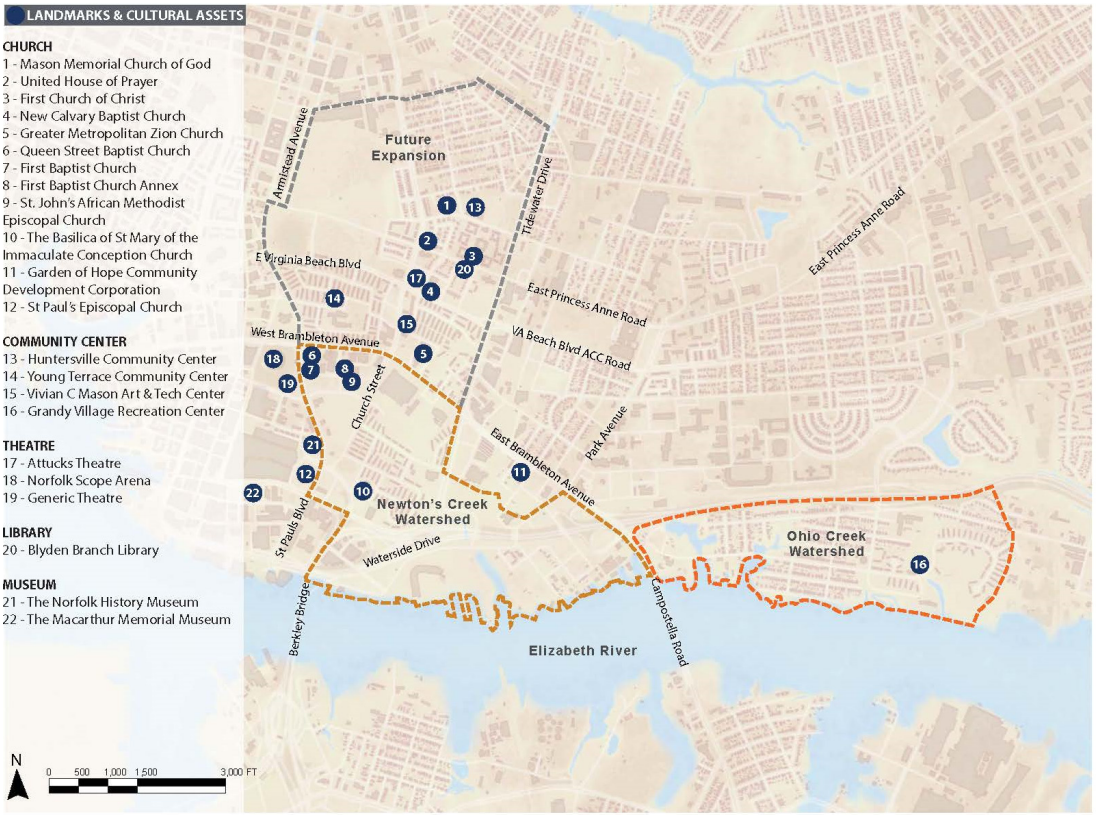

Figure III.7 Landmarks and Cultural Assets in the Target Area

Parks

The City of Norfolk Parks system includes 2 festival parks, 3 beach parks, 6 community parks, 12 dog parks, 17 community centers with active park amenities, and 71 neighborhood parks. The community parks are 10 acres in size or larger, and support larger events and athletic activities. Park programming draws from a larger geographical area and on-site parking is available. Neighborhood parks are usually 10 acres or less and provide some type of recreational component or a green area. Primary park users are from within nearby neighborhoods.[29]

Harbor Park is the only park located within the Target Area and is a baseball stadium for the Norfolk Tides, a minor league team. The park is located along the shore of the Elizabeth River. As noted above, this park is not easily accessible by walking. Figure III.8 identifies the locations of parks and recreation centers in the Target Area.

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[27] *PlaNorfolk 2030. The General Plan of the City of Norfolk. June 2015. pp 11-2*
[28] *Norfolk Baseline Economic Study Report, July 2015*
[29] *http://www.norfolk.gov/rpos/parks.asp*

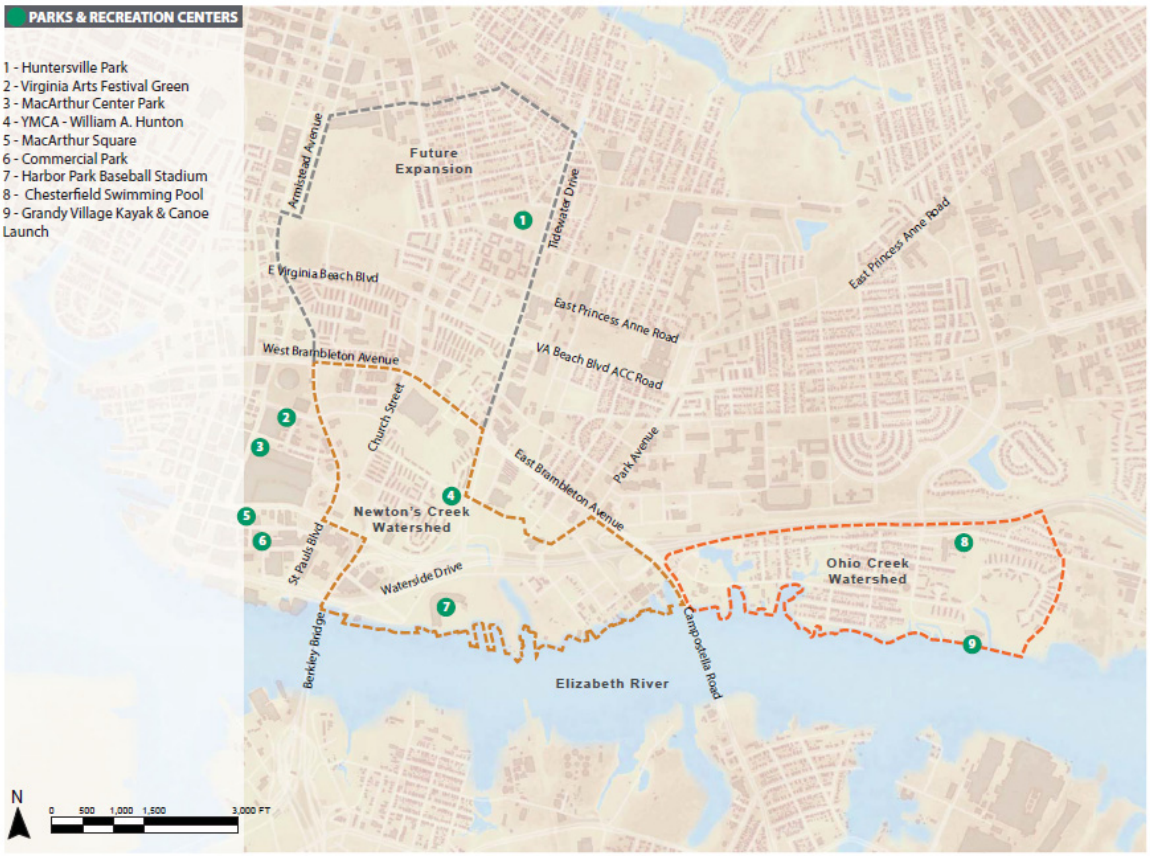


Figure III.8 Parks and Recreation Centers in the Target Area

Transportation

Mass transportation in the city includes “the Tide” Light Rail system, buses, ferries, and paratransit services. “The Tide” Light Rail opened in August of 2011 and runs through the Target Area parallel to I-264, with a stop in Harbor Park and a terminal downtown. Tide is the only rail transit in the region and carries over 120,000 passengers monthly.[30]

Government

Figure III.9 identifies the locations of government buildings within the Target Area.[31] Figure III.10 illustrates the distribution of emergency services in the same area.

[30] *Hampton Roads Transit, Ridership trends, July 2015. http://gohrt.com/public-records/Operations-Documents/Ridership/2015/July-2015-Presentation-Ridership.pdf*
[31] *Regional Background for Norfolk NDRC Grant Application Input*

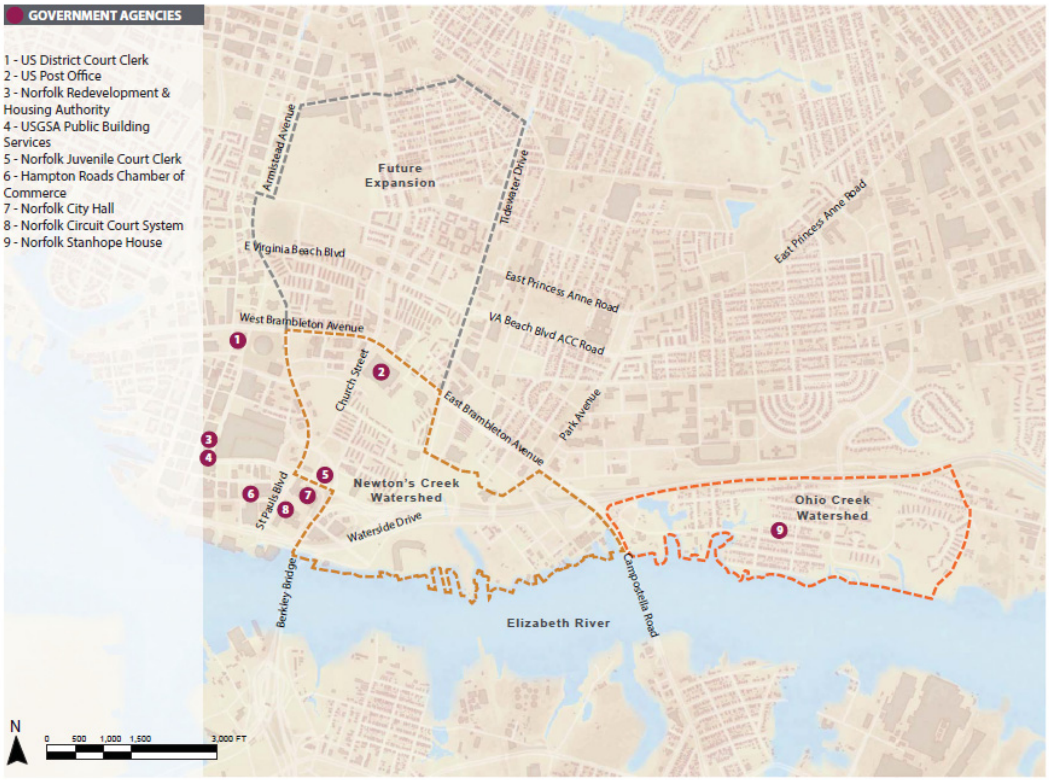


Figure III.9 Government Buildings Located within the Target Area

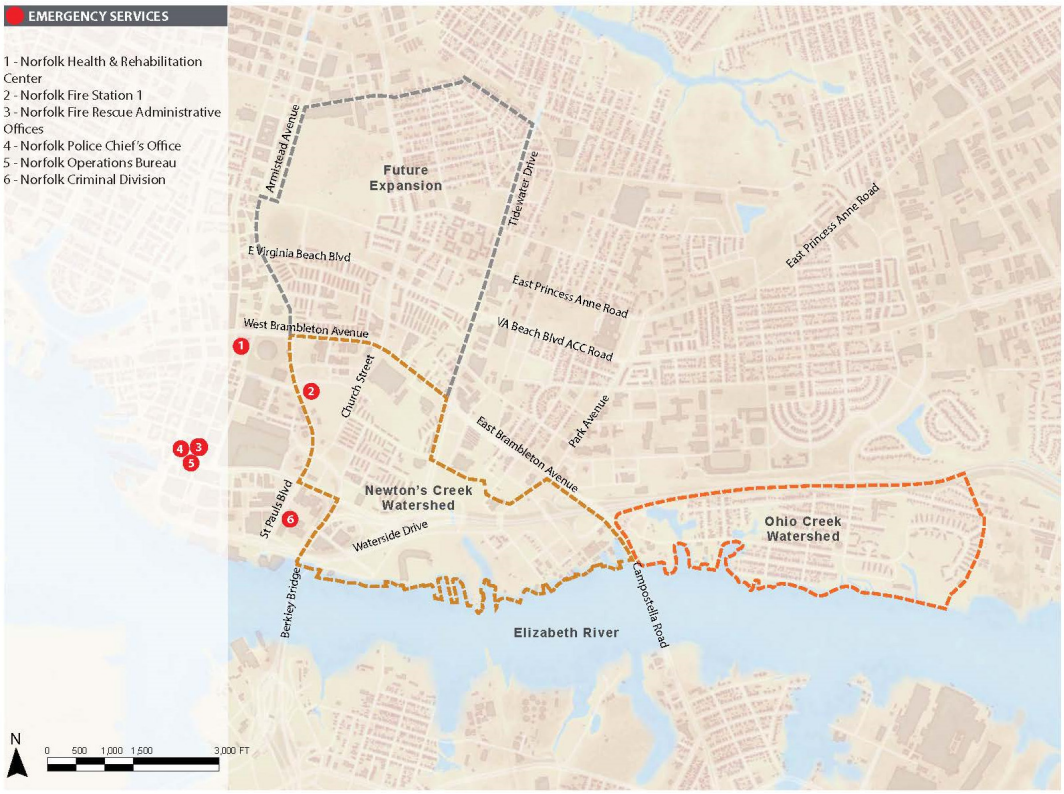


Figure III.10 Emergency Services within the Target Area

Growth Trends

Growth Trends

Economy and Employment

The majority of jobs in Norfolk are in service industry (including healthcare), federal civilian, and military employment sectors.[32] PlaNorfolk 2030 looks to drive economic development and create new capabilities, new companies, and new businesses in clusters including Maritime and Transportation Business, Technology Business, Retail and Commercial Business, and Finance and Business Services. "Most of these industries (will) play a major role in Norfolk's development, especially Maritime and Transportation, while others, such as Technology Business Cluster, will assist Norfolk in the future."

The military is a large force in Norfolk's economy. Naval Station Norfolk, the largest naval complex in the world, supports the readiness of the United States' Atlantic fleet. The military provides direct employment to over 44,000 people in the City of Norfolk[33], and these jobs pay 30% more than average wages in the region.[34] The Navy's large presence anchors a significant maritime and defense industry cluster, which includes ancillary industries such as shipbuilding. HRPDC estimates that military contracts in the region support 55,000 direct and 49,000 indirect and induced jobs.[35] The Port of Virginia is another significant economic asset, handling 11% of East Coast foreign trade by value. The port drives ancillary industry growth, notably in transportation, shipbuilding, and freight. Many Multi-national maritime companies maintain North American headquarters in Norfolk.[36] However, even with such a high presence of military activity, Norfolk has experienced consistent job losses since 2004, losing 22,666 jobs between 2001 and 2014, of which 60% were government jobs.[37]

[32] *PlaNorfolk 2030. The General Plan of the City of Norfolk. June 2015. pp. 5-2*
[33] *Hampton Roads Planning District Commission, Economic Impact of the Department of Defense in Hampton Roads, 2013, pp. 33*
[34] *Norfolk Baseline Economic Study Report, July 2015, pp. 27*
[35] *Ibid.*
[36] *Ibid, pp. 28*
[37] *Ibid, pp. 38*

Current Risk Context

Risk Associated with Stormwater Management

Stormwater Management Risk

Norfolk is an older colonial city with some original historical infrastructure dating back to the 1800s. Infrastructure improvements were most recently performed in the 1950's due to rapid urbanization. That upgraded infrastructure is currently approaching the end of its serviceable life and is due for upgrades. Early stormwater system designs did not consider future development or tidal impacts.

The existing municipal stormwater system is separate from the sewer system and is managed by the Norfolk Public Works Stormwater Division. The portions of the system designed before the 1950s was sized to accommodate a 2-year storm. The newer portions were designed to accommodate a 10-year storm event. Stormwater in Harbor Park is managed by an underground collection and conveyance pipe network that discharges storm water directly in the Elizabeth River or to a series of concrete lined ditch system under the elevated section of Interstate 264. The concrete lined ditches discharge to a waterway near the Norfolk Southern railroad tracks.

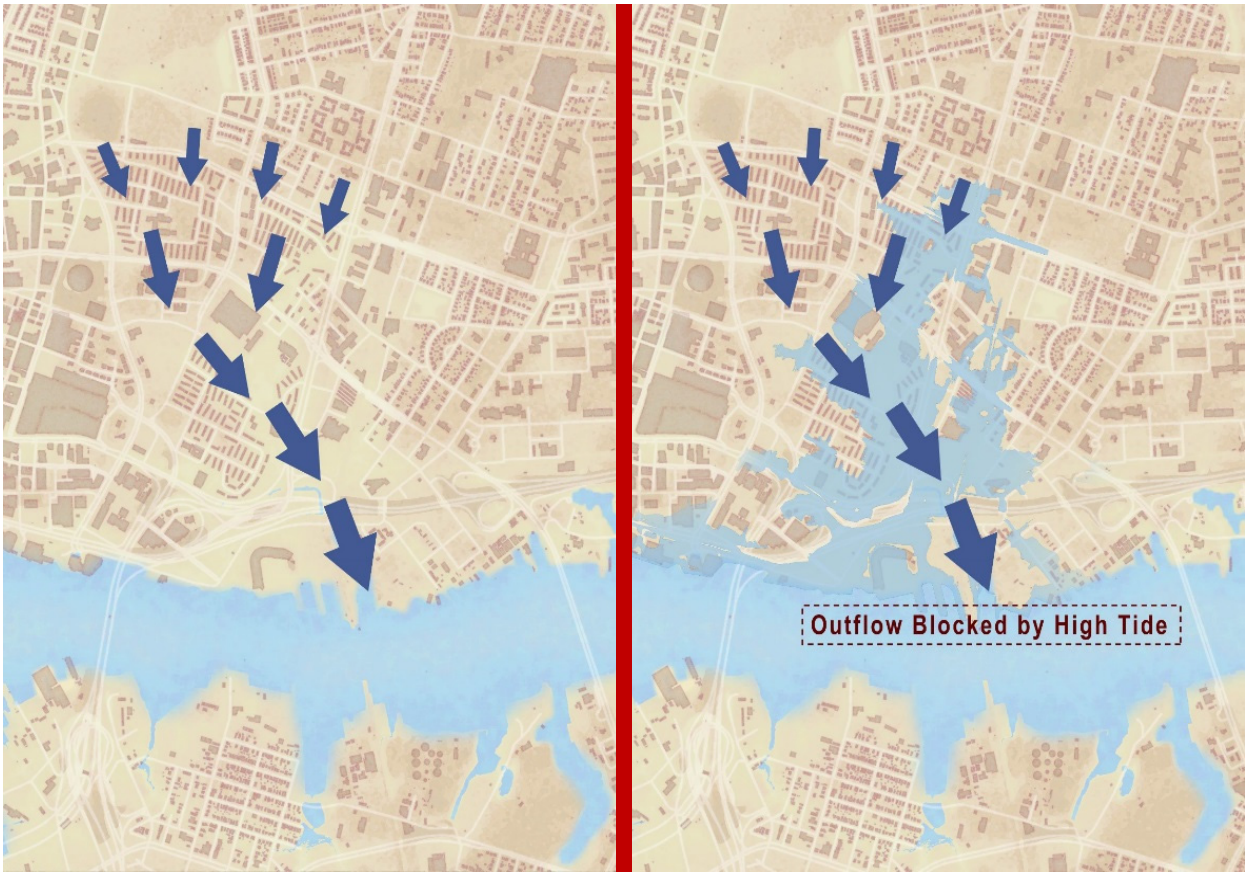


Figure III.11 Schematic Comparison of Stormwater Flows and Potential Flooding in the St. Paul's Area and Harbor Park during Regular and High Tide Scenarios

None of the system was designed to handle the additional backwater flows caused by storm surges or high tide, which may occur concurrently.[38] Figure *III.*11 above demonstrates current normal flows in the Newton's Creek Watershed and the flooding issues that can occur at high tide when flows are blocked.

With recent increases in flooding incidents, projected sea-level rise, the continuation of land subsidence due to fill settlement, elevation below 15 feet, undersized underground stormwater system, and the prevalence of impervious surfaces, the flooding situation is only expected to worsen in the future.

[38] *Briefing Book Tidewater District. pp. 22.*

Coastal Flood Risk

Coastal Flood Risk

With about 144 miles of shoreline and almost completely surrounded by bodies of water (including bays, rivers, and tidal creeks), the city is at greater risk for coastal flooding than other parts of Virginia.[39] The Hampton Roads metropolitan region, and the Target Area of the City of Norfolk in particular, are at risk of inundation from coastal storms, a risk that is being exacerbated by sea-level rise (SLR). The Hampton Roads area of the Virginia coast is experiencing SLR at a much faster rate than the global average due to local land subsidence, glacial rebound, and ocean circulation dynamics.[40] SLR is occurring at nearly twice the global rate, and there is evidence that this rise is actually accelerating. Intermediate projections from the United States Army Corps of Engineers and National Oceanic and Atmospheric Administration (NOAA) are at around 2.5 feet for the area by 2065 (see Figure III.3).[41] Already within the City of Norfolk, the historic waterfront neighborhood of The Hague (just northwest of the Target Area) experiences street flooding during high tide, a phenomenon that used to occur only during storm surge events. The area now experiences over 100 hours of street flooding per year, as opposed to less than 50 hours per year between 1930 and 1990.[42] The neighborhoods in the Target Area are built on low-lying coastal land and in some areas filled wetlands, and are vulnerable to coastal flooding from rising sea-levels as well as coastal storm surge.

The majority of the St. Paul's Area (Newton's Creek Watershed) is within the 100 year floodplain (AE Elevation 7.6 flood zone). The current development in this area was built on the former creek with the flood risk areas reflecting the old creek area. A large portion of Tidewater Drive drains to this area, causing existing stormwater systems to back up and making it unable to handle the load of an abnormal rain event. This causes significant flooding on Tidewater Drive and within the Tidewater Gardens public housing, with the entrance to Downtown from Tidewater Drive having at least one lane flooded during these events. Upgrades to the existing stormwater system have been made but are unable to fully address this problem.[43]

Figure III.12 Target Area Inundation with 2.5 feet of SLR

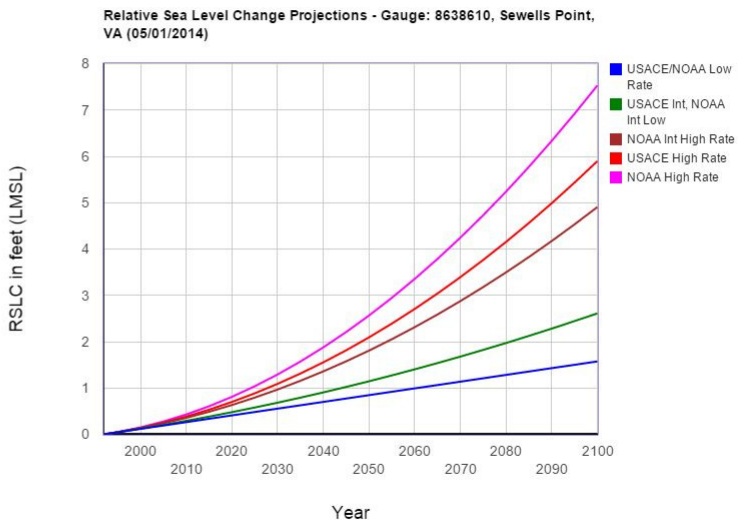
[39] *Phase 1 – Attachments-ATT401237-ExhibitDNeed.pdf (pg. 26 of Phase 1 Application)*
[40] *Atkinson et al, Sea level Rise and Flooding Risk in Virginia, Sea Grant Law and Policy Journal, Vol. 5 No. 2. pp. 6, 2013*
[41] *USACE and NOAA curves obtained from http://www.corpsclimate.us/ccaceslcurves.cfm.*
[42] *Atkinson et al, Sea level Rise and Flooding Risk in Virginia, Sea Grant Law and Policy Journal, Vol. 5 No. 2., 2013*
[43] *Saint Paul's Area Plan, pp. 29*

8638610, Sewells Point, VA
NOAA's Published Rate: 0.01457 feet/yr
All values are expressed in feet relative to LMSL

Year	USACE Low NOAA Low	USACE Int NOAA Int Low	NOAA Int High	USACE High	NOAA High
1992	0.00	0.00	0.00	0.00	0.00
1995	0.04	0.05	0.05	0.05	0.05
2000	0.12	0.12	0.14	0.14	0.15
2005	0.19	0.20	0.24	0.25	0.28
2010	0.26	0.29	0.36	0.38	0.43
2015	0.34	0.38	0.49	0.53	0.61
2020	0.41	0.48	0.63	0.70	0.81
2025	0.48	0.58	0.79	0.88	1.04
2030	0.55	0.68	0.97	1.09	1.29
2035	0.63	0.79	1.16	1.31	1.57
2040	0.70	0.90	1.36	1.55	1.88
2045	0.77	1.02	1.58	1.81	2.21
2050	0.85	1.14	1.81	2.09	2.56
2055	0.92	1.27	2.05	2.39	2.95
2060	0.99	1.40	2.31	2.71	3.35
2065	1.06	1.54	2.59	3.04	3.79
2070	1.14	1.68	2.88	3.39	4.24
2075	1.21	1.82	3.18	3.76	4.73
2080	1.28	1.97	3.50	4.15	5.24
2085	1.36	2.12	3.83	4.56	5.77
2090	1.43	2.28	4.17	4.99	6.33
2095	1.50	2.44	4.53	5.43	6.92
2100	1.57	2.61	4.91	5.90	7.53

Print Table

8638610, Sewells Point, VA
NOAA's Published Rate: 0.01457 feet/yr



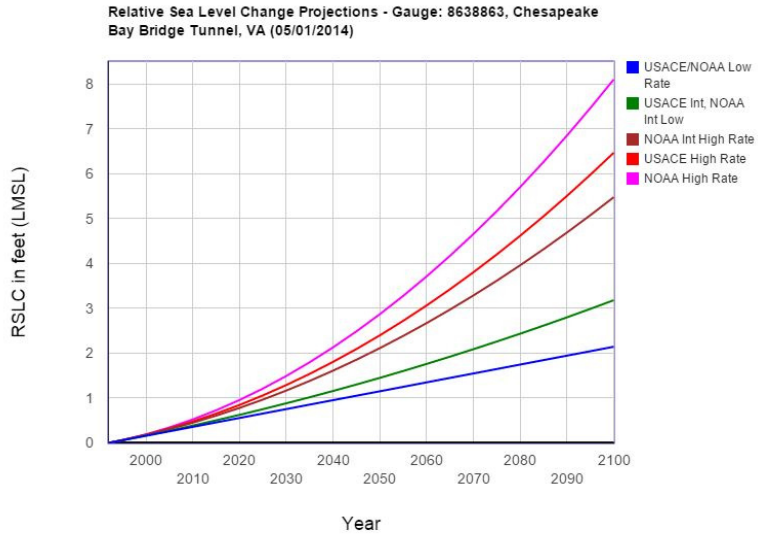
Print Curves

8638863, Chesapeake Bay Bridge Tunnel, VA
NOAA's Published Rate: 0.01985 feet/yr
All values are expressed in feet relative to LMSL

Year	USACE Low NOAA Low	USACE Int NOAA Int Low	NOAA Int High	USACE High	NOAA High
1992	0.00	0.00	0.00	0.00	0.00
1995	0.06	0.06	0.06	0.06	0.06
2000	0.16	0.16	0.18	0.18	0.19
2005	0.26	0.27	0.31	0.32	0.34
2010	0.36	0.39	0.45	0.48	0.52
2015	0.46	0.50	0.61	0.65	0.73
2020	0.56	0.63	0.78	0.85	0.96
2025	0.66	0.75	0.97	1.06	1.21
2030	0.75	0.88	1.17	1.29	1.49
2035	0.85	1.02	1.38	1.54	1.80
2040	0.95	1.16	1.61	1.81	2.13
2045	1.05	1.30	1.86	2.09	2.49
2050	1.15	1.45	2.11	2.40	2.87
2055	1.25	1.60	2.38	2.72	3.28
2060	1.35	1.76	2.67	3.06	3.71
2065	1.45	1.92	2.97	3.43	4.17
2070	1.55	2.09	3.29	3.80	4.66
2075	1.65	2.26	3.62	4.20	5.17
2080	1.75	2.44	3.96	4.62	5.70
2085	1.85	2.62	4.32	5.05	6.26
2090	1.95	2.80	4.69	5.51	6.85
2095	2.04	2.99	5.08	5.98	7.46
2100	2.14	3.18	5.48	6.47	8.10

Print Table

8638863, Chesapeake Bay Bridge Tunnel, VA
NOAA's Published Rate: 0.01985 feet/yr



Print Curves

Figure III.13 Sea Level Rise Predictions from USACE and NOAA Nearest Target Area, Sewell's Point and Chesapeake Bay Bridge Tunnel

Lack of Neighborhood Connectivity

Lack of Neighborhood Connectivity

In addition to flood risk reduction, a key issue to be addressed by the proposed activities is to improve mobility and connectivity of the targeted waterfront neighborhoods, which have suffered decades of urban renewal and disinvestment and are physically disconnected from the surrouding city by highways and vacant land.

Figure III.6 Norfolk Target Area in 1950 and Today (note the images are at different altitudes) below shows two aerial images of downtown Norfolk (in the background) and the St. Paul's Area (in the foreground). The image on the left was taken in 1950, and the image on the right is from today. The historic Saint Mary's Church is used as a reference point in both images. Note particularly the extent of urban clearance that has taken place over time for the construction of Interstate 264, the Harbor Park stadium and parking areas, and the Tidewater Gardens public housing development, in the lower left.

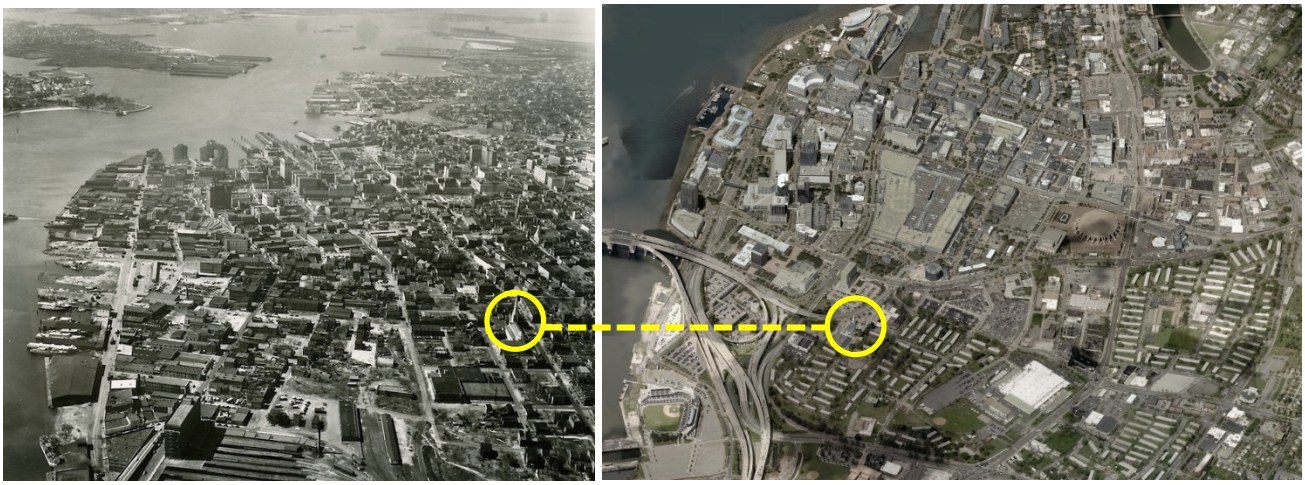


Figure III.6 Norfolk Target Area in 1950 and Today (note the images are at different altitudes)

The neighborhood of St. Paul's Quadrant, including the public housing developments of Tidewater Gardens, Calvert Square, and Young Terrace, is cut off physically and psychologically from downtown and the waterfront. Figure III.75 below shows many of the key spatial discontinuities in the Target Area: areas are separated by highways, with few cross-connections, and there are large amounts of low-performing open space, mostly parking lots, large grassy areas and vacant land, notably along the waterfront.

Figure III.75 I-264 and the Berkley Bridge near Harbor Park and Tidewater Gardens

Similarly, the neighborhood of Chesterfield Heights, in the Ohio Creek Watershed, is entirely cut off from the rest of Norfolk by I-264.

Figure III.86 Chesterfield Heights

From the "**St. Paul's Area Plan**" published by the City in 2012, we find this description of the problem in the Newton's Creek Watershed Target Area (pages 7- 14):

"The current character of St. Paul's is defined by an auto-oriented access pattern created by the urban renewal efforts in the 1940s, 1950s and 1960s. Those efforts promoted a new development and access pattern to replace the blighted buildings and network of streets and blocks that had developed prior to World War II. The new public housing in and around St. Paul's filled an important need for affordable family housing after the war, and the widened streets and new highway connections along and across the Elizabeth River dramatically improved regional access by car."

"Today, many of the aspects originally seen as improvements register as major obstacles, making St. Paul's isolated and unattractive for new private-sector investment. Issues created by current development patterns include:

Challenge 1: Current development patterns block St. Paul's potential community and economic value.

"Key land uses, including housing, offices and shopping, are separated from each other on large "superblocks." This physical isolation of land uses severely limits the interrelationships among activities that are a uniquely valuable advantage of urban settings. Lack of connection limits choice among different types of housing, jobs, transportation, retail and other services."

"The superblock layout of Tidewater Gardens undermines its intent as a residential neighborhood. As in many public housing developments of its day, design of the site and buildings compromises a sense of address, feelings of safety, and the ability of residents to make use of outdoor spaces. The front doors of most units face an internal walking path, not a street. These internal paths lack visibility from traffic and buildings, as well as the critical mass of pedestrians that creates the perception of safety. Open areas between buildings lack

definition between private and shared areas, and thus generate little sense of ownership or stewardship on the part of residents, which in turn means these areas get less use and maintenance than they might."

"St. Paul's auto-oriented development pattern leaves it a generic place with little defining quality, in the same way that many suburban development locations lack definition. It lacks the uniqueness and amenities needed to create a more focused market position, key to attracting higher-value urban commercial and housing demand. Businesses in St. Paul's tend to lack an inherent connection to Downtown. Reliance on surface parking. Development with greater economic and community value would come only with higher densities, mixed-uses, improved walkability and transit access that together free up current parking lots to be replaced with buildings and parks."

Challenge 2: Physical separation from the surrounding area creates both real and perceived barriers

"Broad arterial roads on three sides (St. Paul's Boulevard, Brambleton Avenue and Tidewater Drive) and elevated highways on the remaining side (I-264 and Berkley Bridge ramps) physically isolate St. Paul's. Tidewater Gardens residents cited this band of high-traffic roads among the top five most disliked physical characteristics in a 2006 resident survey. The heavy traffic – much of it funneled toward Interstate and bridge access – and its associated noise, pollution, hazard to children, and interruption of convenient walking routes—significantly compromises resident quality of life."

"These same roads surrounding St. Paul's offer a poor walking environment because they were designed for vehicles, not people. Crosswalks can be very long where multiple turn lanes occur, and this coupled with short signal durations and heavy traffic makes it hard for even able-bodied people to cross the street in the time provided."

"The lack of a traditional street grid within and around St. Paul's is unwelcoming, disorienting, and provides a poor setting for development. "Superblocks" in St. Paul's (especially the U.S. Postal Service distribution facility and portions of Tidewater Gardens) make St. Paul's difficult to access… and … there are missing elements in St. Paul's internal street network. Many streets lack street trees and sidewalks."

"The poor walking environment, both within and surrounding St. Paul's, limits pedestrian access to current and future transit options. Access to transit depends on reasonable walking conditions between transit stops and destinations – conditions generally not present today. One critically needed pedestrian improvement connection is between Tidewater Park Elementary School and the rest of St. Paul's. The walking path linking the school with Charlotte Street and most of Tidewater Gardens has poor visibility from streets and buildings, and is susceptible to flooding."

Challenge 3: Lack of economic diversity

"Income segregation further isolates St. Paul's. The 618-unit Tidewater Gardens public housing development is the only housing in St. Paul's. All residents have incomes at or below 40% of Area Median Income. Added to the approximately 1,000 public housing units nearby at the Young Terrace and Calvert Square public housing developments, this marks St. Paul's as a place of poverty."

Other challenges to the St. Paul's Quadrant (similar throughout the Tidewater Drive Target Area) include:

Challenge 4. The physical condition and layout of the Tidewater Gardens public housing community calls for its replacement (This facility is over 60 years old and lacks modern-day amenities and appropriate parking for residents.)

Challenge 5. Stormwater flooding is a chronic threat to safety and property. The neighborhood suffers chronic stormwater flooding problems.

Challenge 6. Real and perceived crime acts as a deterrent to potential investment. Current Tidewater Gardens residents cited crime as a major issue in the St. Paul's area.

Challenge 7. Lack of neighborhood-serving retail. The predominant retail in the St. Paul's area is fast-food.

Challenge 8. Lack of recreation accessible to all segments of the community.

Challenge 9. High unemployment and lack of job skills of current Tidewater Gardens residents.

Challenge 10. Lack of adequate, suitably located parking to serve the needs of the current development in St. Paul's

Affordable Housing Need

Affordable Housing Need

Housing prices in the Hampton Roads region have been growing faster than state and national averages since approximately 2005, with above-average growth throughout the recession and recovery. This can be attributed in part to a strong employment base in the military assets in the region, as well as innovation in the public and private sectors, including health care and local government.

But the supply of new affordable housing has not kept pace with demand; as of the development of the 2012-2016 HUD Consolidated Plan, waitlists for public housing totaled over 1,800 families, while the waitlist for housing assistance vouchers reached over 8,300.[44] Housing production has shifted towards multi-family, mixed-use, and otherwise higher density housing in recent decades as noted in the Briefing Book prepared for the City's 2015 Dutch Dialogues event: "Between 1992 and 2011, 42.1% of the building permits were for single-family detached units, far less than current composition of the housing stock (79.2% low density). This shift away from single-family detached housing illustrates Norfolk's increasing market strength in the area of urban living, which is unique in the region and may represent a shift away from the suburbanization that the region has experienced over the past several decades."[45]

The existing housing stock that is affordable is also at risk. PlaNorfolk 2030 notes that, "Deterioration of older housing is a direct threat to the stability of many of Norfolk's low income neighborhoods… exacerbated by absentee landlords and limited financial resources available to residents for maintenance and repairs."[46] Recurrent flooding also adds to the deterioration of these aging housing units, as poor ground saturation and intermittent flooding of structures brings a host of damages—mold, the slow disintegration of foundation components that were not constructed of flood-resistant materials, and other structural elements that may be compromised due to land subsidence or the constant presence of high water tables from sea level rise. A six-page report of the structural and infrastructure deficiencies in the Tidewater Gardens complex, for example, was presented by the Norfolk Housing Redevelopment Authority in 2010, describing additional problems such as erosion, severe drainage issues, poor soils, and accessibility challenges that are all exacerbated by the recurrent flooding.[47]

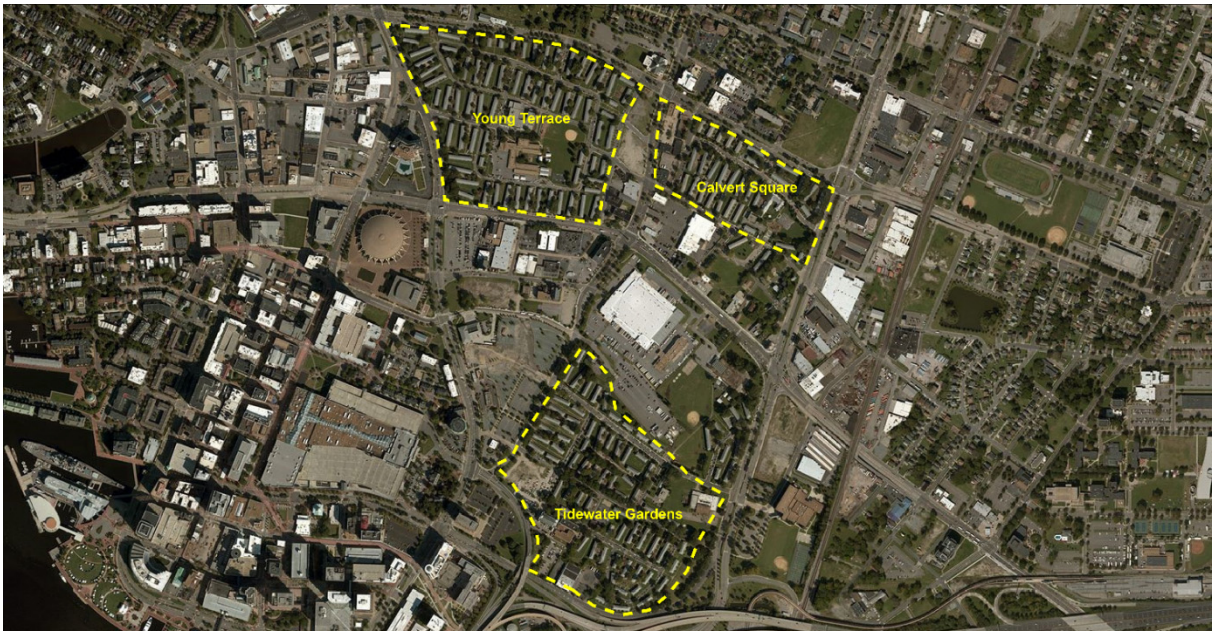


Figure III.97 Subsidized Housing in the St. Paul's Area

[44] *100 Resilient Cities Norfolk SWOT Analysis, July 2015, pp. 43*
[45] *Dutch Dialogues Briefing Book, pp. 73.*
[46] *PlaNorfolk 2030, pp. 7-1*
[47] *Letter dated November 6, 2010 from Vanasse Hangen Brustlin, Inc. to the Norfolk Housing Redevelopment Authority.*

The St. Paul's Area in the Target Area is home to three subsidized housing "super-blocks"-- a total of 1,673 public housing units in the developments of Tidewater Gardens, Young Terrace and Calvert Square. The vision of the St. Paul's Area Plan (published in 2012) was incorporated into PlaNorfolk 2030. As a way of de-concentrating poverty is this area, the City plans to create a more economically revitalized neighborhood by 1) demolishing these aging structures, some of which are more than 60 years old, in great need of repair or updating (for example, they utilize antiquated heating systems); replacing the housing with a careful blend of mixed-use, mixed income development; 3) addressing economic segregation by opening up connections to other areas of the City including the downtown; and 4) investing in resources for safe, healthy and rewarding living such as updated and green stormwater infrastructure techniques to reduce flooding on the site and in adjacent areas.

The Expanded St. Paul's Area / Tidewater Gardens Transformation Plan outlines the City's goals to redevelop the Tidewater Gardens public housing complex (within the St. Paul's Area) in this manner, and forms a portion of the proposed project. A portion of the Target Area is located in a state enterprise zone which designates areas eligible for various state and local incentives such as grants, tax and fee relief, and free professional specialists and training support.[48]

If the proposed projects are not implemented soon, the continuation of nuisance flooding and potential damages from coastal storm surge may render these housing units uninhabitable over time.

[48] *Dutch Dialogues Briefing Book, pp. 8*

Economic Risk

Economic Risk

The Hampton Roads region has a unique interdependency with the military. The region is home to the largest concentration of U.S. defense facilities in the world as well as the third largest commercial port on the east coast. Nearly a quarter of the nation's active-duty military personnel are stationed here, and a third of the U.S. naval shipbuilding and repair capacity is housed in the region. The world's largest navy base, the Norfolk Naval Station, and its companion Naval Air Station are located in the northwest quadrant of Norfolk. The Navy's Little Creek Amphibious Base is located on the Chesapeake Bay shoreline between Norfolk and Virginia Beach. Norfolk also is home to NATO's Allied Command Transformation, the only NATO headquarters on U.S. soil. The Norfolk Naval Shipyard which pre-dates the Civil War and the Portsmouth Naval Hospital are within the City of Portsmouth.[49] Figure 18 below indicates various military and critical infrastructure institutions in the Hampton Roads region.

The Federal Government currently creates about 45% of gross regional product, mostly in defense related spending and supporting activities.[50] The 100 Resilient Cities Norfolk SWOT analysis noted that this means that much of the area's economy is derived from sectors (like the military) over which there is no local control, and which provides little or no property tax revenue. The SWOT identified as potential threats the undiversified economic base, as well as lack of connections between connections between creative businesses and legacy industries, as well as untapped potential connecting skilled workers leaving the military with local businesses and entrepreneurship.[51]

The recurrence of flooding in the Target Area continues to adversely affect the area. Structures are aging and deteriorating due to flooding; due to consistent business interruptions (inaccessible streets, flooded interiors and even power outages), new commercial interests have been known to look elsewhere, and the primary type of business remaining in the area is fast food restaurants. Without the proposed project, the Target Area will continue to experience the economic stresses of recurrent flooding, and will be less resilient against shocks.

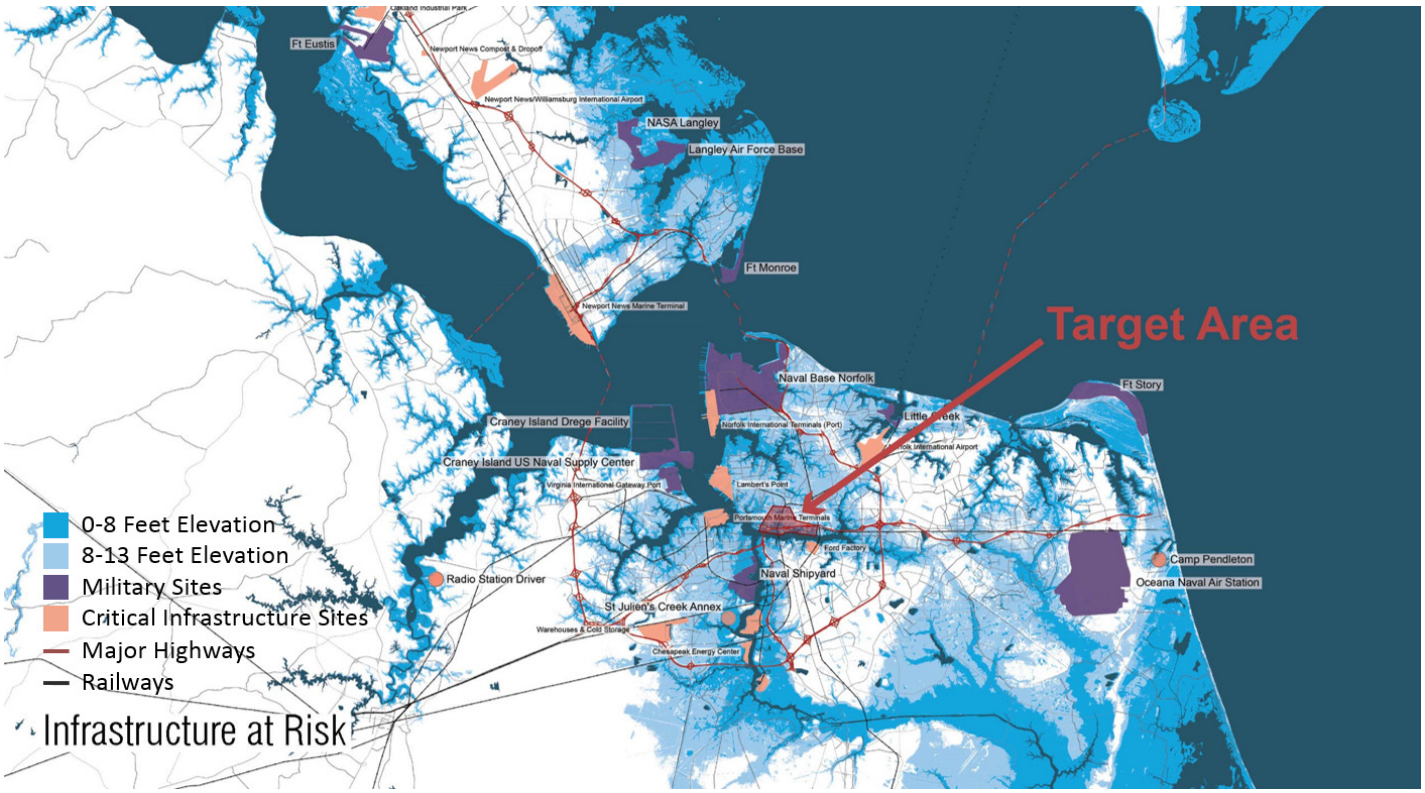


Figure III.18 Critical Economic Risks within the Hampton Roads Region

[49] *Ibid.*
[50] *Ibid. pp. 10*
[51] *100 Resilient Cities Norfolk SWOT Analysis, pp. 46.*

Environmental Risk

Environmental Risk

The Eastern Branch of the Elizabeth, which runs parallel to the Target Area and is the discharge point for both the Ohio Creek Watershed and Newton's Creek Watershed, has been called the "lost branch" by the Elizabeth River project due to its low visibility and accessibility to Hampton Roads residents.[52] The State of the Elizabeth River scorecard of 2014 gave the Eastern Branch a score of D, indicating an urgent need to address its environmental quality issues; The Eastern Branch and its tributaries suffer from high levels of bacteria, low levels of dissolved oxygen, and high levels of river bottom contaminants, important metrics of estuarine health.[53]

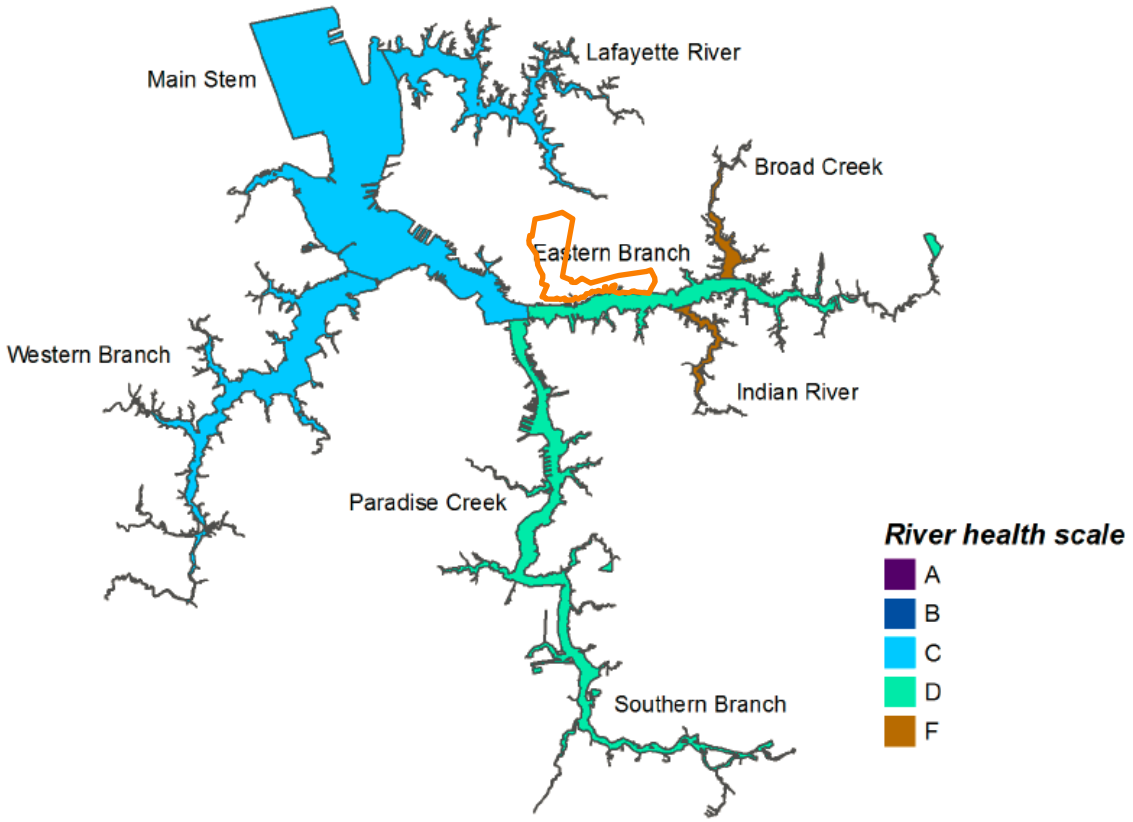


Figure III.19 Health Scores of the Elizabeth River Branches, 2014. Virginia Dept. of Environmental Quality (Target Area Watersheds Outlined In orange)

The Elizabeth River has lost 50% of its tidal wetlands since 1945.[54] Wetlands act like a sponge, soaking up stormwater and dampening storm surges. By trapping polluted runoff, wetlands help slow of the flow of nutrients, sediment and chemical contaminants into rivers, streams and the Chesapeake Bay. Hundreds of species of fish, birds, mammals and invertebrates depend on wetlands. But shoreline development and deterioration, as well as sea level rise pose major threats to these critical habitats: development along the shoreline blocks the creation of further wetland habitat and creates excess sediment; and sea level rise floods wetlands with saltwater, destroying plants faster than they can migrate to higher ground.[55]

Urbanized areas contribute significantly to stormwater runoff; urban runoff is responsible for about 15% of phosphorous, 14% of nitrogen, and 9% of sediment loads in the Chesapeake Bay.[56]

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[52] *Eastern Branch Environmental Restoration Strategy, The Elizabeth River Project, November 2014, pp. 7*
[53] *State of the Elizabeth River Scorecard, 2014. Virginia Department of Environmental Quality*
[54] *NOAA Living Shorelines Proposal, the Elizabeth River Project*
[55] *The Chesapeake Bay Program, Wetlands Overview: http://www.chesapeakebay.net/issues/issue/wetlands*
[56] *Storm Water Management and the Chesapeake Bay, 2001. Chesapeake Bay Program: http://www.chesapeakebay.net*

Recent Hurricane Impacts

Hurricane Irene Damages

The City of Norfolk was impacted by Hurricane Irene in August 2011 causing singificant damage to public assets including water/wastewater, public safety and transporation facilities as well as creating large amounts of debris. These impacts were experienced throughout Norfolk, including the Target Area as well. According to the National Weather Service (NWS), Hurricane Irene was upgraded to a Category 1 storm before making landfall with 63 MPH wind gusts measured at the Norfolk Naval Station. Further, the NWS reported a mean lower low water (MLLW) measurement of 7.54 feet at Sewell's Point with the city reporting 7.63 feet at the same location, meaning that the average height of the lowest tide recorded during landfall of the storm was 7.63 feet below the peak surge height. Damage experienced throughout Norfolk was related to high wind and storm surge.

FEMA project worksheets were developed for damaged assets throughout the city amounting to approximately $3.2 million. A significant portion of these project worksheets resulted from debris removal costs followed by emergency protective measures for water and wastewater utilities as well as police and fire services. Recovery from Hurricane Irene is on-going with many open Project Worksheets.

As part of this application, analysts also modeled the impacts of Irene and associated damages. This step was necessary to accurately characterize and estimate quantative impacts as disaster damages are recovered in a variety of ways including Public Assistance, Individual Assistance and Private Insurers. These damage information sources are not always coordinated to represent total impact. This model also estimated the cost associated with mental stress, loss of productivity and shelter needs. To run the model, analysts used an Irene inundation map provided by the City of Norfolk and overlaid this information on an inventory of all structures within the Target Area. The estimated flood depth was calculated at each impacted struture location and physical damages were estimated using US Army Corps of Engineers Depth-Damage functions. These results were then analyzed to identify building and contents damage as well as relocation and inventory and summed for the Target Area. Please refer to Direct Physical Damages Section for complete methodology.

Table III.1 Hurricane Irene Modeled Loss Results

	Estimated Irene Building Loss	Estimated Irene Contents Loss	Estimated Irene Inventory Loss	Estimated Irene Relocation Costs	Sum of Total Irene Costs
Newton's Creek Watershed	$3,764,723.55	$10,679,459.46	$1,181,968.40	$335,254.31	$15,961,405.72
Ohio Creek Watershed	$1,498,271.59	$1,730,557.85	$43,610.09	$111,887.41	$3,384,326.94
Grand Total	$5,262,995.14	$12,410,017.31	$1,225,578.49	$447,141.72	$19,345,732.66

Hurricane Isabel Damage

Hurricane Isabel impacted the City of Norfolk in September 2003 resulting in significant debris, power outages, and other damage from high winds and storm surge. Impacts from this storm were felt throughout the Hamton Roads area. Storm surge was reported on Fisherman's Island in excess of 4 feet. Approximately 200,000 cubic yards of debris were collected by the City of Norfolk following Hurricane Isabel.

PART IV BENEFITS INCLUDED IN THE BENEFIT COST RATIO

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Definitions and Acronyms

Definitions

- **Affordable housing:** Housing for which occupants pay no more than 30 percent of his or her income for gross housing cost.[1]
- **American Community Survey:** A nationwide survey designed to provide communities with a fresh look at how they are changing. It is a critical element in the Census Bureau's reengineered 2010 census plan. The ACS collects information such as age, race, income, commute time to work, home value, veteran status, and other important data from U.S. households.
- **Base Flood Elevation (BFE):** The elevation of the base flood, including wave height, relative to the North American Vertical Datum (NAVD), specified within the City of Norfolk Flood Insurance Study (FIS).
- **Casualty:** A person who is killed, wounded or injured by some event, and is usually used to describe multiple deaths and injuries due to violent incidents or disasters.
- **Census Block Group:** A geographical unit used by the U.S. Census Bureau which represents sstatistical divisions of census tracts, are generally defined to contain between 600 and 3,000 people, and are used to present data and control block numbering. A block group consists of clusters of blocks within the same census tract that have the same first digit of their four-digit census block number. It is the smallest geographical unit for which the bureau publishes sample data, i.e. data which is only collected from a fraction of all households.[2]
- **Climate Change:** A change in the statistical distribution of weather patterns when that change lasts for an extended period of time (i.e., decades to millions of years). Climate change may refer to a change in average weather conditions, or in the time variation of weather around longer-term average conditions (i.e., more or fewer extreme weather events).
- **Coastal Flooding:** Occurs when normally dry low-lying land is flooded by seawater. The extent of coastal flooding is a function of the elevation inland flood waters penetrate, which is controlled by the topography of the coastal land exposed to flooding.
- **Critical/Essential Facility:** Facilities that are needed for response activities before, during, and after a flood (e.g., hospitals, nursing homes, police stations, fire stations, and emergency operations centers); public and private utility facilities that are vital to maintaining or restoring normal services to flooded areas before, during, and after a flood; and structures or facilities that produce, use, or store highly volatile, flammable, explosive, toxic, and/or water-reactive materials.
- **Depth Damage Function:** A mathematical relationship between the depth of flood water above or below the first floor of a building and the amount of damage that can be attributed due to water.
- **Disability:** A physical or mental impairment that substantially limits one or more of the major life activities of such for an individual.
- **Displacement Time:** The time during which occupants are displaced to temporary locations while damage is repaired.[3]
- **Direct Effects:** Represents the initial impacts that occur as a result of an activity in an industry. For example, residential displacement time will have a direct effect on the real estate industry.

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[1] *http://www.huduser.org/portal/glossary/glossary_a.html*
[2] *https://www.census.gov/geo/reference/gtc/gtc_bg.html*
[3] *http://www.fema.gov/media-library-data/20130726-1736-25045-7076/bca_reference_guide.pdf*

- **Economic Loss of Function (ELOF):** The time that a facility is not capable of conducting business. In general, this is shorter than repair time because business will rent alternative space while repairs and construction are being completed.[4]
- **Employment:** All jobs that are created or lost as a result of the activity, including full-time, part time, and temporary positions.
- **Family:** All persons living in the same household who are related by birth, marriage, or adoption.
- **Family Income:** Reported income from all sources for the householder and other household members related to the householder.
- **Flood Insurance Study (FIS):** The official report provided by the Federal Emergency Management Agency (FEMA) containing the Flood Insurance Rate Maps (FIRMs), the Floodway Boundary and Floodway Map (FBFM), the water surface elevation of the base flood, and supporting technical data.
- **Geographic Information Systems (GIS):** A system designed to capture, store, manipulate, analyze, manage, and present all types of spatial or geographical data.[5]
- **Gross Margins:** A company's total sales revenue minus its costs of goods sold.
- **Housing Stock:** The number of existing housing units based on data compiled by the U.S. Census Bureau and referable to the same point or period of time.
- **IMPLAN:** A private company that provides economic impact data and modeling for assessing economic impacts of project decisions in all industry sectors.
- **Indirect Effects:** The impact of direct effects on industries that support those that are directly affected. Such as industries that provide equipment and materials for directly impacted industries.
- **Induced Effects:** The response to a direct effect that occurs through re-spending of income received by a component of value-added. In other words, the change of local spending that result from income changes as a consequence of the activity.
- **Labor Income:** The expected combined income of employment in each industry sector generated by project implementation expenditures.
- **Level of Protection:** The recurrence interval to which the proposed project offers protection.[6]
- **Light Detection and Ranging (LiDAR):** A remote sensing method that uses light in the form of a pulsed laser to measure ranges to the earth. These light pulses, used with other data, generates information about the Earth's surface characteristics.
- **Losses Avoided:** Losses that would occur if the project was not implemented.
- **Low-to-Moderate Income:** Moderate income is "generally defined' as cash-income of 140% of the area median income, with low income being 80% of the median.[7]
- **Normalize:** Normalization refers to the process of converting figures of different origins, in this case the different dollar amounts from different years, into a value that can be recognized and interpreted consistently.

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[4] *HAZUS-MH Earthquake Technical Manual. Page 15-18.*
[5] *http://www.esri.com/what-is-gis*
[6] *http://www.fema.gov/media-library-data/20130726-1736-25045-7076/bca_reference_guide.pdf*
[7] *http://portal.hud.gov/hudportal/HUD?src=/program_offices/comm_planning/communitydevelopment/rulesandregs/memoranda/lmidef84*

- **North American Industry Classification System (NAICS):** The North American Industry Classification System (NAICS) is the standard used by Federal statistical agencies in classifying business establishments for the purpose of collecting, analyzing, and publishing statistical data related to the U.S. business economy.
- **Occupancy Class:** HAZUS uses occupancy classes to categorize structures based on their construction type and building use.
- **Output:** Value of industry production. In IMPLAN these are annual production estimates for the year of the data set (2013) and are in producer prices. For manufacturers this would be sales plus/minus change in inventory. For service sectors production this equals sales. For retail and wholesale trade, output is the gross margin.
- **Project Useful Life:** The estimated amount of time the project will be effective.
- **Recurrence Interval[8]:** The average or mean time in years between an expected occurrence of an event of specified intensity.
- **Relocation Expenses:** Disruption costs that include the cost of shifting and transferring, and the rental of temporary space.[9] Relocation expenses are assumed to be incurred once the building reaches a damage state 'slight' in the earthquake model. Below that threshold, it is unlikely that occupants will need to relocate.
- **Restoration Time:** Time for physical restoration of the damage to the building, as well as time for clean-up, time required for inspections, permits and the approval process, as well as delays due to contractor availability.[10]
- **Sea level rise:** The increase in mean sea level, or the average level of the ocean's surface, due to the loss of land based ice and thermal expansion caused by the warming of the oceans.
- **Social Vulnerability Index (SoVI):** An index based on a number of factors contained within county-level socioeconomic and demographic data used to determine social vulnerability to environmental hazards.[11]
- **Storm Surge:** The rising of the sea as a result of atmospheric pressure changes and wind associated with a storm.
- **Target Area:** The census block groups that make up the project area which includes the 100 year floodplain and 2.5 feet of sea level rise.
- **Urban Heat Island:** Describes the phenomenon where urban air and surface temperatures are higher than nearby rural areas.
- **Value Added:** Consists of compensation of employees, taxes on the production of goods and services and imports on less subsidies, and gross operating surplus.
- **Watershed:** An area or ridge of land that separates waters flowing to different rivers, basins, or seas.
- **Willingness to Pay:** The maximum amount an individual is willing to sacrifice to procure a good or avoid something undesirable.

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[8] *http://www.fema.gov/media-library-data/20130726-1736-25045-7076/bca_reference_guide.pdf*
[9] *HAZUS-MH Flood Technical Manual. Page 14-22.*
[10] *HAZUS-MH Flood Technical Manual. Page 14-25.*
[11] *http://webra.cas.sc.edu/hvri/products/sovifaq.aspx*

Acronyms

- **°F:** degrees Fahrenheit
- **ACS:** American Community Survey
- **ARC:** American Red Cross
- **BCA:** Benefit Cost Analysis
- **BCR:** Benefit Cost Ratio
- **BLS:** Bureau of Labor Statistics
- **BRV:** Building Replacement Value
- **CDC:** Centers for Disease Control
- **CPI:** Consumer Price Index
- **CRV:** Contents Replacement Value
- **CSRV:** Contents-to-Structure Ratio Value
- **DDF:** Depth-Damage Function
- **DEM:** Digital Elevation Model
- **DOHMH:** Department of Health and Mental Hygiene
- **ELOF:** Economic Loss of Function
- **EPA:** U.S. Environmental Protection Agency
- **EU:** European Union
- **FAA:** Federal Aviation Administration
- **FEMA:** Federal Emergency Management Agency
- **FIMA:** Federal Insurance and Mitigation Administration
- **FFE:** First Floor Elevation
- **GIS:** Geographic Information System
- **GPIN:** Geographical Parcel Identification Number
- **ISRV:** Inventory-to-Structure Ratio
- **LiDAR:** Light Detection and Ranging
- **LMI:** Low- to Moderate-Income
- **MEP:** Mechanical/Engineering/Plumbing
- **NAVD88:** North American Vertical Datum of 1988
- **NDRC:** National Disaster Resiliency Competition

- **NFPA:** National Fire Protection Association
- **NOAA:** National Oceanic and Atmospheric Administration
- **NREL:** National Renewable Energy Laboratory
- **NRHA:** Norfolk Redevelopment and Housing Authority
- **PFIRM:** Preliminary Flood Insurance Map
- **PTSD:** Post-Traumatic Stress Disorder
- **SAM:** Social Accounting Matrix
- **SAMHSA:** Substance Abuse and Mental Health Services Administration
- **SF:** Square Feet
- **SLR:** Sea Level Rise
- **STEP:** Sheltering and Temporary Essential Power
- **TAMI:** Technology, Advertising, Media, and Information
- **TM:** Technical Manual
- **TSA:** Temporary Sheltering
- **UHI:** Urban Heat Island
- **USACE:** U.S. Army Corps of Engineers
- **VOE:** Value of Enjoyment
- **WTP:** Willingness to Pay

Introduction

Introduction

The methodologies included in Attachment F are intended to provide sufficient detail to the reader to understand the research and processes developed to arrive at the identified benefit cost ratios (BCAs) that represent the analysis results. Each of the Target Area projects identified within the application will not only provide those populations directly impacted a significant amount of benefits but also those indirectly impacted. In other words, these projects will carry benefits far beyond the immediate Target Areas into the community, region, and even the state as a whole. In order to gain an understanding of the various projects being instituted and the numerous geographies being impacted, the Norfolk Key Intervention Sites Infographic found in the Overview will help to visualize the scope and scale of the projects. An additional BCA Results Infographic also found within the Overview helps to provide a quick understanding of the benefits derived from each of the projects, as well as a brief snapshot of the calculations developed throughout Attachment F.

The methodologies have been broken down into a series of compartments based upon the benefits being realized. The first section focuses on the direct physical structural damages including impacts to critical facilities during the design storm event. The second section discusses the benefits derived from avoiding human impacts such as displacement, relocation costs, mental health and anxiety, shelter needs, and even casualties. The section immediately following will look at calculated environmental benefits discussing the added value of provisioning services, regulating services, supporting services, and cultural services. Fourth, Attachment F will focus on social benefits derived from the Target Areas project implementation including recreation, aesthetic, and general health benefits. The Methodologies section will also focus heavily on identified economic benefits including added economic output and employment compensation. Table IV.1 displays an overview of the benefits calculated and included into each of the Target Area's benefit cost ratio. Although there are a significant amount of quantitative benefits, there are also numerous qualitative benefits as well including reduction in Urban Heat Island (UHI) affect, direct benefits to and from affordable housing to the local economy, the economic and social benefits associated with maintaining historic structures and the Chesterfield Heights historic district, benefits associated with stormwater management due to project installation, and others.

It is important to note that although the proposed projects are not considered final, the circumstances surrounding the Natural Disaster Resilience Competition (NDRC) require that each Target Area and the projects contained within be evaluated for cost-effectiveness. Therefore, the benefits established above operate under the assumption that each project has been finalized. The applicant recognizes that as project design continues to move forward, benefits and costs are liable to change.

Table IV.1 Overview of Benefits

Benefit Category	Benefit Calculated	Description
Direct Physical Damages	Structures / Buildings	Analysts applied USACE depth-damage functions (DDFs) to vulnerable structures, critical/essential facilities, and modes of transport in the benefitting area. The DDFs consider the type of structure/asset, structure or contents replacement value, and expected flood depth within the structure to determine the dollar value of contents or structure damage.
	Critical / Essential Facilities	
	Transportation	
Human Impacts	Displacement / Relocation	Natural disasters threaten or cause direct impact to structures but can also seriously harm health, social, and economic resources, which lead to psychological distress. Methodologies to calculate expected losses avoided for Human Impacts are a product of flood depth and damage to people's homes.
	Mental Health / Stress / Anxiety	
	Shelter Needs	
	Lost Productivity	
	Casualties	
Social Value	Recreational Benefits	Social benefits are based on added recreational and community gathering space. There are health cost reductions and willingness to pay values associated with these amenities.
	Health Benefits	
	Aesthetic Benefits	
Environmental Benefits	Provisioning Services	Environmental benefits are gained heavily from the implementation of the projects, which are designed to incorporate expansion of park spaces/wetlands, provide connectivity between neighborhoods and the waterfront, and offer aesthetically pleasing public gathering spaces.
	Regulating Services	
	Supporting Services	
	Cultural Services	
Economic Revitalization	New Employment	Economic gains are based on the addition of new retail and commercial space and expected job growth and gains as a result.
	Housing Benefits	
	Economic Output	

1.0 Resiliency Values

Hazard Analysis

HAZARD SCENARIOS

Coastal Storms and Flooding

The City evaluated risk under three sets of storm surge flood scenarios in addition to Hurricane Irene (Figure IV.*1*). These scenarios are based on the probability that a given flood elevation will be equaled or exceeded in any particular year.

The three sets of storm surge flood scenarios were estimated:

1. Estimated storm surge at present conditions
2. Estimated storm surge given sea level rise (SLR)
3. Estimated storm surge given SLR and including conceptual flood mitigation measures.

Figure IV.1 Estimated Flood Depth - Hurricane Irene

Estimated SLR over the useful life of the Project (50 years) was estimated as an increase of 2.5 ft based on projections by the Virginia Institute of Marine Science (VIMS)[12] and are presented in Figure IV.2. Each set of scenarios includes flood elevations for the 10%, 2%, 1%, and 0.2% annual chance coastal flood events based on FEMA's December 16, 2014 Revised Flood Insurance Study (510104V000B) and associated Flood Insurance Rate Maps (FIRMs). Estimated wave action (approximately 0.5 ft in the vicinity of the study area and based on the 1% annual chance event) was added to the stillwater elevation of each flood elevation. This approach has been selected for its consistency with current FEMA Benefit Cost Analysis Guidance.

[12] *Virginia Institute of Marine Science (VIMS), 2013. Recurrent Flooding Study for Tidewater Virginia (SJR 76, 2012)*

Analysts developed a series of inundation maps to visualize each flood scenario. Inundation maps showing the extent of flooding during each of the sets of scenarios are shown on

Figure *IV.3* and Figure 4, respectively. Inundation maps showing the estimated depth of flooding given the 1% annual chance plus 2.5 feet of SLR with the proposed improvements for each scenario are shown on Figure *IV.5*5 through **Error! Reference source not found.**6.

Analysts evaluated grade elevations with Light Detection and Ranging (LiDAR) data collected in 2013 and compared these grade elevations to expected flood elevations to determine the extent of flooding under each scenario.

Engineers evaluated flood extents for connectivity to the actual source of flooding, and all areas not expected to flood due to disconnection from the flood source were removed. Flood elevations associated with their appropriate scenarios can be graphed and used to interpolate probabilities of historical flood events as well.

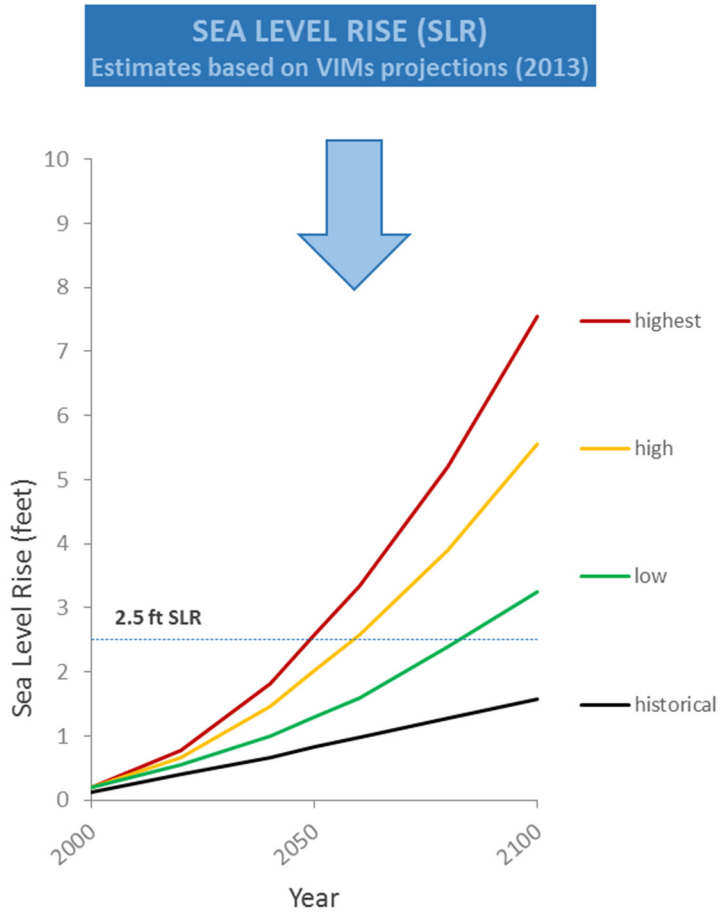

Figure IV.2. Sea Level Rise Scenarios

Figure IV. provides an interpolation of the data (presented in Table IV.1) for the Hurricane Irene event within the Target Area both with and without consideration of SLR. Based on the regression analysis, the Hurricane Irene elevation of 5.94 feet North American Vertical Datum of 1988 (NAVD88) would have a 5.9% chance of being repeated without consideration of SLR and would be likely to occur almost annually when SLR is included. The Proposed Project would protect the area to the 1% annual chance flood event plus SLR, plus freeboard. This equates to just above the 0.34% annual chance flood event (Figure IV.). The elevations required to meet this level of protection vary throughout the Target Area based on topography and flood elevation.

Figure IV.3 Estimated Flood Extent of 1% Annual Chance of Occurrence under Present Conditions

Figure IV.4 Estimated Flood Extent of 1% Annual Chance of Occurrence Given 2.5 Feet of Sea Level Rise

Figure IV.5 Estimated Flood Extent of 1% Annual Chance and Proposed Improvements

Figure IV.5 Estimated Flood Extent of 1% Annual Chance Given 2.5 Feet of SLR and Proposed Improvements

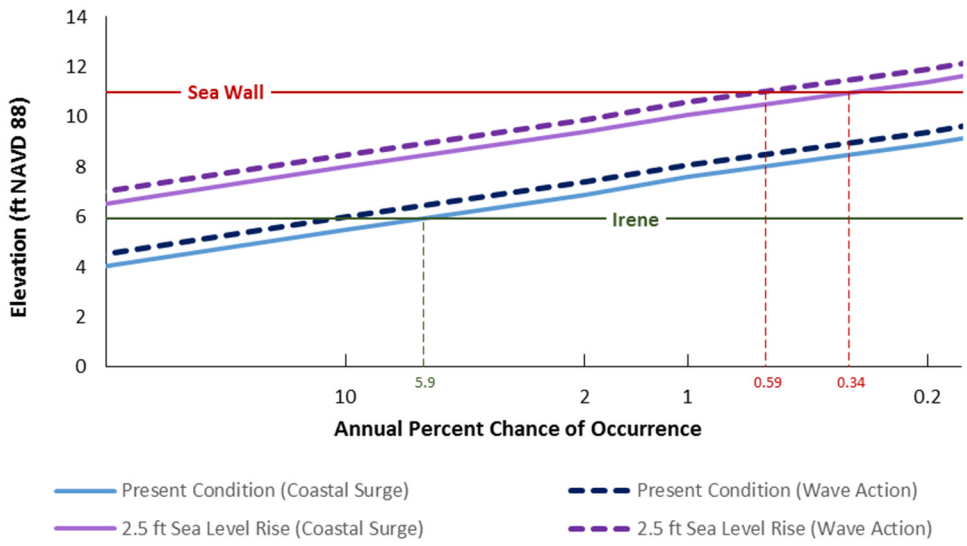

Figure IV.7 Hurricane Irene Interpolation With and Without SLR at Project Area.

Table IV.2 FEMA-Projected Coastal Surge With and Without SLR[13]

Event	Elevation (ft. NAVD)			
	Present Condition		Sea Level Rise	
	Coastal Surge	Wave Action	Coastal Surge	Wave Action
10 %	5.5	6	8	8.5
2 %	6.9	7.4	9.4	9.9
1 %	7.6	8.1	10.1	10.6
0.2 %	8.9	9.4	11.4	11.9
Irene (5.9%)	5.94			

Source: FEMA (2014). Flood Insurance Study, City of Norfolk, Virginia FIS#510104V000B

[13] FEMA (2014). Flood Insurance Study, City of Norfolk, Virginia FIS#510104V000B

Direct Physical Damages - Buildings

Direct Physical Damages - Buildings

The proposed project will significantly reduce the risk of direct physical damage due to stormwater and coastal flood events. Direct physical damages to buildings are based on impacts to structure, contents, and inventory. Structural damage is damage that applies to real property, contents damage is damage that applies to personal property, and inventory damage is damage that applies to materials and goods held by a business.

This section provides an overview of the existing conditions in the City of Norfolk; outlines the approach taken to refine Norfolk's Real Estate Assessor data; identifies the methodology used to estimate direct physical damages using depth damage functions; documents assumptions and uncertainties; and provides an overview of the results for modeled coastal and stormwater inundation scenarios in the Target Areas.

An initial flood exposure analysis shows that approximately 1,373 structures are estimated to benefit from the implementation of the proposed projects at the proposed coastal level of protection discussed in Section 2.0 Project Description. The majority of these structures are also vulnerable to stormwater flooding due to the low topography of the Target Areas. Table 1 provides the number of structures, total square footage, total building replacement value, total contents replacement value for the structures in the flood hazard area. Figure 1 depicts the location of structures vulnerable to coastal surge in the Target Areas. A detailed breakdown of the structures included in the exposure analysis is provided in Appendix F-16. The methodology used to calculate building, content, and inventory replacement values is provided in in this section.

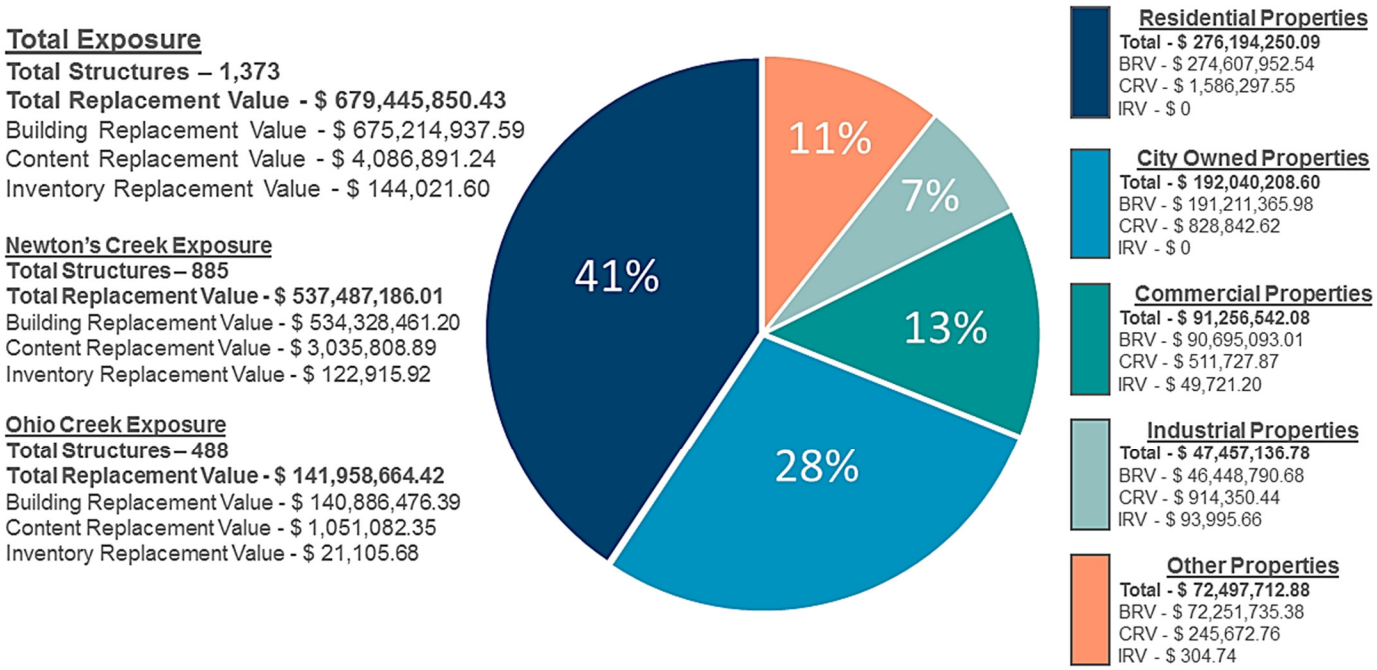

Figure IV.1.2.1 Norfolk Proposed Project Total Study Area, Total Exposure by Building Occupancy Type, 100-Year with 2.5 Ft. of Sea Level Rise, 2015

Sources

This subsection provides insight into the process analysts used to develop the Norfolk Coastal Adaptation and Community Transformation Plan structure inventory, necessary for the calculation of direct physical damages expected to be avoided by the proposed project. Prior to the calculation of damages, the structure inventory had to be evaluated and modified to ensure accuracy of the results. The following sources were used to develop both the structure inventory and direct physical damages:

- **City of Norfolk 2015 Real Estate Data.** Provided information for each of the structures present within the Target Areas.
- **City of Norfolk 2015 Parcel Boundaries.** Analysts used this GIS layer to determine the outline of parcels within the Target Areas.
- **2013 City of Norfolk Light Detection and Ranging (LiDAR) Data.** Provided grade elevations for the structures in the dataset and a Building_3D
- **Federal Emergency Management Agency (FEMA) Hazus Default Building Replacement Values.** A dollar value per square foot used to determine the total building replacement value for each structure record.
- **U.S. Army Corps of Engineers (USACE) West Shore Lake Pontchartrain Hurricane and Storm Damage Risk Reduction Study, Contents to Structure Ratio Values (2014).** A ratio applied to the building replacement value to determine the contents replacement value for each structure record.
- **Federal Emergency Management Agency (FEMA) Hazus Default Inventory Values (2006).** A dollar value per square foot used to determine the inventory replacement value for commercial and industrial structure records.
- **Modeled 10%, 2%, 1%, and 0.2% Inundation Depth Data with Sea Level Rise (2015).** Modeled by the analysts, these GIS raster files with flood elevations were used to determine the depth of flooding in each structure. A description of this data set is provided in the Hazard Analysis Section.

Developing the Structure Inventory

In order to determine direct damages, the analysts were first required to develop a structure inventory of buildings within the Target Areas. The following steps were used to develop the inventory:

1. *Gather Real Estate Data.* Analysts pulled relevant information in the Real Estate data. A basic description of the type of information, the name(s) of relevant fields, and a description of how the data was analyzed is provided below:
    - *Parcel Number* - [Routing_number] parcel number that relates to the parcel data layer in GIS.
    - *Owner Name* – [Owner1] name of the current owner.
    - *Property Address* – [prop_street] the address for the property including street number and name.
    - *Property Class Description* – [property_class], [PropClassDesc] coded value for the property zoning type and description. The property class information was used to relate the correct damage estimate to specific structures.
    - *Building Square Footage* – [finish_living_area], [Area] the finish_living_area contains the square footage for residential structures including some apartments. The Area field contains square footage for non-residential structures and the majority of apartments. These data were used as part of the cost estimation for each structure.

- *Number of Stories* – [story_height] the number of stories for a given structure. The information is used to determine the appropriate damage estimate for each structure.
- *Basement* – [crawl_code], [bsmnt_fin_area] the crawl_code field contains the type of crawl space. The bsmnt_fin_area shows the number of square feet in a basement when present. These data were used to determine the elevation of the first floor living space.

2. *Analyze City of Norfolk parcel information*. The parcel information was included in a larger set of data layers provided by the City. This data layer contains the parcel information for the City of Norfolk. A basic description of the type of information, the name(s) of relevant fields, and a description of how the data was analyzed is provided below:
    - *Parcel Number* – [GPIN] parcel number that relates to the real estate data set.
    - *Parcel Latitude and Longitude* – the central point of each parcel was created using GIS analyses tools to create the latitude and longitude of each parcel.
3. *Examine LiDAR Data and Layers derived from Data.* The LiDAR information was provided by the City of Norfolk and covers all areas of the City. It contains the processed ground elevation information and a polygon layer called Building_3D. The ground elevation information is a raster data set. The Buildng_3D layer is a polygon layer derived from the LiDAR data and contains building footprints. Two data files were present:
    - *Buildings_3D* - Generated from the 2013 LiDAR dataset containing building base and top elevations
    - *Buildings* - Information had a higher degree of accuracy with regard to building footprints, but used an older LiDAR data set to apply elevations.

Since analysts wanted to maintain the elevation information stored in the Buildings_3D polygon file, this file served as the primary analysis layer. Analysts developed centroids from this layer and made the following adjustments to the dataset. Duplicate points representing the same building were deleted. The data point with the lowest base elevation was retained in most cases. If the difference between the base and top elevation was high, the point with the largest difference was retained.

Points representing multiple buildings were copied and placed into each Building layer polygon. In residential areas where the Buildings layer does not have an equivalent 3D_Buildings center point, the values were left null. In areas where it was clear that the structure was a shed or outbuilding, and there was no equivalent 3D_Building center point, the value was left null.

4. *Determine Data Gaps and Remediate Needs.* Structure data was captured using the three data sets mentioned above and merged together in ArcGIS. Each data set was evaluated for accuracy and completeness. Where data gaps were identified, analysist developed a methodology to remedy the gap in information.
5. *Structure Footprint Development and Identification.* Determining the location of a structure is important to obtain the grade and flood elevation for use in the analysis. Since analysts wanted to maintain the elevation information stored in the Buildings_3D polygon file, this file served as the primary analysis layer. Analysts developed centroids from this layer and made the following adjustments to the dataset. Duplicate points representing the same building were deleted. The data point with the lowest base elevation was retained in most cases. If the difference between the base and top elevation was high, the point with the largest difference was retained.

Points representing multiple buildings were copied and placed into each Building layer polygon. In residential areas where the Buildings layer does not have an equivalent 3D_Buildings center point, the values were left null. In areas where it was clear that the structure was a shed or outbuilding, and there was no equivalent 3D_Building center point, the value was left null.

6. *Structure Square Footage.* In determining building square footages, the “finished living area” was

used for residential structures and the total building "area" was used for non-residential and apartment buildings. For structures where these two fields contained a null value, an average square footage of the property class was calculated and applied to the record.

7. *Structure First Floor Elevation.* A base grade elevation of the parcel was determined using the 2013 LiDAR data set provided by the City of Norfolk for comparison. In order to determine the structure's grade elevation, the value contained in the 3D_Buildings layer field under the "base building elevation" was used. This information was compared to the parcel centroid elevation, and if a significant difference between the two was identified, the value defaulted to the 2013 LiDAR elevation.

Identifying the type of foundation for each structure is important to determine the first floor elevation (FFE). The City of Norfolk Real Estate data includes a field indicating the presence or absence of a basement and the presence or absence of a crawlspace. Based on this information, the following foundation elevations in **Error! Reference source not found.** were added to the grade elevations of the parcel centroid to determine the FFE. Elevation above grade values were obtained from FEMA's Hazus Loss Estimation Software.

Table IV.1.2.1 Foundation Type and Elevation above Grade

Foundation Type	Elevation Above Grade (Feet)
Crawl Space	3
Slab	1
Basement	0

Source: FEMA Hazus 2.1 Technical Manual

8. *Number of Stories.* Number of stories is necessary to determine the correct depth damage function appropriate for each structure as described in the following section. To determine the number of stories for each structure, the building height and was divided by an estimated story height of 10 feet. While several records contained a "number of stories" attribute in the Real Estate dataset, many of the records had a null value. In order to establish a building height for the null records, the 3D_Buildings layer "base building elevation" and "building top elevation" was used.

In the case that multiple points existed, the lowest and highest points were retained, and the difference between these two values was estimated to be the building elevation. In cases where a building height and number of stories value were absent an average building height by structure occupancy type was applied to the structure record.

Calculating Direct Physical Damages

Damage to buildings, contents, and inventory are estimated using the depth of flooding and application of a depth-damage function associated with the building occupancy type. Flood depth damage functions (DDFs) are in the form of depth-damage curves, relating depth of flooding (in feet), as measured from the top of the first finished floor, to damage expressed as a percent of the total replacement cost. DDFs are unique for building, contents, and inventory. For each structure, a building occupancy code based on structure use and appropriate damage function is assigned, and modeled flood elevations (1-foot increments) are used to determine the associated flood damages. The percent flood damage is multiplied by the total replacement value (building, contents, and inventory) for each structure to produce an estimate of the dollar loss.

Direct physical damage is calculated using a library of readily available DDFs extracted from FEMA's Hazus. DDFs extracted are from a variety of sources including the following:

- Federal Insurance and Mitigation Administration (FIMA) FIA;
- USACE Chicago District
- USACE Galveston District
- USACE New Orleans District
- USACE New York District
- USACE Philadelphia District

Each source provided specific depth damage functions which were applied to each structure record based on building occupancy type. Figure 2 provides an example depth damage relationship for an Average Light Industrial Structure from the USACE Galveston District.

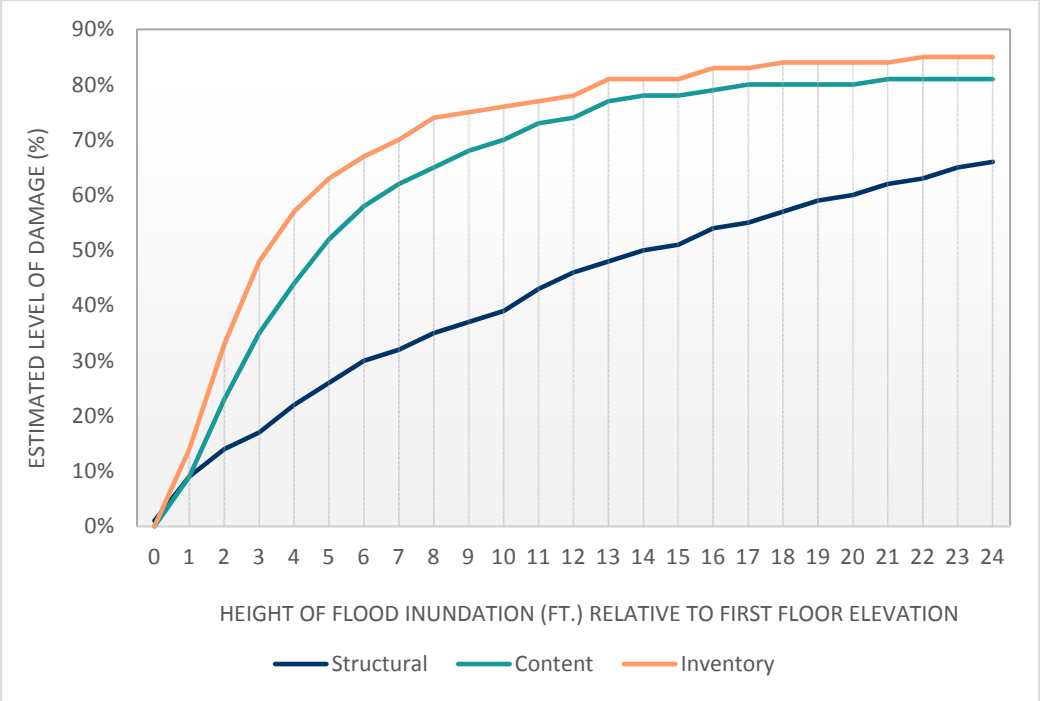

Figure IV.1.2.2 Structural, Content, and Inventory Damage from Inundation, USACE Galveston Average Light Industrial Use

Once the structure inventory was developed, analysts then applied the depth damage functions to each structure through the following process:

1. *Map Structure Inventory to the Appropriate Occupancy Codes.* Relating the appropriate occupancy code to the individual structure records is an important step in ensuring development of defensible results. These occupancy codes provide direct links to the classifications used within RS Means and the FEMA Hazus software to estimate building and content replacement costs. Each occupancy type required individual analysis to ensure alignment of the most accurate code to the structure inventory record. For the purposes of this analysis, the Real Estate data provided by the City of Norfolk offered a "Property Class Description" field, simplifying the relation to the appropriate occupancy type. Due to a high level of specificity in the "Property Class Description" for each field, each occupancy code was mapped based on the property class description. Appendix F-17 Structure Inventory Mapping provides the Structure Occupancy Code Mapping results.

The structure inventory was later refined to identify specific critical infrastructure assets, utilities, transportation resources, public facilities, and essential facilities (such as fire departments, schools, shelters, and other assets).

2. *Develop Replacement Values.* Building Replacement Values (BRVs), content to structure ratios, and inventory to structure ratios are all required to determine the total expected damage to structures within the study area. The BRV value provides an approximate per square foot valuation of the replacement cost required to repair/reconstruct a similar type building. Similarly, the content and inventory values are derived as percentages of the BRV, essentially indicating what would be required to replace any of the contents (e.g., office supplies, computers, equipment) or inventory (items for sale) that might have been damaged.

BRVs were extracted from the FEMA Hazus Default Inventory database and normalized for inflation using the Consumer Price Index (CPI) calculator from 2006 to 2015. Content and inventory ratios were derived from the *USACE West Shore Lake Pontchartrain Hurricane and Storm Damage Risk Reduction Study* and again required normalization through the CPI calculator from 2014 to 2015[1]. These developed values are all provided within Appendix F-11: Annualized Building, Content, and Inventory Replacement Values.

3. *Determine Modeled Flood Depths and Apply Depth-Damage Functions.* Inundation modeling was developed for the 10-percent, 2-percent, and 1-percent annual chance flood events plus 2.5 feet of sea level rise via the methods discussed in the Hazards Analysis Section. In order to determine the flood depths at the structure location, the established structure FFE was subtracted from the corresponding maximum surface water flood elevation. These final flood depths at each event were then matched to damage using appropriate DDFs.

4. *Calculate Physical Loss Values.* Direct physical damage for buildings is a product of total structure square footage, replacement value, flood depth, and the associated damage percentage at that flood depth. The results from this analysis are provided in the detailed results section of this methodology.

Detailed Results

Detailed results of the total structural damages, critical facility impacts, and transportation impacts are provided in Table 2 through

. All results have been annualized and normalized using a 7 percent discount rate over the project useful life.

Table IV.1.2.2 Total Expected Building Damage Costs due to Coastal Flooding in 2015 Dollars

Loss Category	Expected Costs in 2015 Dollars by Annual Chance Coastal Flood Event, Including 2.5 feet of SLR over the Project Useful Life			Post-Mitigation Benefits	
	10-Year Event	50-Year Event	100-Year Event	Annual Benefits	Net Present Value of Total Benefits
Building Damage Costs ($)	$9,034,034.65	$18,144,614.58	$26,392,731.31	$1,530,223.07	$21,117,491.52
Contents Damage Costs ($)	$24,043,400.92	$47,228,096.29	$62,553,419.15	$3,974,436.21	$54,848,292.79
Inventory Damage Costs ($)	$1,830,570.75	$3,221,330.47	$3,756,260.78	$285,046.29	$3,933,715.79
Total Property Loss ($)	$34,908,006.32	$68,594,041.34	$92,702,411.24	$5,789,705.57	$79,899,500.10

[1] USACE. 2014. West Shore Lake Pontchartrain Hurricane and Storm Damage Risk Reduction Study – Final Integrated Feasibility Study Report and Environmental Impact Statement. November.

Table IV.1.2.3 Newton's Creek Watershed Expected Building Damage Costs due to Coastal Flooding in 2015 Dollars

Loss Category	Expected Costs in 2015 Dollars by Annual Chance Coastal Flood Event, Including 2.5 feet of SLR over the Project Useful Life			Post-Mitigation Benefits	
	10-Year Event	50-Year Event	100-Year Event	Annual Benefits	Net Present Value of Total Benefits
Building Damage Costs ($)	$7,566,448.35	$11,812,265.22	$16,011,271.31	$1,153,002.85	$15,911,750.67
Contents Damage Costs ($)	$22,283,523.10	$39,354,393.05	$50,863,925.51	$3,524,079.43	$48,633,247.57
Inventory Damage Costs ($)	$1,784,674.05	$3,077,054.86	$3,589,999.87	$275,908.50	$3,807,611.81
Total Property Loss ($)	$31,634,645.49	$54,243,713.13	$70,465,196.69	$4,952,990.78	$68,352,610.06

Table IV.1.2.4 Ohio Creek Watershed Expected Building Damage Costs due to Coastal Flooding in 2015 Dollars

Loss Category	Expected Costs in 2015 Dollars by Annual Chance Coastal Flood Event, Including 2.5 feet of SLR over the Project Useful Life			Post-Mitigation Benefits	
	10-Year Event	50-Year Event	100-Year Event	Annual Benefits	Net Present Value of Total Benefits
Building Damage Costs ($)	$1,467,586.30	$6,332,349.36	$10,381,459.99	$377,220.22	$5,205,740.85
Contents Damage Costs ($)	$1,759,877.83	$7,873,703.25	$11,689,493.65	$450,356.78	$6,215,045.22
Inventory Damage Costs ($)	$45,896.70	$144,275.61	$166,260.91	$9,137.79	$126,103.99
Total Property Loss ($)	$3,273,360.83	$14,350,328.21	$22,237,214.55	$836,714.79	$11,546,890.06

Essential Facilities and Critical Infrastructure

Essential Facility and Critical Infrastructure Loss of Service Costs

FEMA defines a critical, or essential, facility as a facility for which "even a slight change of flooding is too great a threat."[1] Typical essential facilities, necessary for disasters, include hospitals, fire stations, EMS stations, police stations, and similar facilities. Critical infrastructure and lifelines include utilities and services, such as wastewater service, electrical power services, and transportation infrastructure. It is necessary to separate the analysis of essential facilities and critical infrastructure from the analysis of general residential and commercial buildings because, in addition to damage costs and displacement consequences that may be the result of flood impacts, these assets serve the public, and impacts related to service interruption can cascade and result in further economic, environmental, and societal losses. The FEMA BCA Reference Guide (BCAR) defines loss of function (or service) as, "Cost and direct economic impacts that occur when physical damages are severe enough to interrupt the function of a building or other facility." The value of the service provided by essential facilities and critical infrastructure can be quantified and included as benefits within the benefit cost analysis in addition to any expected physical property damages. FEMA quantifies standard service values for many typical critical and essential facilities, which will be explained and used later on in the analysis.

Principle Resources and Data Sources

The Federal Emergency Management Agency's (FEMA) Benefit Cost Analysis Re-engineering (BCAR) outlines methods to value essential facility and critical infrastructure loss of service. Geographic information systems (GIS) data provided by the Norfolk GIS Department was used to determine asset locations.

Detailed Approach

The first step to analyze essential facilities and critical infrastructure is to identify the number and types of facilities that meet FEMA's definition located within the Target Area. These assets were located and grouped into the following categories:

- Pump Stations
- Electrical Substation
- Fire Station
- Schools (often house large numbers of children and two serve as shelters)
- Roads

No other essential assets and critical infrastructure were specifically identified within the Target Area.

Analysts gathered the following information for each asset: location, size of service population, facility size, operating budget, and any other facility-specific information. A log of this information was developed to document the information gathered on all facilities. The analysis was completed for facilities in each category above, and the methods for each are outlined respectively below.

Pump Stations

Service loss avoided is a function of pump station location, service population, flood depth, and estimated downtime by flood depth.

[1] *Federal Emergency Management Agency. 2015. Critical Facility. [Web page] Located at: https://www.fema.gov/critical-facility.*

- As the service population for each individual pump station was not readily available, analysts divided the total population in Norfolk City (242,803)[2] by the total number of wastewater pump stations (198), stormwater pump stations (12), or water pump stations (8) in the city to assign a proportionate population share to each asset. The number of pump stations was provided by Norfolk City Geographic Information Systems Department.
- The loss of function time is based on flood depth and damage state. While FEMA provides depth loss of service functions for this asset type, a comparison of these functions with historical losses at other sites determined that more conservative figures would be necessary. For example, where FEMA's function might identify 45 days of lost service correlated to a particular flood depth, a comparison of pump station impacts from other flood events in the United States that ARCADIS has recorded (See Appendix F-19) indicates that a pump station downtime of 5 days for the correlating flood depth may be more appropriate given that the City would take certain emergency response and preparedness measures to limit interruption (e.g., generators, spare parts, emergency repairs, etc.). It was determined eight pump stations would experience a loss of function, summarized in Table IV.1.3.1.
    - It is important to note, the pump stations analyzed include submersible and dry pit submersible assets. While an asset may be submersible, critical components needed for function, such as power source or emergency generators, may not be.
- In order to value the service provided by the pump stations to the population, analysts applied FEMA's standard value for wastewater service, $45 per capita member of the service population per day, or FEMA's standard value for water service, $103 per capita member of the service population per day.[3] FEMA has estimated these values using nationwide economic data by economic sector and water importance factors from the Economic Census and North American Industry Classification System (NAICS). Importance factors were obtained from the FEMA-sponsored publication ATC-25.

Table IV.1.3.1 Service Population and Loss of Function Time

Pump Station	Type	Service Population	FEMA Standard Value	Flood Depth at First Floor			Days of LOF		
				10-Year	50-Year	100-Year	10-Year	50-Year	100-Year
Newton's Creek									
PS 004	Sewage Pump Station	1,226	$45	1.8	3.27	3.9	5	7	7
PS 005	Sewage Pump Station	1,226	$45	2.2	3.6	4.3	5	7	7
PS 129	Sewage Pump Station	1,226	$45	3.1	4.5	5.21	7	7	15
RS 132	Sewage Pump Station	1,226	$45	-0.84	0.5	1.2	-	-	5
East Brambleton Avenue - East of May Avenue	Pump Station	20,234	$103	7.13	8.5	9.23	15	15	15

[2] *US Census Bureau. American Community Survey 2013 5-Year Estimates. [Web Page] Located at: http://factfinder.census.gov/faces/nav/jsf/pages/community_facts.xhtml#none*
[3] *FEMA Benefit-Cost Analysis Re-engineering (BCAR). Development of Standard Economic Values. Version 5.0. August 2011. Pages 38 and 42.*

Pump Station	Type	Service Population	FEMA Standard Value	Flood Depth at First Floor			Days of LOF		
				10-Year	50-Year	100-Year	10-Year	50-Year	100-Year
Ohio Creek									
PS 141	Sewage Pump Station	1,226	$45	4.9	6.3	7	5	15	15
PS 147	Sewage Pump Station	1,226	$45	0.35	1.75	2.45	-	5	5
WPS-I16-00001	Finished Water Pump Station	26,978	$103	-0.12	1.88	1.98	-	5	5
Total		54,568					37	61	74

The value of lost service is calculated as follows:

$$Value\ of\ lost\ service = service\ population * FEMA\ standard\ value * days\ of\ lost\ function$$

Limitations, Uncertainties, Assumptions, and Sensitivities

- Service population data was not readily available for pump stations, therefore it was necessary to obtain a general estimate of service population based on total population and pump stations within Norfolk City.
- It was assumed the first flood elevation of pump stations is one foot above grade.

Detailed Results

With a total impacted population of 54,568, and the FEMA standard value of $45/person/day for loss of wastewater service, or $103/person/day for water service, the estimated total loss of function is summarized below. Benefits for each annual flood chance event were multiplied by their probabilty of occurrence and addded together to determine annual benefits. Annualized benefits were multiplied by a present value coefficient for a 50-year project useful life at a 7% discount rate.[4]

[4] *Association of Floodplain Managers. 2008. Discount Rate. Page 3. Located at: http://www.floods.org/PDF/WhitePaper/ASFPM_Discount_%20Rate_Whitepaper_0508.pdf*

Table IV.1.3.2 Value of Pump Station Loss of Function

Pump Station	Expected Losses by % Annual Chance Flood Scenario			Expected Benefits	
	10-Year	50-Year	100-Year	Annual Benefits	Net Present Value
Newton's Creek					
PS 004	$275,850.00	$386,190.00	$386,190.00	$39,170.70	$540,584.88
PS 005	$275,850.00	$386,190.00	$386,190.00	$39,170.70	$540,584.88
PS 129	$386,190.00	$386,190.00	$827,550.00	$54,618.30	$753,773.29
RS 132	$0.00	$0.00	$275,850.00	$2,758.50	$38,069.36
East Brambleton Avenue - East of May Avenue	$31,261,530.00	$31,261,530.00	$31,261,530.00	$4,063,998.90	$56,086,216.56
Total	$32,199,420.00	$32,420,100.00	$33,137,310.00	$4,199,717.10	$57,959,228.97
Ohio Creek					
PS 141	$275,850.00	$827,550.00	$827,550.00	$52,411.50	$723,317.80
PS 147	$0.00	$275,850.00	$275,850.00	$8,275.50	$114,208.07
WPS-I16-00001	$0.00	$13,893,670.00	$13,893,670.00	$416,810.10	$5,752,290.32
Total	$275,850.00	$14,997,070.00	$14,997,070.00	$477,497.10	$6,589,816.19
Total	$32,475,270.00	$47,417,170.00	$48,134,380.00	$4,677,214.20	$64,549,045.16

Electrical Substation

The Reeves Avenue Electrical Substation is located in the Newton's Creek Watershed. The FEMA BCAR provides a method to estimate the value of lost service, though analysis determined the electrical substation would not be impacted in any of the study events, therefore benefits are not calculated in this analysis.

Fire Stations

Fire Station 1 is located within the Newton's Creek Watershed, and the service area is Young Terrace.[5] Based on flood depths from the resiliency analysis, it was determined the fire station would not be impacted during an event, therefore there would be no loss of service. As such, benefits are not calculated in this analysis.

Schools

Norfolk's Coastal Adaptation and Community Transformation Plan will protect four schools in the Target Area from flooding. Norfolk public schools were closed Monday, October 29, 2012 after Hurricane Sandy.[6] There is no historical data regarding school closures for Hurricane Irene.

In accordance with the FEMA BCAR Guide and Supplement, expected loss data can be used to calculate benefits to be used in the benefit-cost analysis. Days of lost service are determined using modeled flood depths and damage state, determined in the Direct Physical Damages section. Three of the four schools would be impacted by a storm event, summarized in Table IV.1.3.3.

Analysts determined the annual operating budget for each school to calculate the loss of service from a school closure. Annual operating budgets published by the City of Norfolk School Board were used for the FY 2015-2016 to calculate daily operating budget and value loss of service.[7] The operating budget per day is applied to the time the school is out of service to determine the loss of function cost. The value of school closure is summarized in Table IV.1.3.4.

Table IV.1.3.3 Impacted Schools

School	Flood Depth			Loss of Function (Days)			Daily Operating Budget
	10-Year Event	50-Year Event	100-Year Event	10-Year Event	50-Year Event	100-Year Event	
Newton's Creek							
Tidewater Park Elementary School*	3	4	5	135	180	225	$10,563.58
Ruffner Academy	1	2	3	45	90	135	$20,705.69
Ohio Creek							
Chesterfield Heights Academy*	-	-	1	0	0	45	$11,446.91

*Serves as an emergency shelter.

[5] http://www.virginiafirefighters.com/norfolk.htm
[6] http://blog.checkeredflag.com/my_weblog/2012/10/hampton-roads-closures-and-cancellations-due-to-hurricane-sandy.html
[7] School Board's Proposed Education Plan and Budget 2016. Located at: http://www.npsk12.com/pdf/FY_2016_School_Boards_Proposed_Ed_Plan-Budget.pdf

Detailed Results

Results are provided for three different flood events. Benefits for each event were multiplied by their probability of occurrence and then added together to obtain annual benefits. A present value coefficient for a 50-year project useful life at a 7% discount rate was applied to annual results to determine net present value[8].

Table IV.1.3.4 Value of School Closure

School	Expected Losses by % Annual Chance Flood Scenario			Expected Benefits	
	10-Year Event	50-Year Event	100-Year Event	Annual Benefits	Net Present Value
Newton's Creek					
Tidewater Park Elementary School	$1,426,082.67	$1,901,443.56	$2,376,804.45	$204,405.18	$2,820,944.00
Ruffner Academy	$931,756.19	$4,050.00	$12,150.00	$93,378.12	$1,288,687.70
Total	$2,357,838.86	$1,905,493.56	$2,388,954.45	$297,783.30	$4,109,631.71
Ohio Creek					
Chesterfield Heights Academy	$0.00	$0.00	$515,110.81	$5,151.11	$71,089.13
Total Benefit	$2,357,838.86	$1,905,493.56	$2,904,065.26	$302,934.41	$4,180,720.85

Roadway Service Impacts

Transportation assets and systems can also experience significant losses during a flood event. Nuisance flooding is common in the Target Area and occurs on a regular basis, so much so that even high tides can impact a number of roads. Loss of function of roadway systems is determined through the per-hour value of time, detour route, and number of vehicles that would be likely to travel along a roadway. In order to determine this value, analysts focused on residential properties captured within the Target Areas that would be surrounded by floodwaters during the 10%, 2%, and 1% annual chance flood event plus 2.5 feet of SLR. Once residential properties were identified, analysts applied the Northeast average number of vehicles per household derived from the U.S. Department of Transportation Summary of Travel Trends: 2009 National Household Travel Survey.[9] Additionally, analysts incorporated the average daily vehicle trips extracted from the same document. To complete the analysis, the FEMA BCAR Development of Standard Economic Values rate of $29.63 was applied per vehicle per hour for the lost time cost of road closures which was assumed to be inundated for a period of 12 hours.

Sources

Analysts used methodologies derived from the FEMA BCA Toolkit Version 5.1 to develop a total economic loss per day value for each of the identified inundated roads. Specifically, analysts used the sources identified below to calculate the transportation losses:

[8] *Association of Floodplain Managers. 2008. Discount Rate. Page 3. Located at: http://www.floods.org/PDF/WhitePaper/ASFPM_Discount_%20Rate_Whitepaper_0508.pdf*
[9] *U.S. Department of Transportation (2009). Summary of Travel Trends: 2009 National Household Travel Survey. Page 9. http://nhts.ornl.gov/2009/pub/stt.pdf*

- **FEMA Supplement to the Benefit-Cost Analysis Reference Guide.**[10] Analysts used the methodology provided within the guide to develop the total economic losses of roadways.
- **FEMA Benefit-Cost Analysis Re-engineering (BCAR) Development of Standard Economic Values.** Analysts used this resource to determine the appropriate hourly value per vehicle per hour to be applied to the AADT.
- **U.S. Department of Transportation Summary of Travel Trends 2009.** This document provided the average number of vehicles per household and the daily vehicle trips.
- **Inundation Mapping.** Mapping provided by hydrologic and hydraulic experts helped to identify properties that would not have an identifiable detour during each of the inundation scenarios.
- **City of Norfolk Parcel Information and Real Estate Data.** This information allowed analysts to identify parcel information and property descriptions to determine which parcels were residential uses.

Expected Impacts

Analysts followed the below procedure to determine the expected loss of function for roadways. The analysis was performed using the inundation model developed to reflect the 10%, 2%, and 1% annual chance flood event plus 2.5 feet of SLR.

1. *Identify Parcel and Property Uses.* Analysts used the City of Norfolk Parcel Information and Real Estate Data to identify all parcels within the Target Areas and determine the appropriate property uses and descriptions. This information was provided to the city by the Norfolk Property Appraiser.
2. *Apply Flood Inundation Mapping.* Analysts applied each of the developed flood inundation maps to the Target Areas to determine the total number of residential structures within the areas potentially impacted by each flood scenario.
3. *Identify Properties with No Access to Detour Routes.* In order to calculate loss of economic function, analysts were required to determine the fastest alternate route for each of the identified inundated roads that a driver would take to get from one point to another without passing through flood waters. This presented a challenge because a number of identified structures did not have access to a road that was not likely closed due to flood inundation. The Figures below provide a visual of each watershed with the inundation mapping applied and residential structures identified with no detour route.

The FEMA Supplement to the Benefit-Cost Analysis Reference Guide states “For road or bridge losses that do not have detours, the number of daily trips should be based on the number of one-way trips, and the delay time should be 12 hours per one-way trip.”[11] Therefore, because these roads would remain severely inundated and a detour would not exist, a delay time of 12 hours was applied as a standard value.

[10] *FEMA (2011). FEMA Supplement to the Benefit-Cost Analysis Reference Guide. http://www.fema.gov/media-library-data/1396549910018-c9a089b8a8dfdcf760edcea2ff55ca56/bca_guide_supplement__508_final.pdf*
[11] *FEMA Supplement to the Benefit-Cost Analysis Reference Guide (2011). Page 5-14. http://www.fema.gov/media-library-data/1396549910018-c9a089b8a8dfdcf760edcea2ff55ca56/bca_guide_supplement__508_final.pdf*

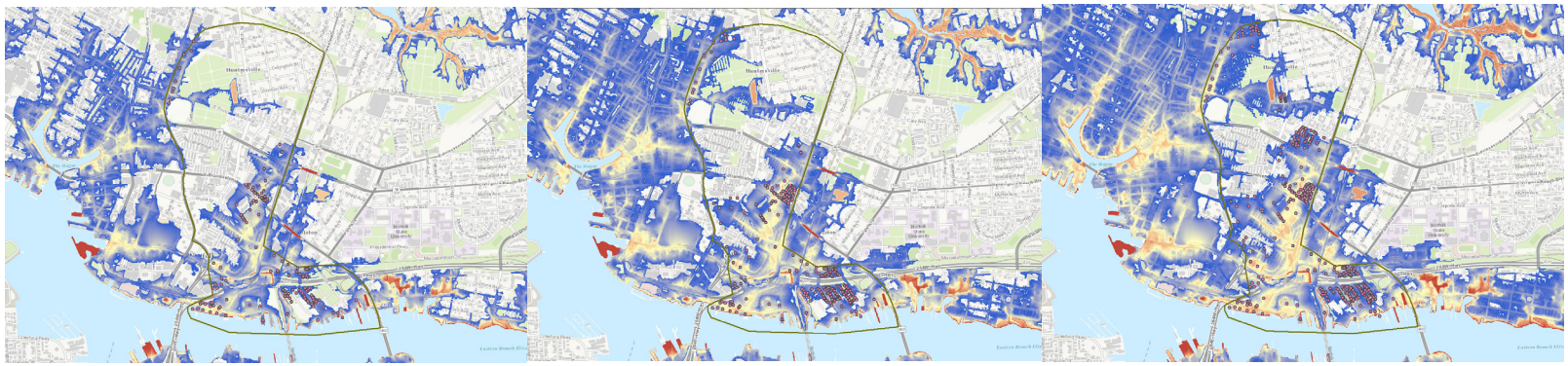

Figure IV.1.3.1 Newton's Creek Watershed Structures with No Detour During the 10%, 2%, and 1% Annual Chance Flood Event plus 2.5 Feet of SLR

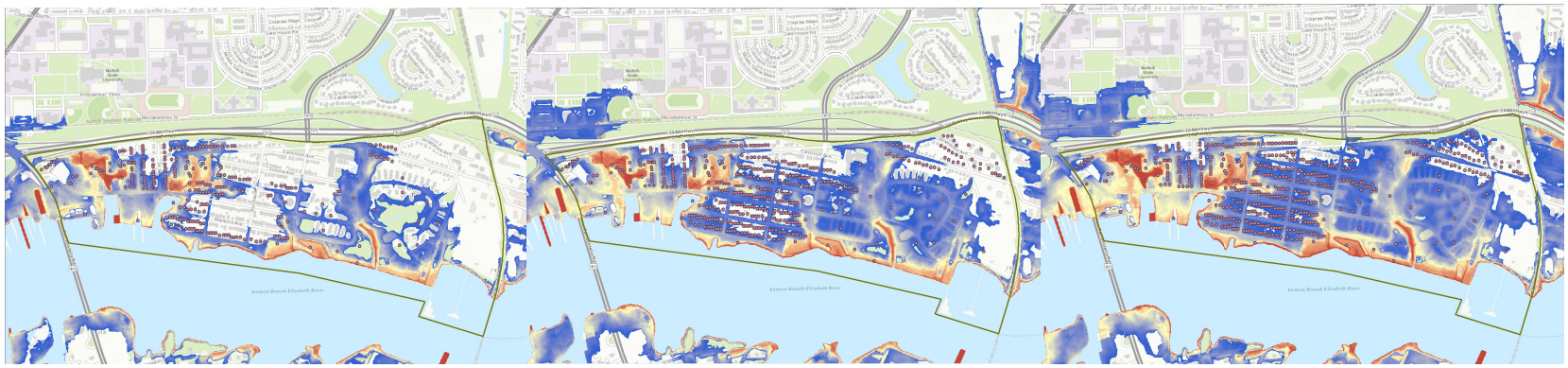

Figure IV.1.3.2 Ohio Creek Watershed Structures with No Detour During the 10%, 2%, and 1% Annual Chance Flood Event plus 2.5 Feet of SLR

4. *Determine Value per Vehicle per Hour.* The FEMA BCAR Development of Standard Economic Values provides a value of $29.63 to be applied per vehicle per hour for the lost time cost of road closures based on the following equation[12]:

$$(\%PPaV * (WR * .05)) + (\%CV * WR) * PPV = HVTV$$

Where:

%PPaV	=	Percent of Personal Passenger Vehicles
WR	=	Wage Rate
%CV	=	Commercial Vehicles
PPV	=	Average Persons Per Vehicle
HVTV	=	Hourly Value of Time per Vehicle

It is important to note that the HVTV is calculated based on information provided by the National Household Travel Survey (NHTS) and the Department of Transportation. According to the NHTS, 82 percent of vehicles on the road are personal passenger vehicles, with the remaining 18 percent being commercial vehicles. This study also indicated that the average number of persons per vehicle is approximately 1.67. Finally, the national average hourly wage of $30.07 was used to produce the final outcome.

5. *Calculate Roadway Loss of Function per Watershed.* Analysis was then completed by determining the roadway loss of function per watershed using the following equation:

$$((UpPD * VpH * VTpD) * DT) * HVTV$$

Where:

UpPD	=	Number of Units per Property Description
VpH	=	Average Vehicles per Household
VTpD	=	Average Number of Vehicle Trips per Day
DT	=	Delay Time
HVTV	=	Hourly Value of Time per Vehicle

Analysis Limitations

In taking care to appropriately identify roadway loss of function within the Target Areas, the following assumptions were made:

- The FEMA BCAR 2011 Hourly Value of Time per Vehicle has not been normalized and therefore may be an underestimate when compared to the 2015 valuation.
- Analysts assumed, in concurrence with the FEMA Supplement to the Benefit-Cost Analysis Reference Guide, that if a residential property does not have a clearly defined detour then the delay time should apply the standard value of 12 hours per one-way trip.
- The FEMA Supplement to the Benefit-Cost Analysis Reference Guide states that "For road or bridge losses that do not have detours, the number of daily trips should be based on the number of one-way

[12] *FEMA (2011). FEMA Benefit-Cost Analysis Re-engineering (BCAR) Development of Standard Economic Values. Page 2. https://www.hudexchange.info/course-content/ndrc-nofa-benefit-cost-analysis-data-resources-and-expert-tips-webinar/FEMA-BCAR-Resource.pdf*

trips, and the delay time should be 12 hours per one-way trip." This again reinforces that this analysis is a conservative estimate in that the analysts used the total number of daily trips and applied 12 hours to the total rather than apply 12 hours per one way trip.

- Analysis was only performed on residential properties and therefore the values produced may provide a conservative estimate when it is clear that additional property uses are contained within the inundation areas.
- It should be noted that an alternative approach to calculating transportation loss of function would be to look at the trips per day on the roads themselves. Analysts explored this methodology, but determined that the methodology would be inappropriate for use due to the fact that so much of the community, especially within the Ghent Neighborhood and Downtown, would remain at risk to flooding, that the direction of the trips would be critical to consider. Analysts ultimately felt that isolating the evaluation to the residents directly within the Target Area would be both a more conservative and appropriate approach.

Detailed Results

The results of the roadway loss of function costs are presented below by compartment and for the entire proposed project.

Table IV.1.3.5 Total Roadway Loss of Function Costs During the 100-Year Flood Event plus 2.5 Feet of Sea Level Rise

	Expected Losses by % Annual Chance Flood Scenario			Expected Benefits	
	10%	2%	1%	Annualized Value	Net Present Value
Newton's Creek Watershed	$241,657.35	$321,149.90	$740,870.56	$37,997.44	$524,374.91
Ohio Creek Watershed	$731,331.45	$1,376,810.95	$1,469,022.31	$115,359.59	$1,591,993.45
Total	$972,988.90	$1,697,960.85	$2,209,892.87	$153,357.03	$2,116,368.36

Coordination with Other Benefits

Essential facilities are analyzed separately from residential and commercial structures when identifying flood risk and the ability to provide service. This is not the case for economic loss of function, also known as output loss. Output loss measures the loss of industry production for businesses and facilities that are impacted by flooding, while facility loss of function values how service interruptions negatively impact the service population. Because the loss of functions and the methods used to determine value varies, it is appropriate to report both losses together, as is the case with schools. This is not the case for pump stations, as the value per capita per day is based on economic data. Therefore, loss of function is valued here for pump stations, and has been removed from the Economic Loss of Function benefits.

Detailed Results

The methods described above were used to calculate the loss of function if essential facilities and critical infrastructure in the Target Area were to flood. The calculations were performed using depth damage functions take from the FEMA BCA toolkit. The essential facilities and critical infrastructure analyzed in this analysis include:

- Pump Stations
  - PS004
  - PS005
  - PS 141
  - PS 147
  - WPS-I16-00001
  - PS 129
  - RS 132
  - East Brambleton Avenue - East of May Avenue
- Schools
  - Tidewater Park Elementary School
  - Ruffner Academy
  - Chesterfield Heights Academy

The loss of function value presented below is the cost associated with losing the facility or infrastructure's critical function. This translates as benefits in the BCA as it represents the costs avoided by protecting the facilities from flooding. These values are added to other losses avoided and additional benefits to determine total annual benefits, net present value, and the benefit cost ratio. Table IV.1.3.6 shows results for each type of essential facility or critical infrastructure in each watershed by recurrence interval. The net present value is determined using a present value coefficient for a 50-Year project useful life at a 7% discount rate.[13]

Table IV.1.3.6 Essential Facility and Critical Infrastructure Loss of Function Results

Facility	Loss of Service Costs for Each Annual Chance Flood Scenario			Benefits	
	10%	2%	1%	Annualized	Net Present Value
Pump Stations					
Newton's Creek	$32,199,420.00	$32,420,100.00	$33,137,310.00	$4,199,717.10	$57,959,228.97
Ohio Creek	$275,850.00	$14,997,070.00	$14,997,070.00	$477,497.10	$6,589,816.19
Total	$32,475,270.00	$47,417,170.00	$48,134,380.00	$4,677,214.20	$64,549,045.16
Schools					
Newton's Creek	$2,357,838.86	$1,905,493.56	$2,388,954.45	$297,783.30	$4,109,631.71
Ohio Creek	$0.00	$0.00	$515,110.81	$5,151.11	$71,089.13
Total	$2,357,838.86	$1,905,493.56	$2,904,065.26	$302,934.41	$4,180,720.85
Roads					
Newton's Creek	$241,657.35	$321,149.90	$740,870.56	$37,997.44	$524,374.91
Ohio Creek	$731,331.45	$1,376,810.95	$1,469,022.31	$115,359.59	$1,591,993.45
Total	$972,988.90	$1,697,960.85	$2,209,892.87	$153,357.03	$2,116,368.36
TOTAL LOSS OF FUNCTION	$35,806,097.76	$51,020,624.41	$53,248,338.13	$5,133,505.64	$70,846,134.37

[13] *Association of State Floodplain Managers. 2008. Discount Rate. Page 3. May 17. Located at: http://www.floods.org/PDF/WhitePaper/ASFPM_Discount_%20Rate_Whitepaper_0508.pdf*

Human Impacts

Human Impacts

The implementation of Norfolk's Coastal Adaptation and Community Transformation Plan is expected to help the City avoid losses normally experienced by the human population as a result of the 1% annual chance flood event plus sea level rise. The details of how such impacts are quantified is presented herein. Human impacts as a result of flood events are evaluated in four ways: fatalities, business and residential displacement, mental stress and anxiety, and lost productivity. Avoidance and reduction of such impacts has the potential to reduce some aspects of social vulnerability that may be present within the Target Area, and will increase resiliency in the social fabric of the community. Table 1 below summarizes the Human Impacts evaluated herein.

Table IV.1.4.1 Human Impacts Benefits Calculated

Benefit	Description	Page
Fatalities Avoided	This methodology calculates the potential number of lives lost due to flood events that will be avoided in the Target Area. The number of fatalities are quantified using Federal Aviation Administration (FAA) standard values.	
Displacement	Displacement consists of relocation costs avoided that are associated with the threat and impact of flooding. Displacement is a function of the flood depth and direct physical damage. Shelter needs are considered a function of displacement.	
Mental Stress and Anxiety	The proposed project is expected to reduce the psychological impacts associated with residents who personally experience flooding of their homes. This is evaluated using FEMA standard methodology.	
Lost Productivity	This differs from mental stress and anxiety as it measures the reduction of psychological effects that impact work productivity for residents who may experience flooding in their homes. This is also evaluated using FEMA standard methodology.	

Fatalities Avoided

Fatalities Avoided

Fatalities are an unfortunate risk inherent to natural disasters. Flood events are considered some of the most frequently occurring natural hazards, contributing to 44-percent of natural hazard-related fatalities worldwide.[1] Moreover, studies have determined that "coastal flood events are even more catastrophic than inland floods in terms of loss of life".[2] One of the benefits of the Norfolk Coastal Adaptation and Community Transformation Plan watershed projects is that the risk of fatalities due to storm surge will be reduced. The approach analysts have taken to identify the benefits associated with reduced risk of fatalities is a function of physical damage to structure and contents, population emergency preparedness, and warning system capabilities.

According to various news articles, Hurricane Irene resulted in five fatalities throughout the State of Virginia.[3] Although no fatalities occurred within Norfolk during this event, this does not indicate the absence of such risk for the City.[4] Due to a lack of publicly available data, injuries are not included as a quantified benefit in this methodology.

Data Sources

Norfolk's Coastal Adaptation and Community Transformation Plan is expected to reduce the number of fatalities that can be anticipated to occur in the Target Area as a result of storm surge. Most existing methodologies that estimate fatalities use two groups of characteristics: hydraulic characteristics such as water depth, rate of water rising, stream velocities, wind, and temperature; and by area characteristics including factors such as population density, land use, warning systems, and vulnerability of the population.[5] Analysts reviewed several approaches that can be used to estimate fatalities as a result of natural disasters:

- Methodology One attempts to develop a relationship between water depth and mortality as a fraction of the inhabitants in the area; the main limitation of this method is that the relation is only based on data from one event; circumstances and characteristics of the community have likely changed since the event.[6]
- Methodology Two is dependent upon water depth and the rate of water rise; this method's limitation is that the number of fatalities estimated are influenced to a large degree by the value chosen for the rate of rising water;[7] this has the potential to result in outliers that will skew the results.
- Methodology Three considers material loss, population preparedness, and warning capabilities. Analysts identified this approach as most appropriate since it accounts for both event damage characteristics and the community's capacity to prepare for and react to flood events, which are related to vulnerability. This is especially important because of Norfolk's initiatives to increase flood hazard awareness.

The approach chosen to estimate reduced fatalities within the Target Area is based on a study completed by the Brno University of Technology in 2013.[8] Through this approach, analysts consider the number of fatalities expected for the 10%,-percent, 2%,-percent, and 1-percent annual chance flood events, including sea level

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1 International Federation of Red Cross and Red Crescent Societies. 2013. World Disasters Report – Focus on Technology and the Future of Humanitarian Action. [web page] Located at: http://worlddisasterreport.org/en/.
2 Brazdova, M. and J. Riha. 2014. A simple model for estimation of the number of fatalities due to floods in central Europe. Nat Hazards Earth Syst Sci. 14 June 12.
3 Associated Press. 2012. Hurricane Irene Facts: A Region-by-Region Look at the Storm's Toll. Huffington Post. [web page] located at: http://www.huffingtonpost.com/2012/08/27/hurricane-irene-damage-statistics-2011_n_1832342.html.
4 Associated Press. 2011. Hurricane Irene Deaths. Huffington Post. [web page] located at: http://www.huffingtonpost.com/2011/08/28/hurricane-irene-deaths_n_939421.html.
5 Jonkman, S.N. and J.K. Vrijling. 2002. Loss of life models for sea and river floods. Flood Defence. Wu et al. (eds) Science Press, New York Ltd.
6 Ibid.
7 Ibid.
8 Brazdova, M. and J. Riha. 2014. A simple model for the estimation of the number of fatalities due to floods in central Europe. Nat Hazards Earth Syst Sci. 14. June 12.

rise. Additional data required to supplement the Brno approach include standard life safety values from the Federal Aviation Administration (FAA): the FAA's Willingness to Pay value for one fatality is $5.8 million. The Federal Emergency Management Agency (FEMA) has acknowledged the validity of the life safety values and permits their use in benefit cost analyses. In addition, material loss information from Direct Physical Damage - Buildings evaluation was used in this approach.

Detailed Approach for Fatalities

The Brno approach to estimate loss of life is based on three main factors: material loss (in dollars), population preparedness, and warning. The relationship of these factors is expressed in the equation presented below. There are, of course, additional factors that are important to consider in estimating the loss of life in a natural hazard event. Nevertheless, factors such as debris, climatic conditions, water quality, and time of day, were not available for Brno's analysis due to a lack of data.

The equation for fatality estimates is presented below:

$$LOL = 0.075 * D^{0.384} * (P + 2)^{-3.207} * (W + 2)^{-1.017}$$

Where:

LOL: Loss of life

D: Material Loss (in dollars)

P: Population preparedness

W: Warning

D Factor

The D factor (material loss) consists of building damage and contents loss; both values are determined through the approach to estimate Direct Physical Damage (Buildings). For the purposes of this analysis, only structure damage and the damage of contents and inventory within such structures are evaluated for the appropriate flood scenarios. Such losses are assumed to reflect both the destructive ability of the event and the number of endangered inhabitants. Damage to constructed assets, such as roads or utility systems, are not considered in this analysis. The D Factors for the scenarios analyzed are included in Table IV.1.4.2 below.

Table IV.1.4.2 D Factor for the 10%, 2%, and 1% Annual Chance Events

Cost	10% Annual Chance	2% Annual Chance	1% Annual Chance
Building Damage	$9,034,034.65	$18,144,614.58	$26,392,731.31
Contents Damage	$24,043,400.92	$47,228,096.29	$62,553,419.15
Inventory Damage	$1,830,570.75	$3,221,330.47	$3,756,260.78
Total Property Loss	$34,908,006.32	$68,594,041.34	$92,702,411.24

P Factor

Factor P (population preparedness) expresses the preparedness of the community for flood management and resiliency, and is intended to reflect the population's awareness of flooding and required preparations. This value is determined by rating eight sub-factors on a scale of -1 to 1 according to Figure 3 below.

Analysts interviewed Norfolk City planners and emergency management personnel in order to appropriately capture population preparedness. The City expects that Target Area residents are very knowledgeable about flood risk in their community, as they frequently experience nuisance flooding during small rain events. Nevertheless, larger events such as tropical storms and hurricanes may present potential issues with community preparedness and response. Thus the P Factor is evaluated for three flood scenarios: the 10%,-percent, 2%,-percent, and 1-percent annual chance flood events.

The following values for P_1 to P_8 were determined for this analysis (Error! Reference source not found.). Aggregated preparedness was determined using the formula $P = \frac{1}{8} * \sum_{i=1}^{8} Pi$, where *P* is the sub-factor score.[9]

Table IV.1.4.3 Evaluated P Values

P Subfactor	Factor Description	Evaluation of Existing Conditions (10%)	Evaluation of Existing Conditions (2%)	Evaluation of Existing Conditions (1%)
P_1	Flood awareness and general knowledge of hazards	0.5	0.5	-0.5
P_2	Flood memory	1.0	1.0	0.0
P_3	Existing flood documentation	1.0	1.0	1.0
P_4	Understanding of activities and behavior during floods	0.0	0.0	-0.5
P_5	Initiatives and activities of flood committees	1.0	1.0	1.0
P_6	Response to hydrological forecast	0.0	0.0	0.0
P_7	Response to flood warning	0.5	0.5	-0.5
P_8	Evacuation and rescue activities	0.5	0.5	0.5
	Aggregated Preparedness	**2.25**	**2.25**	**0.75**

9 Brazdova, M. and J. Riha. 2014. A simple model for the estimation of the number of fatalities due to floods in central Europe. Nat Hazards Earth Syst Sci. 14. June 12.

P_i	Score				
	−1.0	−0.5	0.0	0.5	1.0
P_1	No flood awareness or knowledge about flood hazard, sometimes ignorance	Poor awareness, underestimation of flood hazard	Common flood awareness	Fair knowledge about flood hazards obtained mostly from the media	Excellent knowledge about flood hazards via the media, education, training, etc.
P_2	Area never flooded, no experience with flooding	Area flooded decades ago, poor records concerning flood losses	Area flooded decades ago, good records concerning the risks	Flooding still in the memory of the population	Personal experience with flooding
P_3	Flood extent maps or flood management plans not available	Existing flood extent maps are outdated	Flood extent maps drawn up based on current hydrologic data, but only poor flood management plans exist	Flood extent maps drawn up, flood management and evacuation plans available	Flood extent maps drawn up, updated digital versions of flood management and evacuation plans available
P_4	Individuals have no idea about actions to take during floods	Limited (vague) understanding of what to do during floods	General understanding of what to do before and during a flood	Quite good knowledge of flood management plans and corresponding activities	Perfect knowledge of flood management plans and understanding of what to do in the event of flooding, good preparedness
P_5	No flood committee established	Flood committee established but not trained, only equipped with flood fighting facilities	Flood committee established and generally trained, poorly equipped with flood-fighting facilities	Only moderately experienced but trained committee with standard flood fighting facilities	Experienced and well-trained flood committee equipped with flood-fighting facilities
P_6	No response to hydrological forecast, no understanding or belief	Poor understanding of hydrological forecast and poor response	Approximate understanding of forecast and adequate response	Fair understanding of hydrological forecast and good response	Very good understanding of hydrological forecast and very good response
P_7	No response to warning, no idea about warning procedures and response	Only poor response to warning, warning system not trusted	Adequate response	Good response to warning	Immediate and fast response to warning
P_8	Rescue system does not exist, no staff or equipment available	Organized rescue system does not exist, volunteer basis, no trained staff available with randomly acquired equipment	Poorly organized but functioning rescue system, basic rescue equipment of adequate quality	Functioning rescue system, trained staff with equipment of fair quality	Efficiently functioning rescue system, well-trained, experienced and well-equipped personnel

Figure IV.1.4.1 P Factor Descriptions

W Factor

Factor W (warning) includes those factors that influence warning of the community that an event is forecasted. The contributing factors include a hydrological forecast, the type of warning system employed, the speed of flooding, and the rate of water level rise. The scale of sub-factors is included in Figure IV.1.4.2 below.

W_i	Score				
	−1.0	−0.5	0.0	0.5	1.0
W_1	No hydrologic forecast, forecast not possible (e.g. at small catchments)	Only vague and general forecast	General forecast for medium size catchment	Hydrologic forecast provided in a standard way by hydrologic services	Reliable hydrologic forecast based on contemporary technical and modelling techniques
W_2	Flood may arrive within several tens of minutes	Flood arrives faster than in 45 min	Flood arrives within several hours	Flood arrives within 1 day	Flood arrives within several days
W_3	Warning system does not exist	Poorly designed and functioning warning system	Only moderately reliable warning system	Fully functioning traditional warning system	Sophisticated warning system including digital online alarm systems
W_4	Water rises at a rate of several metres per hour (floods in 1998, 2009)	Water level rise about 1 m per hour (small catchments in 2013)	Rate of several metres per day	About 1 m per day (floods in 1997, 2002)	Water level rise of several metres over several days

Figure IV.1.4.2. W Factor Descriptions

To evaluate factor W_4, water rise rates were determined based on the storm event hydrographs in Figure 3 through 5. These hydrographs show the 1%, 2%, and 10% annual chance events, plus sea level rise, compared to Hurricane Irene.

Evaluations for W_1 to W_4 values for each flood scenario are provided in Table 4. The aggregated effect of Factor W was evaluated using the following calculation:

$$W = \frac{1}{4} * \sum_{i=1}^{4} Wi,$$

where W is the sub-factor score.[10]

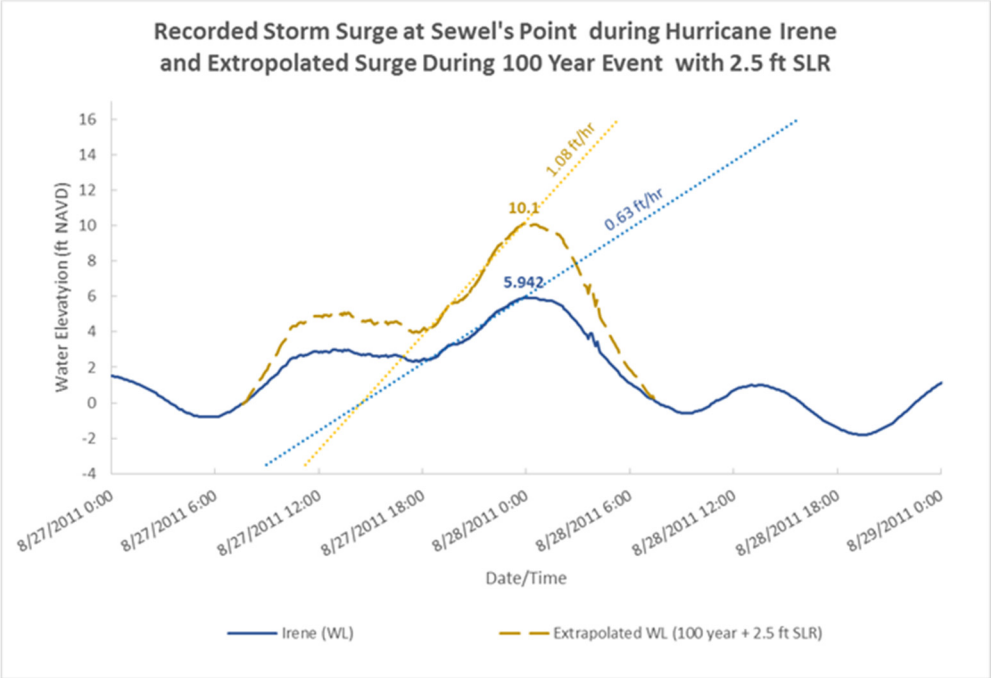

Figure IV.1.4.3 Hydrograph of 1% Annual Chance Even plus Sea Level Rise

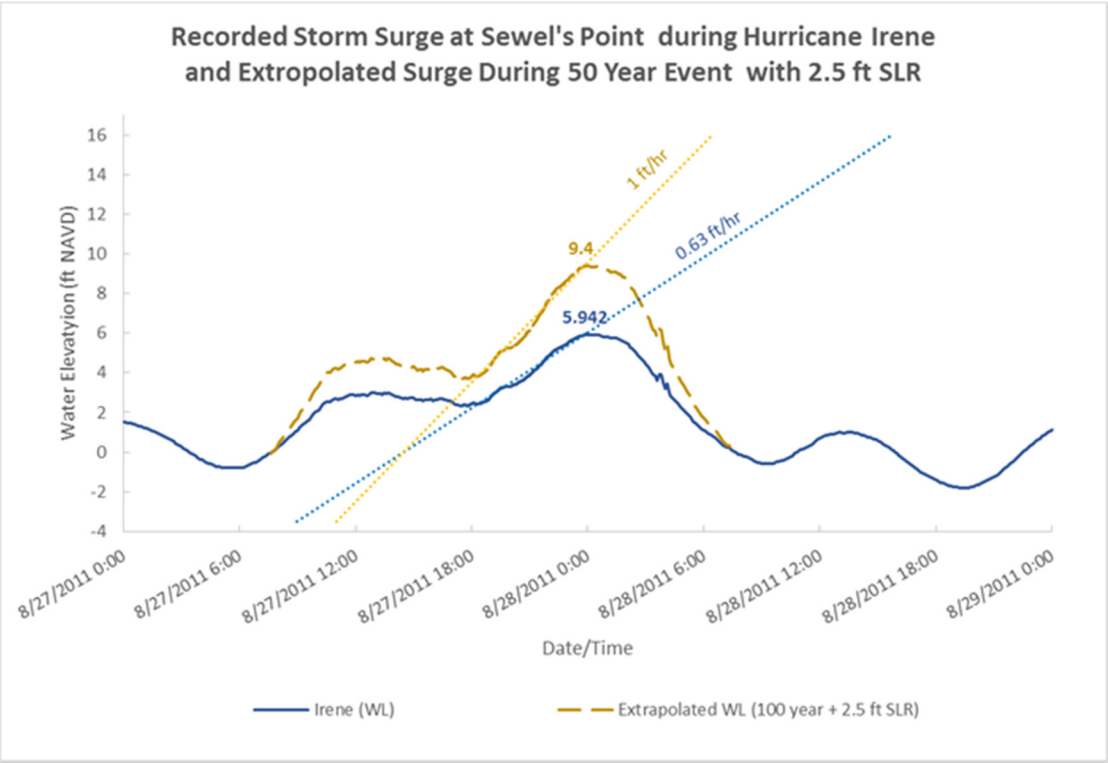

Figure IV.1.4.4 Hydrograph of 2% Annual Chance Event plus Sea Level Rise

[10] *Brazdova, M. and J. Riha. 2014. A simple model for the estimation of the number of fatalities due to floods in central Europe. Nat Hazards Earth Syst Sci. 14. June 12.*

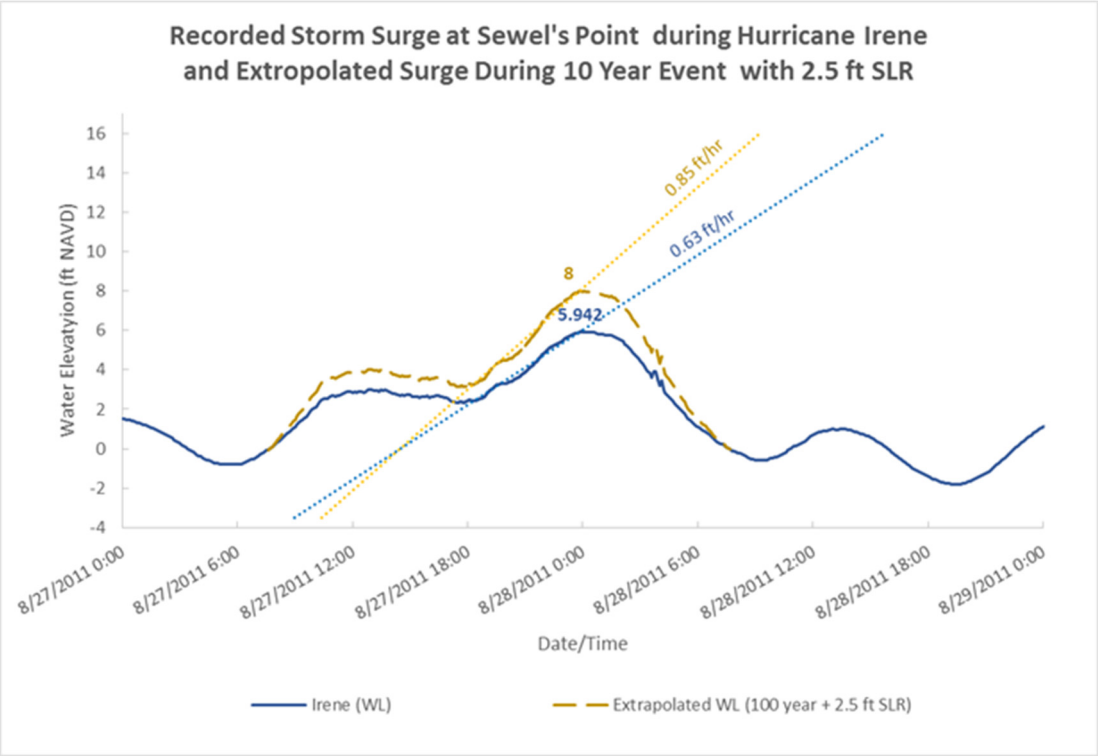

Figure IV.1.4.5 Hydrograph of 10% Annual Chance Event plus Sea Level Rise

Table IV.1.4.4 W Values

W Subfactor	Subfactor Description	Evaluation of Existing Conditions (10%)	Evaluation of Existing Conditions (2%)	Evaluation of Existing Conditions (1%)
W_1	Reliability of hydrological forecast	0.5	0.5	0.5
W_2	Speed of flood arrival	0.0	0.0	0.0
W_3	Warning system	1.0	1.0	1.0
W_4	Rate of water level rise	0.0	0.0	0.0
	Total	**0.875**	**0.875**	**0.875**

Limitations, Uncertainties, Assumptions, Sensitivities

- Although a large cause of lost life during natural hazard events, road damages that result from flooding are not incorporated into the analysis. Therefore, the results presented do not include casualties related to road closures or damage.
- Loss of life post-disaster can be affected by many factors not considered in this methodology, including the financial and physical health of the population, mental stress and anxiety, failure to obey or untimely evacuation orders, structure vacancy, and other factors not considered.
- Injuries are not considered in this analysis due to a lack of historical data that can be reasonably applied to the Target Area.

Detailed Results

Results are obtained by plugging the factors (D, P, and W) into Equation 1, repeated below for ease of reference. The result of the calculations for each annual chance event evaluated is listed below in Table IV.1.4.5.

$$LOL = 0.075 * D^{0.384} * (P + 2)^{-3.207} * (W + 2)^{-1.017}$$

Where:

LOL: Loss of life

D: Material Loss (in dollars)

P: Population preparedness

W: Warning

Table IV.1.4.5. Expected Loss of Life per Flood Scenario Evaluated

Annual Chance Event	Expected Loss of Life
10 percent	0.79
2 percent	0.25
1 percent	1.17

As referenced above, the FAA's life safety value is $5,800,000 per death. This value can be applied to the expected loss of life to determine the total cost of the lost lives for the BCA. This is considered a loss avoided because the proposed project would prevent the casualties estimated by the methodology.

Incorporation into the BCA

The casualty values reported above represent expected fatality losses avoided for the entire Target Area. The benefits for the Target Area as a whole were annualized and given a net present value to incorporate into the BCA.

Table IV.1.4.6. Annualized and Net Present Values for Casualties Benefits

Category	10% Annual Chance Event	2% Annual Chance Event	1% Annual Chance Event	Annualized	NPV
Study Area Fatalities	$4,566,651.11	$1,465,363.06	$6,796,636.41	$553,938.74	$7,644,504.13

Mental Stress and Anxiety Benefits

Mental Stress and Anxiety

Natural disasters threaten or cause loss of health, social, and economic resources, which leads to psychological distress.[11] Literature indicates that individuals who experience a high number of stressors, such as property damage or displacement, are more likely to experience symptoms of mental illness, post-traumatic stress disorder (PTSD), and higher levels of stress and anxiety.[12] Those with initially low levels of health, social, or economic resources, such as the elderly or low-to medium-income (LMI) individuals, are more vulnerable to the negative impacts of natural disasters and tend to experience relatively steeper declines in emotional and physical health.[13] Furthermore, the loss of social, health, and economic resources after a natural disaster is associated with declines in psychosocial functioning,[14] the interaction related to one's psychological development in, and contact with, a social environment.

As mental health issues increase after a disaster, so will mental health treatment costs. Increased health care costs burden individuals and society as a whole.[15] The overwhelming majority of the Target Area is characterized as LMI and includes various types of vulnerable populations (See **Section III Existing Conditions**); these populations are at higher risk to mental health impacts after natural disasters. LMI residents have fewer resources to prepare for disaster events and are less prepared to invest in recovery. This can lead to a progressive depletion of resources and hamper recovery efforts.[16] Flood protection measures will reduce damage to homes, public transportation, and critical systems, and reduce risk of mental illness post-disaster, as people will be subject to fewer stressors.

Existing Conditions

Numerous studies have shown that there are mental health impacts after disasters, but only a few studies have tried to place a monetary value on these impacts after disaster events. The American Red Cross (ARC) estimates that 30 to 40% of an impacted population will need mental health assistance.[17] Galea (2005) has found that 1 to 11% of an impacted population will experience PTSD.[18] Wang et al (2007) conducted a survey of Hurricane Katrina survivors and found that 31% of respondents met the criteria for a mood or anxiety disorder.[19] Further, research conducted by Schoenbaum et al (2009) demonstrated that the prevalence of

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[11] Hobfoll, S.E. 1989. Conservation of resources: A new attempt at conceptualizing stress. American Psychologist. 44:513–524. [PubMed: 2648906].

[12] Rhodes, J., Chan, C.,Pacson, C., Rouse, C.E., Waters, M., and E. Fussell. 2010. The Impact of Hurricane Katrina on the mental and physical health of low-income parents in New Orleans. Am J Orthopsychiatry. April; 80(2): 237-247.

[13] Galea, S., Tracy, M., Norris, F., and S.F. Coffey. 2008. Financial and social circumstances and the incidence and course of PTSD in Mississippi during the first two years after Hurricane Katrina. Journal of Traumatic Stress. 21:357–368. [PubMed: 18720399]

[14] Sattler, D.N., Preston, A., Kaiser, C.F., Olivera, V.E., Valdez, J., and S. Schlueter. 2002. Hurricane Georges: A crossnational study examining preparedness, resource loss, and psychological distress in the U. S. Virgin Islands, Puerto Rico, Dominican Republic, and the United States. Journal of Traumatic Stress. 15:339–350. [PubMed: 12392221]

[15] Office of the Assistant Secretary for Planning and Evaluation. Undated. The Effect of Health Care Cost Growth on the U.S. Economy. United States Department of Health and Human Services. Pages 46 – 49.

[16] Sümer, N., Karancı, A.N., Berument, S.K., and H. ve Güneş. 2005. The role of personal resources in predicting psychological distress following the 1999 Marmara, Turkey Earthquake. Journal of Traumatic Stress. 18:331–342. [PubMed: 16281230]

[17] Welker, Catherine. 2011. American Red Cross Liaison Officer to FEMA Headquarters Disaster Services. Personal correspondence, December 6.

[18] Galea, Sandro; Nandi, Arijit Nandi; and David Vlahov. 2005. The Epidemiology of Post-Traumatic Stress Disorder after Disasters. Epidemiologic Reviews, (July) 27 (1): 78-91. Located online at: http://epirev.oxfordjournals.org/content/27/1/78.full.pdf+html.

[19] Wang, Phillip; Gruber, Michael; Powers, Richard; Schoenbaum, Michael; Speier, Anthony; Wells, Kenneth; and Ronald Kessler. 2007. Mental Health Service Use among Hurricane Katrina Survivors in the Eight Months After the Disaster. Psychiatric Service. Vol. 58 Number 11. November.

mental health issues after Hurricanes Katrina and Rita was 6% for major health issues and 26% for mild to moderate health issues.[20]

Eighty-six percent of the Target Area is characterized as LMI, and vulnerable populations in the Target Area include seniors, people with disabilities, and children. For more details, see Part III Existing Conditions and Attachment F Appendices. These populations are at a higher risk of mental health issues after a disaster event, as they may have lower levels of health, social, or economic resources.[21]

Historical Losses

Mental health impacts of previous natural disasters provide a foundation upon which projected mental health costs can be estimated. While there is little information regarding mental health impacts post-Irene, the mental health impacts of similar events, such as Hurricanes Sandy or Katrina, support an understanding of the impacts that could occur in Norfolk. Modelers have determined Irene to be a 17 year event. For more detail, see Hazard Analysis in this Part IV Benefits Included in the Benefit Cost Ratio, Resiliency Benefits. Hurricane Sandy is considered to be 50- to 100-Year event,[22] and studies have found Katrina to have a 21 year return period.[23] Therefore, given the extent of impact in Norfolk after Irene, the impacts of Sandy and Katrina provide a reasonable understanding of what could happen in Norfolk during similar and or greater events. Furthermore, Norfolk's Coastal Adaptation and Community Transformation Plan intends to protect against the impacts of a 100-year storm event, meaning the mental health impacts described throughout this analysis could be prevented in the future.

After Hurricane Katrina, low-income families were disproportionately stranded in the City or shelters, which increased the chance of experiencing deprivation, stress, and fear.[24] Research conducted by Rhodes et al (2010) found that prevalence rates for low–income survivors for mild to moderate mental illness rose from 23.5% to 37.5%, prevalence for severe mental illness rose from 6.9% to 14.3%, and the prevalence of high perceived stress rose from 20.2% to 30.9%. Additionally, 47.7% of the respondents were classified as having probable PTSD. The New York Times reported that Beth Israel Hospital Medical Center in Lower Manhattan saw a 69% increase in psychiatric patients in the November following Hurricane Sandy, and, in Brooklyn, Maimonides Medical Center reported a 56% increase in psychiatric emergency room visits in the month following the storm.[25]

Research conducted after Hurricanes Katrina and Sandy provides evidence of increased mental health illness post-disaster and rates at which these increases are likely to occur. The cost of treatment can be estimated using this research.

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[20] *Schoenbaum, Michael; Butler, Brittany; Kataoka, Sheryl; Norquist, Grayson; Springgate, Benjamin; Sullivan, Greer; Duan, Naihua; Kessler, Ronald; and Kenneth Wells. 2009. Promoting Mental Health Recovery After Hurricanes Katrina and Rita: What Can Be Done at What Cost. Archives of General Psychiatry, Vol. 66, #8, August.*

[21] *Galea S, Tracy M, Norris F, and S.F. Coffey. 2008. Financial and social circumstances and the incidence and course of PTSD in Mississippi during the first two years after Hurricane Katrina. Journal of Traumatic Stress. 21:357–368. [PubMed: 18720399]*

[22] *Sweet, Zervas, Gill, and Park. Hurricane Sandy Inundation Probabilities Today and Tomorrow. Undated. Located at: http://www1.ncdc.noaa.gov/pub/data/cmb/bams-sotc/extreme-events/2012/BAMS-Extremes-of-2012-Section-06.pdf*

[23] *Elsner J.B., Jagger T.H., and Tsonis, A.A., December 2005. Estimated Return Periods for Hurricane Katrina. Located at: http://myweb.fsu.edu/jelsner/PDF/Research/ElsnerJaggerTsonis2006.pdf*

[24] *Spence PR, Lachlan KA, Griffin DR. Crisis communication, race, and natural disasters. Journal of Black Studies. 2007; 37:539–554.*

[25] *Manuel, J. 2013. The Long Road to Recovery. Environmental Health Impacts of Hurricane Sandy. Environmental Health Perspectives. Vol. 121. Number 5. May 1.*

Expected Impacts

Data Sources

The Federal Emergency Management Agency's (FEMA) Final Sustainability Benefits Methodology Report[26] provided a method to calculate benefits related to avoided mental stress and anxiety costs. 2013 American Community Survey[27] 5-year estimates provided population data, which were distributed among buildings in the Resiliency Analysis. Flood depths obtained from the Resiliency Analysis were used to determine impacted buildings, and therefore, residents.

Detailed Approach

Benefits of avoided mental health treatment costs can be based on three factors: cost, prevalence, and course. Prevalence is the percentage of people who experience mental health problems after a disaster event, and course is the rate at which mental health symptoms reduce or increase over time. Cost is simply the cost of treatment to those who seek it.

Schoenbaum (2009) provides prevalence percentages and mental health expenses, which FEMA has used to derive a standard value for mental stress and anxiety costs. Prevalence percentages are adjusted over different time periods. Mild to moderate impacts will reduce over time as treatment is provided, and severe mental health problems may persist much longer, possibly never being fully resolved.[28] For this reason, mild to moderate prevalence percentages reduce over time, while severe prevalence percentages remain consistent over time. Kessler (2008) supports this trend, reporting increasing rates of PTSD and severe mental health issues between 6 months after a hurricane and approximately 1 year after.[29] It is possible, if left untreated, that PTSD and severe mental illness become more entrenched over time, while mild or moderate mental illness symptoms can be expected to attenuate.[30]

Table IV.1.4.7 Prevalence Rates

Time after Disaster	Severe	Mild/Moderate
7-12 months	6%	26%
13-18 months	7%	19%
19-24 months	7%	14%
25-30 months	6%	9%

Source: FEMA Final Sustainability Benefits Methodology Report.

Schoenbaum provides an estimate of treatment costs in an ideal scenario where all needs are met. FEMA argues that treatment costs from the study must be adjusted to consider only those with mental health

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[26] *Federal Emergency Management Agency. Final Sustainability Benefits Methodology Report. August 23, 2012.*

[27] *United States Census. American Community Survey. 2013. Located at: https://www.census.gov/programs-surveys/acs/data.html*

[28] *Schoenbaum, Michael; Butler, Brittany; Kataoka, Sheryl; Norquist, Grayson; Springgate, Benjamin; Sullivan, Greer; Duan, Naihua; Kessler, Ronald; and Kenneth Wells. 2009. Promoting Mental Health Recovery After Hurricanes Katrina and Rita: What Can Be Done at What Cost. Archives of General Psychiatry, Vol. 66, #8, August.*

[29] *Kessler RC, Galea S, Gruber MJ, Sampson NA, Ursano RJ, and S. Wessely. 2008. Trends in mental illness and suicidality after Hurricane Katrina. Molecular Psychiatry. 13:374–384.*

[30] *Rhodes, J., Chan, C.,Pacson, C., Rouse, C.E., Waters, M., and E. Fussell. 2010.. The Impact of Hurricane Katrina on the mental and physical health of low-income parents in New Orleans. Am J Orthopsychiatry. April; 80(2): 237-247.*

problems who will actually seek out treatment (41%).[31] FEMA uses the following steps to adjust total treatment costs from Schoenbaum for percentage of individuals who seek treatment and prevalence.

$$Cost\ per\ person\ seeking\ treatment = Treatment\ cost\ per\ person * prevalence * 0.41$$

This methodology is applied to each time period adjusting for prevalence. The values provided by FEMA have been normalized using the Consumer Pricing Index (CPI) Inflation Calculator,[32] and the costs for both severe and mild/moderate mental health problems over each time period are added together to provide a total treatment cost of $2,706.96 for 30 months. Table 9 provides a summary of treatment costs in current dollars.

Table IV.1.4.8 Cost of Mental Health Treatment after a Disaster

Time after Disaster	Severe	Mild/Moderate	Total per person
7-12 months	$ 220.00	$ 691.27	$ 911.27
13-18 months	$ 256.66	$ 451.98	$ 708.64
19-24 months	$ 256.66	$ 372.22	$ 628.88
25-30 months	$ 218.89	$ 239.28	$ 458.17
		Total	**$ 2,706.96**

Limitations

- Research analysis is limited to 30 months after a disaster; therefore, estimated losses avoided are limited to this time period. Mental health avoided losses beyond 2.5 years after a disaster, though expected, are not valued in this analysis.
- Benefits are calculated for only 41% of the impacted population because research states that only this portion of the population with mental health issues will seek treatment. This significantly lowers the calculated treatment costs and does not consider the full costs to society. The Lost Productivity methodology provided within this BCA may partly address this limitation.

Detailed Results

The results presented below are those for the 1% annual chance event, as this is the level of protection of Norfolk's Coastal Adaptation and Community Transformation Plan. The total number of residents who experience flooding are considered impacted for this analysis, and are included in the total population that may seek treatment. The cost of treatment ($2,706.96) was applied to this population to determine mental stress and anxiety costs.

Table IV.1.4.9 Results by Watershed Transformation Project

Watershed	Residents That May Seek Mental Health Illness Treatment*	Mental Stress and Anxiety Costs
Newton's Creek	3,135	$ 8,485,515.48
Ohio Creek	842	$ 2,279,327.56
Total	**3,977**	**$ 10,764,843.03**

**The percentage seeking treatment (41%) is factored into the treatment cost and not the actual number of people, so this is the number of people who may seek treatment.*

[31] *Wang, Philip S., MD, DrPH; Lane, Michael, MS; Olfson, Mark, MD, MPH; Pincus, Harold A., MD; Wells, Kenneth B., MD, MPH; and Ronald C. Kessler, PhD. 2005. Twelve-Month Use of Mental Health Services in the United States: Results from the National Comorbidity Survey Replication. Archives of General Psychiatry, v. 62, June.*

[32] *U.S. Bureau of Labor Statistics. Undated. CPI Inflation Calculator. [web page] Located at: http://www.bls.gov/data/inflation_calculator.htm.*

Future Trends

As population in the area grows, the population that is subject to possible mental health issues after a disaster can be expected to increase. Additionally, the increasing intensity of storms will put more area at risk to the impacts of natural disasters, adding to the population at risk to mental health impacts. An increase in mental health treatment due to population growth is not considered in this analysis.

Incorporation into the Benefit Cost Analysis

The expected benefits provide an economic value for the first 30 months only because there was insufficient literature to estimate impacts beyond 30 months. Because of this, FEMA adds the results for the recurrence interval at which the project will protect as a lump sum to the net present value rather than determine annual benefits.[33] For this analysis, treatment costs for the 10-, 50-, and 100- year event are multiplied by the probability of occurrence (for each event) and added together to obtain annual results, with the assumption that benefits have only been determined for the first 2.5 years after an event. The annual results are integrated with other losses avoided to determine total benefits, net present value, and the benefit cost ratio. The net present value is calculated using a present value coefficient for a 50-year project useful life at a 7% discount rate.[34]

Table IV.1.4.10 Expected Losses for 2013 Population by Annual Chance Flood Event

Watershed	Expected Losses by Percent Annual Chance Flood Scenario				Benefits
	10%	2%	1%	Annualized	Net Present Value
Newton's Creek	$1,310,729.37	$2,839,832.93	$8,485,515.48	$272,724.75	$138,511,254.56
Ohio Creek	$232,301.95	$1,663,011.68	$2,279,327.56	$79,283.70	$43,252,415.55
Total	**$1,543,031.33**	**$4,502,844.60**	**$10,764,843.03**	**$352,008.46**	**$181,763,670.10**

[33] *Federal Emergency Management Agency. Final Sustainability Benefits Methodology Report. August 23, 2012.*

[34] *Association of Floodplain Managers. 2008. Discount Rate. Page 3. Located at: http://www.floods.org/PDF/WhitePaper/ASFPM_Discount_%20Rate_Whitepaper_0508.pdf*

Lost Productivity

Lost Productivity

Work productivity can be lost due to mental illness. Kessler and Frank (1997) found that the average prevalence of psychiatric work loss days[35] is 6 days per month per 100 workers, and work cutback days[36] is 31 days per month per 100 workers.[37] Further research conducted by Kessler et al (2008) found that respondents with serious mental illness will experience a $16,306 reduction in 12-month earnings compared to respondents without mental illness[38], and a study of 19 countries by the World Health Organization showed a lifetime 32% reduction in earnings for respondents with mental illness.[39] The historical impacts described in the previous section indicate that mental health issues will increase after a disaster, and this, paired with research related to lost productivity due to mental illness, indicates that economic productivity can be impacted by an increase in mental health issues post-disaster.[40]

The implementation of Norfolk's Coastal Adaptation and Community Transformation Plan will reduce the number of stressors (such as damage to homes) post-disaster, in turn reducing mental health impacts. Fewer mental health impacts will reduce lost work productivity. Low- to moderate- income (LMI) individuals and vulnerable populations are at greater risk to experience mental health impacts after a natural disaster because they have initially lower levels of health, social, and economic resources. The protection of life, property, and critical infrastructure for LMI and vulnerable populations allows these groups to recover more quickly after disasters, preventing increased psychological distress, stress, and symptoms of mental illness.

Existing Conditions

The Target Area is home to 2,825 jobs, and a large number of those jobs are held by LMI workers. Industries in the Target Area likely to employ LMI workers include construction, manufacturing, wholesale and retail trade, transportation and warehousing, and accommodation and food service.

Additionally, a large number of LMI households and vulnerable populations that reside in the Target Area are subjected to mental health impacts post-disaster, which in turn makes them vulnerable to work productivity losses.

For more information regarding jobs and vulnerable populations in the Target Area, see Part III Existing Conditions.

Historical Impacts

Hurricane Irene caused substantial economic loss, possibly between 4.7 billion and 40 billion dollars throughout the northeast.[41] The Phase 1 application states, "345 homes in the contiguous sub-county target area sustained damage – 187 dwellings affected, 2 residential dwellings destroyed, 28 residential dwellings

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[35] A psychiatric work loss day is the complete inability to work or perform normal activities due to mental illness or its treatment.

[36] Work cutback day is reduced work activity due to mental illness or its treatment.

[37] Kessler RC, Frank RG. The impact of psychiatric disorders on work loss days. Psychol Med. 1997 Jul; 27(4):861-73. PubMed PMID: 9234464.

[38] Kessler et al. Individual and Societal Effects of Mental Disorders on Earnings on the United States: Results from the National Comorbidity Survey Replication. American Journal of Psychiatry. 165:6. June 2008.

[39] Levinson, et al. 2010. Associations of Serious Mental Illness with Earnings: Results from the WHO World Mental Health Surveys. British Journal of Psychiatry. August; 197(2): 114–121. http://www.ncbi.nlm.nih.gov/pmc/articles/PMC2913273

[40] Insel, Thomas. Assessing the Economic Costs of Serious Mental Illness. American Journal of Psychiatry. 165:6 June 2008. / Kessler et al. Individual and Societal Effects of Mental Disorders on Earnings on the United States: Results from the National Comorbidity Survey Replication. American Journal of Psychiatry. 165:6. June 2008.

[41] Morici: Economic Impact of Hurricane Irene. 28 August 2011. Located at: http://www.cnbc.com/id/44305225 ; NBC News. Hurricane Irene to deliver blow to economy. Web page. Located at: http://www.nbcnews.com/id/44292442/ns/business-us_business/t/hurricane-irene-deliver-blow-economy/#.VgCLud9Viko

sustained major damage, and 128 residential dwellings sustained minor damage." As previously stated, such impacts can increase mental health issues post-disaster. Levinson et al (2010)[42] and Kessler (1997) reveal that mental health issues can impact work productivity, and Schoenbaum et al (2009)[43] shows that mental health issues increase after a disaster. Therefore, it is reasonable that an increase in mental health issues, such as stress, anxiety, and post-traumatic stress disorder (PTSD), after a disaster can contribute to the economic losses associated with disaster events. For more information regarding mental health impacts post disaster, see the Mental Stress and Anxiety section. For more information on the economic impacts of Hurricane Irene, see Part III Existing Conditions.

Expected Impacts

Primary Resources and Data Sources

The Federal Emergency Management Agency's (FEMA) Updated Social Benefits Methodology Report provided the approach taken to determine the benefits calculated in this section. Other data sources include:

- 2013 American Community Survey 5-year estimates: average number of workers per household and income characteristics
- City of Norfolk Real Estate Assessor: number of residential units
- Flood depths, calculated in the Resiliency Analysis, were used to determine the number of impacted buildings.

Detailed Approach

Analysts researched several sources of literature related to lost productivity due to mental illness, and found that Levinson et al (2010)[44] conducted research using the World Health Organization's Mental Health Surveys conducted in 19 countries. The study found that individuals in the United States with mental health illnesses experience as much as a 25.5% reduction in earnings. The national employment compensation in March 2015 was $33.49 per hour.[45] This multiplied by the average number of hours worked per day (6.9)[46] produces a daily value of $231.08. Thus, a 25.5% reduction in earnings of $58.90 daily, or $1,767.77 monthly.

Time periods post-disaster are based on prevalence factors presented in the Mental Stress and Anxiety section. The number of months of each time period after the disaster (column 1 of Table 11) is applied to the monthly productivity loss ($1,767.77) to determine possible lost productivity for that time period. Time periods are based on prevalence factors provided by Levinson. Prevalence factors are used to adjust productivity loss, as only a portion of the population will experience mental health impacts post-disaster. The prevalence factor is based on severe mental health issues because there is insufficient literature to document the impacts of mild/moderate mental health issues on productivity.[47]

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[42] *Levinson, et al. 2010. Associations of Serious Mental Illness with Earnings: Results from the WHO World Mental Health Surveys. British Journal of Psychiatry. August; 197(2): 114–121. http://www.ncbi.nlm.nih.gov/pmc/articles/PMC2913273*

[43] *Schoenbaum, Michael; Butler, Brittany; Kataoka, Sheryl; Norquist, Grayson; Springgate, Benjamin; Sullivan, Greer; Duan, Naihua; Kessler, Ronald; Wells, Kenneth. 2009. Promoting Mental Health Recovery After Hurricanes Katrina and Rita: What Can Be Done at What Cost. Archives of General Psychiatry, Vol. 66, #8, August 2009.*

[44] *Levinson, et al. 2010. Associations of Serious Mental Illness with Earnings: Results from the WHO World Mental Health Surveys. British Journal of Psychiatry. August; 197(2): 114–121. http://www.ncbi.nlm.nih.gov/pmc/articles/PMC2913273*

[45] *Employer Costs for Employee Compensation. March 2015. United States Department of Labor, Bureau of Labor Statistics.*

[46] *Average week hours of overtime of all employees. Web page. Located at: http://www.bls.gov/news.release/empsit.t18.htm*

[47] *FEMA. 2014. Updated Social Benefits Methodology Report. December 18.*

Table IV.1.4.11 Productivity Loss Per Worker

Time After Disaster	Potential Productivity Loss	Prevalence Factor	Productivity Loss per Worker
1-12 months (12 mo.)	$21,213.23	6%	$1,272.79
13-18 months (6 mo.)	$10,606.62	7%	$742.46
19-24 months (6 mo.)	$10,606.62	7%	$742.46
25-30 months (6 mo.)	$10,606.62	6%	$636.39
		Total Productivity Loss per Worker	**$3,394.10**

The total lost productivity per worker for 30 months is applied to the number of wage-earning residents who will experience flooding during a 1% annual chance event, the level of protection of the project. According to the 2013 American Community Survey 5-year estimates, it can be inferred the average number of workers per household in Norfolk City, Virginia is 1.19 workers.[48] This figure is applied to the number of households impacted during the 1% annual chance event to determine the number of wage earning residents who will experience flooding. The average number of people per household (2.43[49]) along with population data was used to determine number of households in the Target Area.

Table IV.1.4.12 Number of Wage Earning Residents

Watershed	Number of Households	Number of Wage Earning Residents
Newton's Creek	5,488	6,530
Ohio Creek	1,124	1,337
Total	**6,611**	**7,867**

Limitations, Uncertainties, Assumptions, Sensitivities

- The average number of workers per household for Norfolk City is applicable to the Target Area. The city is the smallest level of geography at which household and working population data is available.
- Value is provided for the first 30 months only because there is insufficient literature available to analyze longer periods of time.
- Prevalence rates are based on severe mental health issues because there is insufficient literature related to the impacts of mild or moderate mental health issues on work productivity. Therefore, results are considered conservative.

[48] *US Census 2013 American Community Survey 5-Year Estimates. Undated. Located at: http://factfinder.census.gov/faces/nav/jsf/pages/community_facts.xhtml#none*

[49] *US Census 2013 American Community Survey 5-Year Estimates. Undated. Located at: http://factfinder.census.gov/faces/nav/jsf/pages/community_facts.xhtml#none*

Detailed Results

The table below summarizes the loss of productivity by watershed for the 1% annual flood chance, as it is the level of protection of Norfolk's Coastal Adaptation and Community Transformation Plan.

Table IV.1.4.13 Lost Productivity for the 100-Year Event

Watershed	Number of Wage Earning Residents	Productivity Loss
Newton's Creek	6,530	$5,210,403.29
Ohio Creek	1,337	$1,399,586.84
Total	**7,867**	**$6,609,990.13**

Future Trends

As the area impacted by increasingly intense storms grows in size and population, the number of people affected by mental health issues after a disaster will increase; therefore, impacts to work productivity will increase. This increase in work productivity impacts is not accounted for in this analysis.

Incorporation into Benefit Cost Analysis

The annual value is treated in the same manner as mental health treatment costs and is integrated into the benefit cost ratio.

Table IV.1.4.14 Expected Losses for Population in 2013 by Annual Flood Chance Event

Watershed	Expected Losses by Percent Annual Chance				Benefits
	10%	2%	1%	Annualized	Net Present Value
Newton's Creek	$804,833.68	$1,743,756.74	$5,210,403.29	$167,462.54	$2,311,107.92
Ohio Creek	$142,641.52	$1,021,147.33	$1,399,586.84	$48,682.97	$671,861.27
Total	$947,475.20	$2,764,904.08	$6,609,990.13	$216,145.50	$2,982,969.19

Relocation and Economic Loss of Function

Relocation and Economic Loss of Function

Relocation costs and economic loss of function (ELOF) costs are two consequences of displacement that result from disaster impacts. Relocation costs are associated with moving a household or a business to a new location and resuming life or business in that new location. ELOF cost is associated with the interruption of a business or the removal of a piece of real estate from the market as a result of disaster impacts. Both costs can be derived as a function of displacement time.

The value of displacement time can be measured in two ways: restoration time and ELOF. Restoration time is "time for physical restoration of the damage to the building, as well as time for clean-up, time required for inspections, permits and the approval process, as well as delays due to contractor availability."[50] This analysis assumes that all interrupted businesses are eventually able to return to business as usual. As such, ELOF is represented as proportions of restoration time based on the business type and extent of damage. Some businesses may be unable to relocate while they are displaced and will experience ELOF for this entire period; some may relocate and resume business elsewhere. Impacted businesses or residents may thus incur both, one, or neither of relocation and ELOF costs.

Care must be taken to ensure that these two costs are accounted for fully and that there is no duplication of benefits between the two values,[51] particularly in cases where both costs are incurred. For example, a business may have to restock its damaged inventory before being able to relocate and start operations in a new space, thus incurring both ELOF and relocation costs. The purpose of this methodology is to describe the approach taken to account appropriately for such costs associated with displacement.

Sources

Analysts used methodologies from Hazus 2.1 to differentiate ELOF and restoration times, as well as the costs of relocation, supplemented with localized values. Specifically, analysts used the Flood Technical Manual (TM) calculation for relocation expenses and the Earthquake TM calculation for ELOF based on percent damage to the structure. The Earthquake TM is applicable because of the hazard neutral approach to loss of function; additionally, Hazus methodologies related to flood hazard are often built from methodologies developed for earthquake hazard. While the cause and extent of damage differ for these two hazard types, the consequences of such hazards (damage, displacement, loss of function) are generally the same. As such, the Flood TM will often refer to the Earthquake TM for greater detail; this was the case with detailed calculations necessary to determine ELOF.

The data necessary to calculate relocation and ELOF costs were gathered from the sources identified below:

- **Direct Physical Damages (Buildings).** Building damage, contents and inventory loss, and restoration time evaluated for each structure in the **Direct Physical Damages (Buildings)** section are used.
- **Hazus 2.1 One-time Disruption Cost Defaults.** Hazus provides one-time relocation costs per SF based on occupancy type. These costs are provided in 2006 dollars and have been normalized to 2015 dollars based on inflation.
- **2009-2013 American Community Survey 5-Year Estimates, Occupied Housing Units.** This dataset identifies the number of owner-occupied and rented residential structures in the Target Area. Hazus 2.1 default occupancy values were applied to commercial structures (See Appendix F-13).
- **Hazus 2.1 Construction Time Modifiers.** Modifiers represent median values for probability of business or service interruption for various occupancy classes based on damage state and restoration time.

50 Federal Emergency Management Agency. Undated. Multi-hazard Loss Estimation Methodology Flood Model Technical Manual. Page 14-25.
51 Economic loss is calculated as loss of output for industries with impacted structures. The methodology for calculating economic loss is detailed in a separate methodology.

- **FEMA BCA Toolkit 5.1[52].** Analysts extracted depth displacement tables from FEMA's BCA Toolkit to determine displacement time for structures based on flood depth. These tables were compared to restoration time ranges provided within the Hazus 2.1 Flood TM and found to be conservative in comparison (see Appendix F-7 Hazus Technical Manual Excerpts). It should be noted that these tables do not consider flooding below grade (see Assumptions).

Expected Impacts

Analysts followed a series of steps to determine expected relocation and ELOF impacts from storm surge consistent with that experienced during Hurricane Irene. To do so, an analysis was performed to identify structures expected to be impacted for the 10%, 2%, and 1% annual chance events. These structures were then assigned a percentage of owner-occupancy rates, rental rates, and damage state. Owner-occupancy and rental rates were based on local data and the structure's designated occupancy code; the damage state was assigned based on the percentage of structure damage calculated through the Direct Physical damages (Buildings) analysis. Table 15 below shows the percent damage threshold for each damage state assigned.

Table IV.1.4.15 Damage State Correlations

Damage State	None	Slight	Moderate	Extensive	Complete
Correlating Percent Damage Threshold	0%	1%	5%	25%	50%

Source: Hazus 2.1 Earthquake TM

The steps to identify expected relocation and ELOF impacts referenced above are described in more detail below:

1. *Evaluate restoration time.* Analysts correlated estimated flood depth within each structure to USACE depth displacement tables to estimate restoration times for each flood scenario (see Appendix F-11. Code Mapping).
2. *Occupancy Mapping.* Analysts mapped Norfolk Building Classes to Hazus Occupancy codes in order to make appropriate use of Hazus values (Appendix F-11. Code Mapping).
3. *Determine local rental rates by occupancy.* Local rent rates within the Target Area were researched and applied by occupancy. To establish local rent rates, analysts conducted an online survey of residential and commercial structures available for rent within the Target Area; Loopnet, Trulia, and Zillow (all online real estate services) were used to conduct the survey. Available rental units were categorized by commercial and residential uses, and then analysists calculated an average rent price per square foot per year for each use. The results show that the average annual lease per square foot for commercial properties is $11.53, and the average annual lease per square foot for residential properties is $10.17. These values were then converted to an average lease per square foot per day (Price/SF/Day) for use in the Relocation Expenses calculation outlined below.
4. *Process relocation expenses*. The Hazus Flood TM provides guidance to calculate displacement expenses, or disruption costs, to building occupants based on occupancy type using the following equation.

[52] *Federal Emergency Management Agency. 2015. Benefit Cost Toolkit Version 5.1. February 11. Located at: http://www.fema.gov/media-library/assets/documents/92923.*

$REL_i = \Sigma$ if $\%DAM - BL_{i,j} > 10\%$: $Fa_{i,j} * [(1 - \%OO_i) * (DC_1) + \%OO_i * (DC_i + RENT_i * RT_{i,j})]$

Where:

REL_i	=	Relocation costs for occupancy class i
$Fa_{i,j}$	=	Floor area of occupancy group I and depth j (in square feet)
$\%DAM - BL_{i,j}$	=	Percent building damage for occupancy I and water depth j, (from depth-damage function), if greater than 10%
DC_i	=	Disruption costs for occupancy i
$RT_{i,j}$	=	Recovery time (in days) for occupancy I and water depth j
$\%OO_i$	=	Percent owner occupied for occupancy i
$RENT_i$	=	Rental cost ($/ft^2/day) for occupancy i

It is important to note that the equation detailed above incorporates owner-occupied structures when calculating displacement values. The reason for this is that a renter who has been displaced would likely cease to pay rent to the building owner of the damaged property, and instead would pay rent to a new landlord. As such, the renter could reasonably be expected to incur no new rental expenses. Conversely, if the damaged property is owner-occupied, then the owner will have to pay for new rental costs in addition to any existing costs while the building is being repaired. This model assumes it unlikely that an occupant will relocate if a building is slightly damaged (less than 10% structure damage).

5. *Determine ELOF costs.* The ELOF expected to be incurred by businesses that occupy damaged structures was calculated using the following equation.

$LOF_{ds} = BCT_{ds} * MOD_{ds}$

Where:

LOF_{ds}	=	Loss of function for damage state
BCT_{ds}	=	Building construction for cleanup time for damage
MOD_{ds}	=	ELOF modifiers for damage state (Appendix F-7. Hazus Technical Manual Excerpts)

6. *Complete the analysis.* The analysis described above was completed for damages expected at four recurrence intervals: the 10%, 2%, and 1% annual chance flood events, including sea level rise.

Analysts used the ELOF values to then calculate the loss of output for businesses in various industries; another methodology provided by Hazus. The methodology for loss of output calculations, in addition to an economic impact analysis of such losses, is provided as a separate methodology.

Limitations, Uncertainties, Assumptions, and SensitivitiesIn taking care to appropriately identify restoration time and ELOF so that benefits are not duplicated when calculating relocation expenses and output losses, the following assumptions were made:

- Some businesses will choose to relocate their operations while structure damage is being repaired to minimize output loss. To do so, these businesses may rent additional space elsewhere, thus choosing to incur relocation costs during building restoration as opposed to economic losses; this scenario assumes that business output will remain the same upon relocation.
- ELOF does not occur until the building reaches greater than 10% structural damage, calculated in the Direct Physical Damages Evaluation.
- Analysts assume, in concurrence with Hazus 2.1, that businesses that qualify as entertainment (COM8), theatres (COM9), parking facilities (COM10), and heavy industry (IND1) will not relocate after a disaster due to the type of activities that take place in such structures. As such, no relocation costs are associated with these uses, though ELOF is associated with such uses.
- Depth displacement tables used in the analysis do not consider flooding below grade. Utilities often lie below structure the first floor elevation in Norfolk. When these areas flood, occupants may be displaced due to interruptions in utility service, even if flood waters do not reach above the first floor. See Appendix F-9. Damage Functions for the depth displacement tables used in the analysis.

Despite aforementioned limitations and assumptions in the Relocation and Economic Loss of Function approach, there is a high certainty in the analysis as the approach has been approved by at least one federal agencies. Nevertheless, there are uncertainties with regard to underground utility networks and flooding that could exacerbate that loss. Further, LiDAR was used to determine grade elevations, with site checks in several areas. Uncertainty in commercial owner occupancies is also acknowledged, as well as post-disaster behavior of residents and businesses.

Detailed Results: Relocation Costs

The results of the relocation costs are presented below by compartment and for the entire proposed project. ELOF costs are presented in the Economic Losses section.

Table IV.1.4.16 Total Relocation Expected Losses and Benefits by Flood Scenario and Compartment

Location	Expected Losses by % Annual Chance Flood Scenario			Expected Benefits	
	10%	2%	1%	Annualized Value	Net Present Value
Newton's Creek Watershed	$1,087,465.27	$2,129,769.41	$3,027,762.86	$181,619.54	$2,506,398.74
Ohio Creek Watershed	$106,631.36	$417,964.85	$639,858.62	$25,421.02	$350,816.93
Total	**$1,194,096.63**	**$2,547,734.26**	**$3,667,621.48**	**$207,040.56**	**$2,857,215.67**

Shelter Needs

Shelter Needs

After a disaster, significant flooding can prevent individuals from accessing their homes. Even though a home may not be damaged, residents could be displaced if they are evacuated or cannot physically access their property by foot, vehicle, or transit due to flooded roadways or transit systems.[53]

Approximately 11,840 people in the Target Area are at risk to displacement due to flooding during storm events. Low-income individuals, as well as young families and the elderly, are more likely to seek shelter.[54] 44% of the population in the Target Area is either less than 5 years old or older than 65, and 86% of the total population are low- to moderate- income individuals. For more information regarding vulnerable populations see Part III Existing Conditions. The shelter needs of such populations are recognized within this approach, however as quantified benefits associated with such needs are included in the Relocation and Economic Loss of Function benefits, are not incorporated into the benefit-cost ratio.

Historical Impacts

Documented accounts of shelter needs during previous disasters provide context to impacts calculated below. In response to expected impacts of Hurricane Irene, shelters started opening on Friday the 26th[55] and mandatory evacuation for low-lying areas of Norfolk began 8:00 am on Saturday August 27th, 2011.[56] Jim Redick, Emergency Management Director, stated, although evacuation orders were given prior to Irene and public shelters were activated, many people chose to shelter in local churches. Recognizing this trend in Norfolk, Operation Brother's Keeper, a faith based shelter program, has since been implemented. Figure 6 below identifies the locations of Operation Brother's Keeper shelters in the City of Norfolk.

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[53] *FEMA. Undated. HAZUS Flood Technical Manual. Pg. 432 Located at: http://www.fema.gov/media-library-data/20130726-1820-25045-8292/hzmh2_1_fl_tm.pdf*
54 FEMA. Undated. HAZUS Flood Technical Manual. Pg. 432 Located at: http://www.fema.gov/media-library-data/20130726-1820-25045-8292/hzmh2_1_fl_tm.pdf
55 Associated Press. 2011. Voluntary Evacuations Issued in Virginia in Anticipation of Hurricane Irene. August 25. http://www.wusa9.com/news/article/164333/188/Voluntary-Evacuations-Issued-In-Va-
The Virginian-Pilot. 2011. Hurricane Guide/ Irene-related evacuations in Virginia. August 26. http://hamptonroads.com/2011/08/hurricane-guide-irenerelated-evacuations-virginia
56 Associated Press. 2011. State-by-state glance at how Hurricane Irene is predicted to strike states all along the Eastern Seaboard. http://archive.kare11.com/pdf/Hurricane_Irene_state_breakdown.pdf

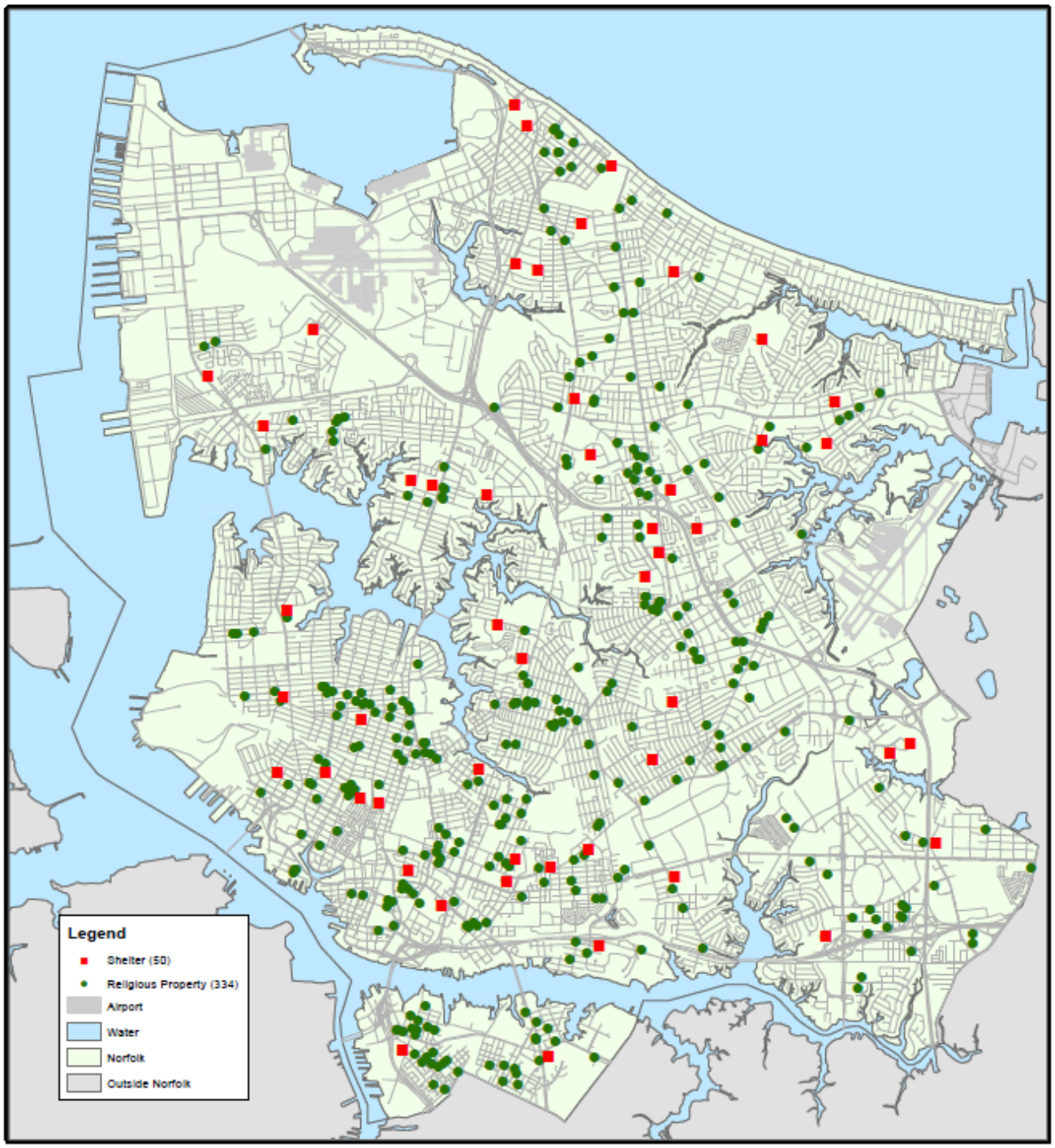


Figure IV.6.4.6 Locations of Operation Brother's Keeper Shelters

Detailed Approach

Short-term sheltering needs are based on a displaced population, determined using flood depths. Access to an area is obstructed at a depth between 6 inches (the typical height of a curb) and 12 inches (when vehicles begin to float). For this analysis, any residential unit with a flood depth that equals or exceeds 12 inches will cause displacement of residents and a need for short-term sheltering. Therefore, the displaced population is the sum of the residential population located within the area where flood depth is equal to or greater than 12 inches.

Analysts have assigned a population to each building based upon the share of residential square footage per building compared to the total residential square footage in the census block group. The ratio of building square footage to total residential square footage in the block group is applied to the total population in the census tract to determine the share of the total population in each building. The residential buildings that experience 12 inches of flooding or greater are considered impacted in this analysis, and the population assigned to these buildings is considered the displaced population.

The number of displaced population seeking shelter is adjusted to account for the likelihood that an individual may seek out other shelter options, such as a hotel or staying with friends or family. Based on FEMA's Hazus methodology, two factors impact these choices: income and age.[57] Individuals who seek shelter are most likely low-income and/or do not have family in the area, and age is a secondary role, as some individuals may seek shelter even if they have the financial means to do otherwise.[58] Low-income families lack the means to find other shelter, and young and elderly families may prefer to use publicly provided shelters; even so, these populations tend to be lower income or dependent on fixed incomes.[59] As a result, weight and modification factors are based primarily on income. FEMA has developed a constant to adjust for income and age. The following equations, provided by Hazus, are used to calculate the number of people using shelters.

$$\begin{aligned} &People\ using\ shelter \\ &\quad = Constant * total\ displaced\ individuals * percentage\ of\ population\ in\ each\ income\ class \\ &\quad * percentage\ of\ population\ in\ each\ age\ class \end{aligned}$$

$$\begin{aligned} Constant = (&weight\ for\ income * relative\ modificaiton\ factor\ for\ income) + (weight\ for\ age \\ &* relative\ modification\ for\ age) \end{aligned}$$

Default weight and modification factors (Table 17 and Table 18), taken from FEMA's Hazus methodology, were used in this analysis to determine the constant described in the second equation. The percentage of the population in each income and age class (as organized in Table 17) was determined for each block group in the Target Area.

57 Federal Emergency Management Agency. Undated. HAZUS Flood Technical Manual. Located at: http://www.fema.gov/media-library-data/20130726-1820-25045-8292/hzmh2_1_fl_tm.pdf
58 Federal Emergency Management Agency. Undated. HAZUS Flood Technical Manual. Located at: http://www.fema.gov/media-library-data/20130726-1820-25045-8292/hzmh2_1_fl_tm.pdf
59 Federal Emergency Management Agency. Undated. HAZUS Flood Technical Manual. Located at: http://www.fema.gov/media-library-data/20130726-1820-25045-8292/hzmh2_1_fl_tm.pdf

Table IV.1.4.17 Relative Modification Factors

Class	Description	Default	Default for Communities with 60% or More of Households with Income > $35,000
Income			
IM_1	Household Income < $10,000	0.40	0.46
IM_2	$10,000 < Household Income < $15,000	0.30	0.36
IM_3	$15,000 < Household Income < $25,000	0.15	0.12
IM_4	$25,000 < Household Income < $35,000	0.10	0.05
IM_5	$35,000 < Household Income	0.05	0.01
Age			
AM_1	Population under 16 Years Old	0.05	-
AM_2	Population Between 16 and 65 Years Old	0.20	-
AM_3	Population Over 65 Years Old	0.50	-

Source: HAZUS

Table IV.1.4.18 Weight Factors for Income and Age

Class	Description	Default
IW	Income Weighting Factor	0.80
AW	Age Weighting Factor	0.20

The average number of persons per household in Norfolk City (2.43[60]) was applied to the number of people using a shelter (calculated using the first equation) to estimate the number of households seeking shelter.

Limitations, Uncertainties, Assumptions, Sensitivities

Sensitivity analyses conducted by FEMA indicated that small modifications in weight and modification factors had little effect on the estimated shelter needs. It was recommended that these factors are used unless there are statistical data available on who uses shelters.

- Default income and wage factors are applicable to the Target Area.

60 US Census 2010 data. Undated. Located at: http://factfinder.census.gov/faces/tableservices/jsf/pages/productview.xhtml?src=CF

Detailed Results

The results of this analysis are provided below by recurrence interval.

Table IV.1.4.19 People Seeking Shelter

Watershed	10-percent Annual Flood Chance	2-percent Annual Flood Chance	1-percent Annual Flood Chance
Newton's Creek	113	242	774
Ohio Creek	8	101	139
Total	121	343	913

Table IV.1.4.20 Households Seeking Shelter

Watershed	10-percent Annual Flood Chance	2-percent Annual Flood Chance	1-percent Annual Flood Chance
Newton's Creek	47	99	318
Ohio Creek	3	42	57
Total	50	141	376

2.0 Environmental Values

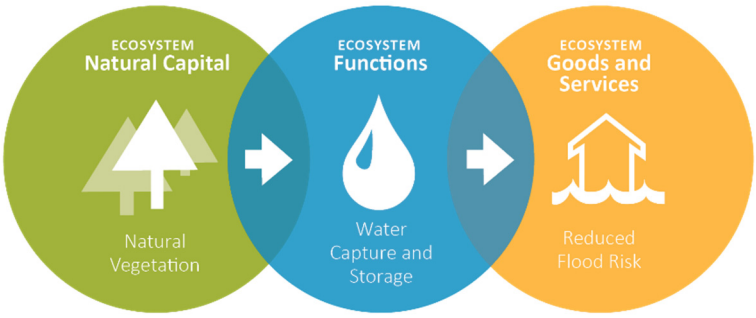
Environmental Value

Norfolk's Coastal Adaptation and Community Transformation Plan will accomplish the following, all of which will provide an abundance of environmental benefits:

- Develop new wetlands;
- Enhance existing wetlands
- Add permeable pavement, rain gardens and trees
- Enhance waterfront areas and shoreline habitats;
- Add stormwater management and storage features

Environmental benefits of Norfolk's Coastal Adaptation and Community Transformation Plan can be grouped into two categories based on valuation methods: those associated with the ecosystem goods and services of natural capital (calculated using the Federal Emergency Management Agency methodology) and those associated with green infrastructure (GI) (calculated using the Green Infrastructure Guide). The environmental benefits of green infrastructure, are inherently ecosystem services, but are differentiated here for methodological purposes.

Ecosystem Goods and Services



Source: Earth Economics

Natural capital is the world's stock of natural assets, such as soil, air, water, and all living things. Natural capital provides a stream of benefits to individual people and to society as a whole. Goods and services produced by natural capital that benefit people are called ecosystem goods and services. For example, natural capital, such as forests and soils, provide the ecosystem service of filtering water independent of treatment plants.

Ecosystem services can be grouped into four broad categories[1]:

- **Provisioning services:** produce the physical materials that society uses. Everything in our economy is made from natural capital such as minerals, gases, and living things.
- **Regulating services:** create and maintain a healthy environment. Ecosystems can provide flood and storm protection, water quality, and gas and climate stability. These services contribute to ecosystem functions and economic resilience.
- **Supporting services:** maintain conditions for life, such as habitat or genetic diversity.
- **Cultural services:** provide meaningful human interaction with nature. Services include spiritual, recreational, aesthetics, educational, and scientific uses.

[1] *Earth Economics. 2015. Earth Economics Ecosystem Valuation Toolkit. [Web page] Located at: http://esvaluation.org/ecosystem-services/*

Green Infrastructure

Beyond the primary purpose of capturing and storing stormwater runoff, which reduces flood risk, GI can improve air quality, contribute to climate regulation, reduce energy use, reduce capital infrastructure costs, and mitigate the impacts of urban heat island effect.[2]

Existing studies and methods allowed analysts to value the following ecosystem goods and services provided by natural capital and green infrastructure, listed in Table 1.

Valued in this analysis
Value available or can be obtained
Study may exist

Table IV.2.1 Environmental Benefits Valued

Environmental Benefit	Wetlands	Riparian	Green Open Space	Bioretention Feature	Permeable Pavement	Rain Gardens
Provisioning Services						
Food						
Fiber/Raw Materials						
Fuel						
Water Supply						
Regulating Services						
Hurricane Storm Hazard Risk Reduction						
Earth Quake Risk Reduction						
Waste Reduction and Filtration/Water Quality						
Climate Regulation						
Water Retention/Flood Hazard Reduction						
Fire Hazard Risk Reduction						
Air Quality						
Supporting Services						
Nutrient Cycling						
Habitat						
Biological Control						
Primary Productivity						
Erosion Control						
Soil Formation						
Pollination						

[2] *Center for Neighborhood Technology. 2010. The Value of Green Infrastructure: A Guide to Recognizing Its Economic, Environmental, and Social Benefits. Pages 9-15. Located at: http://www.cnt.org/sites/default/files/publications/CNT_Value-of-Green-Infrastructure.pdf*

Environmental Benefit	Wetlands	Riparian	Green Open Space	Bioretention Feature	Permeable Pavement	Rain Gardens
Cultural Services						
Recreation/Tourism*						
Scientific Value						
Educational Value						
Aesthetic Values*						
Spiritual/cultural*						
Biodiversity						

*Quantified in the Social Benefits Section of the Benefit Cost Analysis.

Benefit Valuation Methods

The benefits provided by ecosystem goods and services and GI can be valued in a fashion similar to that of economic benefits valued in the economy. Economic valuation theory typically relies on people's willingness to pay for a good or service. Under the umbrella of willingness to pay theory are numerous valuation methods including contingent valuation, hedonic pricing, and travel cost. Other methods used to value environmental benefits include factor income, replacement cost, avoided cost, and market price. Table 2 outlines each of these methodologies in brief.

These methodologies can be used to develop factors specific to the Target Area, a time and resource intensive process, or through transfer of benefit factors from studies of areas similar to the Target Area. For this analysis, the benefits of ecosystem goods and services are calculated through value, or benefit, transfer. The "transfer" refers to the application of derived values from the original study site to the goods and services provided by the project site. Benefit transfer has become popular to value the ecosystem services of natural capital, as it allows for timely and cost-effective analyses. The environmental benefits quantified in this section rely on preliminary yet reliable conceptual design estimates presented in the Project Description section and in the conceptual designs on the following page.

Table IV.2.2 Environmental Benefit Valuation Methods

Method	Description	Example
Contingent Valuation	Involves directly asking people how much they are willing to pay for an environmental service	Asking people how much they are willing to pay for the protection of shoreline and beaches
Hedonic Pricing	Estimates economic values for ecosystems services that directly affect market price	Impact of ecosystem services, such as a scenic view, on housing prices
Travel Cost	Cost of travel required to consume or enjoy ecosystem services	Determining the cost users incur when traveling to and using parks
Factor Income	Enhancement of income by the ecosystem service provision	Increased commercial fishery catch and income due to water quality improvements
Replacement Cost	Cost of replacing ecosystem services with man-made systems	Replacing natural nutrient waste treatment with water treatment systems
Avoided Costs	Value of costs that would be incurred in the absence of an ecosystem service	Flood control provided by barrier islands avoids property damage along coastlines
Market Price	Prices set in the marketplace that appropriately reflect the value to the "marginal buyer"	Market price of wood

Figure IV.2.1 Newton's Creek Perspective Conceptual Design

Figure IV.2.2 Ohio Creek Perspective Conceptual Design

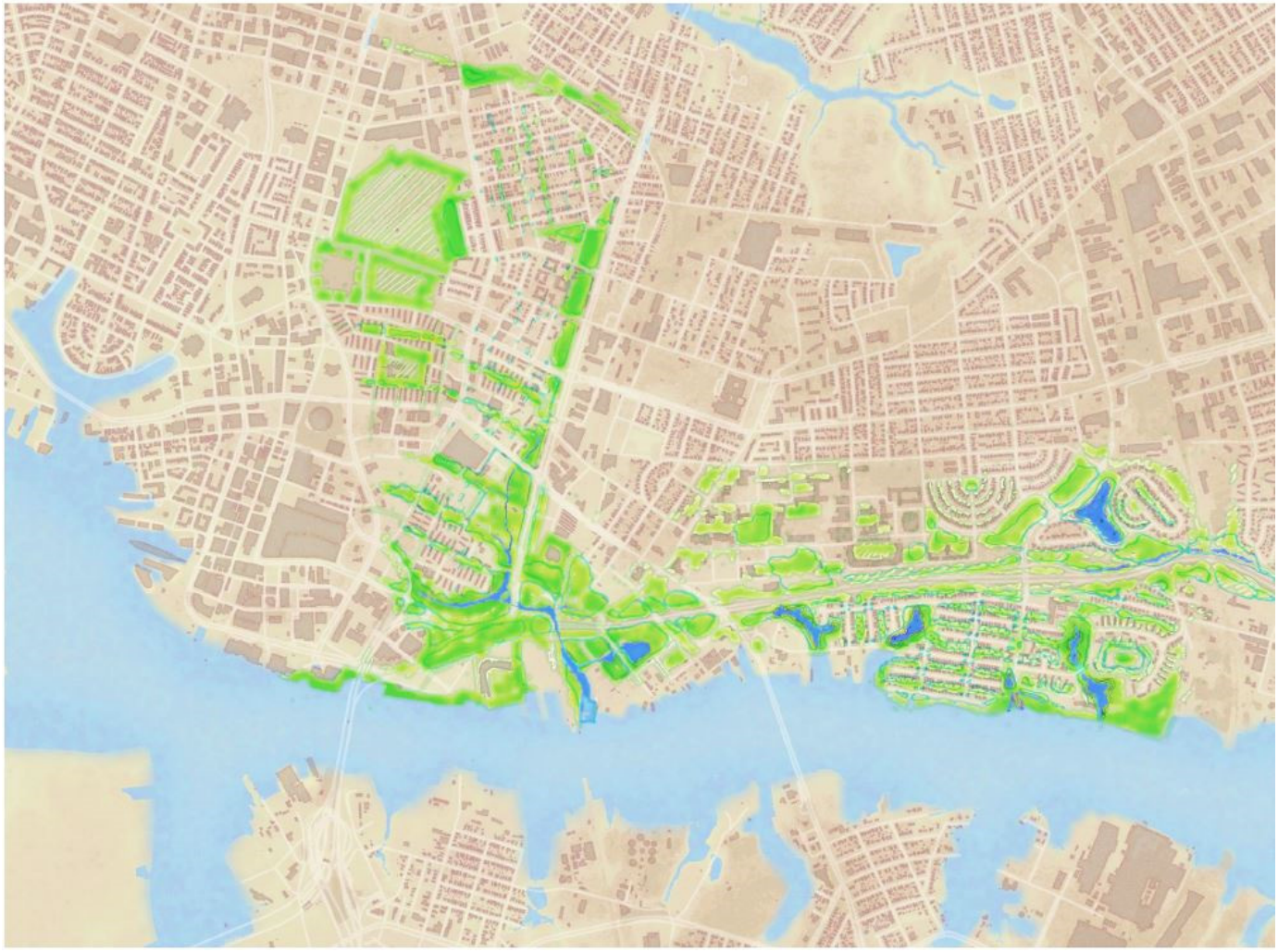


Figure IV.2.3 Target Area Blue Green Network Conceptual Design

Principle Resources and Data Sources

The resources used in this analysis include the Federal Emergency Management Agency's (FEMA's) Final Sustainability Benefits Methodology Report[3], *The Value of Green Infrastructure: A Guide to Recognizing Its Economic, Environmental, and Social Benefits* (The Green Infrastructure Guide) developed by the Center of Neighborhood Technology[4], and Earth Economics[5]. Data needs and sources include:

- Environmental benefit estimates for trees: U.S. Department of Agriculture, U.S. Forest Service, Piedmont Community Tree Guide[6]
- Annual pollutant uptake for shrubs and grasses
- Annual carbon sequestration for shrubs and grasses
- Energy use per gallon of water treatment: Electric Power Research Institute (EPRI)
- Cost per pound of pollutant: Piedmont Community Tree Guide, Green Infrastructure Guide, and the National Highway Traffic Safety Administration Final Regulatory Impact Analysis (FRIA)
- Emission factors: U.S. Environmental Protection Agency (EPA) Emissions and Generation Resource Integrated Database (eGRID)
- Annual precipitation: U.S. Climate Data
- Retention Rates: Green Infrastructure Guide or modeled using HydroCAD

Detailed Approach

The benefits of ecosystem goods and services of natural capital and GI are valued using different approaches. FEMA values ecosystem goods and services based on the square footage of different types of vegetative areas (green open space, wetlands, and riparian), and the Green Infrastructure Guide values the environmental benefits of GI. It was determined that, for certain ecosystem services, such as air quality, it was possible to calculate benefits using both methods. When this occurs, low, medium, and high results are presented in this methodology to provide a range and illustrate sensitivity. Furthermore, it became evident that some of the benefits provided by green infrastructure could not be calculated using the Green Infrastructure Guide, but it was possible to use FEMA methodology, or vice versa. When this occurs, a combination of benefits is calculated, and the combined benefits are included in the benefit cost ratio, as they capture the full range of environmental benefits regardless of methodology. For example, the GI Guide provides a method to calculate air quality, climate regulation, and water quality benefits of bioretention features and rain gardens, but it does not consider erosion control, which is a benefit associated with riparian and green open space, as stated by FEMA. A summary of this evaluation is provided in Table 3 below.

[3] *FEMA. 2012. Final Sustainability Benefits Methodology Report. Contract: HSFEHQ-10-D-0806. August 23.*
[4] *Center of Neighborhood Technology (CNT). 2011. The Value of Green Infrastructure: A Guide to Recognizing Its Economic, Environmental and Social Benefits (The Green Infrastructure Guide). January 21.*
[5] *Earth Economics. 2015. Earth Economics Ecosystem Valuation Toolkit. [Web page] Located at: http://esvaluation.org/ecosystem-services/*
[6] *McPherson, E.G., Simpson, J.R., Peper, P.J., Gardner, S.L., Vargas, K.E., Maco, S.E., and Q. Xiao. 2006. Piedmont Community Tree Guide: Benefits, Costs, and Strategic Planting. November.*

Table IV.2.2 Benefit Methodology Crosswalk

Feature	Environmental Benefit	Aesthetic Benefit*	Recreation Benefit*
Ohio Creek			
Improved Park Space	FEMA	Earth Economics or FEMA	Earth Economics or FEMA
Wetland Protection and Restoration	FEMA	Earth Economics or FEMA	Earth Economics or FEMA
Bioretention Features	Combination of GI Guide and FEMA	Earth Economics or FEMA	-
Permeable Pavement	GI Guide	Earth Economics or FEMA	-
Rain Gardens	Combination of GI Guide and FEMA	Earth Economics or FEMA	-
Newton's Creek			
New Park Space	FEMA	Earth Economics or FEMA	Earth Economics or FEMA
Improved Park Space	Combination of GI Guide and FEMA	Earth Economics or FEMA	Earth Economics or FEMA
Improved Waterfront Areas	Combination of GI Guide and FEMA	Earth Economics or FEMA	Earth Economics or FEMA
Bike and Pedestrian Paths	-	Earth Economics or FEMA	Earth Economics or FEMA
New Inland Wetlands	FEMA	Earth Economics or FEMA	Earth Economics or FEMA
Trees	GI Guide	Earth Economics or FEMA or Tree Guide	Earth Economics or FEMA
Elizabeth River			
Living Shoreline	FEMA	Earth Economics or FEMA	Earth Economics or FEMA

*Quantified in the **Social Benefits Section** of the Benefit Cost Analysis.

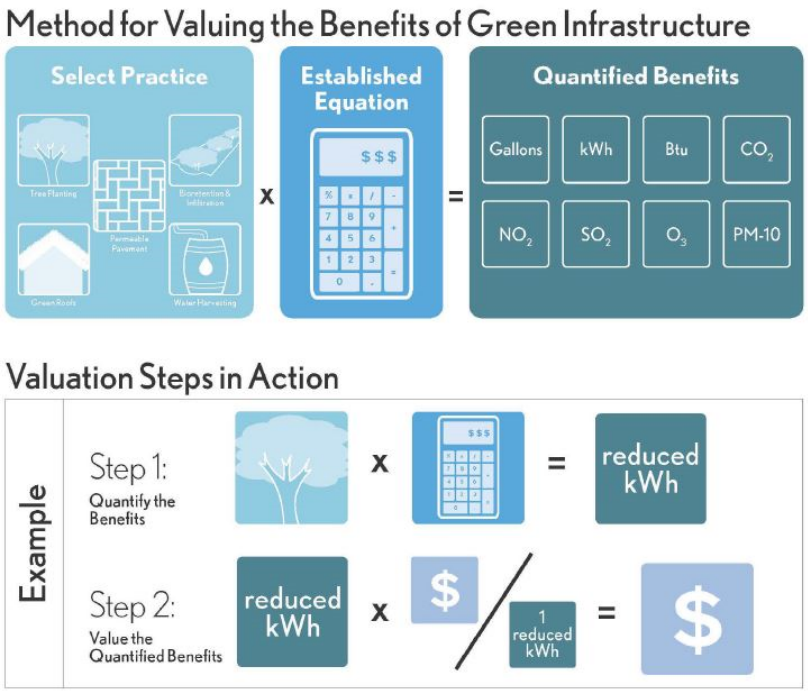
Green Infrastructure Benefits

Green Infrastructure

The environmental benefits of GI elements rely on various approaches derived from the Green Infrastructure Guide and Earth Economics, and are grounded in avoided cost, replacement cost, and market value as valuation methods.

Basic steps taken to value environmental benefits of GI:

1. Quantify the benefit by a defined resource unit. For example, gallons of water intercepted.
2. Translate the estimate of total resource units received from a given benefit to a dollar figure.
    a. At this point, different valuation methods (avoided cost, replacement cost, and market value) are used to assign a dollar value to the environmental benefit.



Source: Center for Neighborhood Technology. U.S. Environmental Protection Agency. The Economic Benefits of Green Infrastructure. A Case Study of Lancaster, PA. February 2014.

The total square footage (Table IV.2.4) of GI features (or for trees, the count) is needed to quantify benefits.

Table IV.2.3 Total Square Feet of GI Elements

Feature	Newton Creek Watershed	Ohio Creek Watershed
Trees (Count)	1,192	
Shrubs	8,740	
Grass/ Planted Cover	603,200	
Permeable Pavement		72,725
Bioretention Features		819,225
Rain Gardens		6,480
Total	611,940*	898,430

*Does not include tree count

Water Quality – Reduced Treatment Costs

The expansion of urban areas and the impervious surfaces associated with them impose significant impacts on water quality. Water that falls on impervious surfaces collects pollutants and enters the stormwater management system. Infiltration of water into vegetated areas and permeable pavement filters out pollutants, such as motor oil. When rainwater is allowed to permeate and be cleaned in the ground, treatment costs are avoided. Features such as natural vegetation, rain gardens, permeable pavers, and bioretention features perform this ecosystem service. When rainwater is filtered by features, such as blue and green roofs, before it enters the system, fewer pollutants need to be removed in the treatment process. Examples of green infrastructure are included below through Figure 5 to Figure 7.

Figure IV.2.4 Example of a Rain Garden

Figure IV.2.5 and Figure IV.2.6 Example of Permeable Pavers

The total square footage (or for trees, the count) of GI is used to estimate the total number of stormwater gallons intercepted by these features, summarized in Table 5 and Table 6. For bioretention areas, the GI area includes the area of the feature and its drainage area. Retention rates were modeled for bioretention features for four different rainfall recurrence intervals, and the average retention rate was used to calculate annual runoff reduction. Retention rates for permeable pavement and rain gardens were provided by the Green Infrastructure Guide.

$$[annual\ preciptation\ (inches) * GI\ area\ (SF) * \%\ retained] * 144\ sq\ inches\ per\ SF * 0.0043\ gallons\ per\ cubic\ inch = total\ runoff\ reduction\ (gal)$$[7]

Table IV.2.4 Total Annual Gallons of Water Intercepted in Ohio Creek Watershed

Feature	Feature Area (Sq. Ft.)	Drainage Area (Sq. Ft.)	Average Retention Rate (%)	Runoff Reduction (gallons)
Grandy Village Storage*	388,975	3,528,360	88.2	100,283,474
East Chesterfield Heights Storage*	26,897	1,611,720	20	9,512,125
West Chesterfield Heights Storage*	5,793	304,920	22.2	2,002,086
Kimball Terrace Storage*	97,244	2,352,240	53.4	37,965,216
Ohio Storage*	227,591	13,721,400	17.8	72,066,409
Permeable Pavement	72,725		80	1,688,666
Rain gardens	6,480		80	150,464.85
Total				223,668,441

*Bioretention feature

The Piedmont Community Tree Guide provides the annual number of gallons intercepted by a tree.

$$1{,}192\ trees * 2{,}566\ gallon\ per\ tree = total\ runoff\ reduction\ (gal)$$

Table IV.2.5 Total Annual Gallons of Water Intercepted in Newton's Creek Watershed

Feature	Feature Area (Sq. Ft.)	Annual Rainfall Interception (gal/tree)	Runoff Reduction (gallons)
Trees (Count)	1,192	2,566	3,058,672

The value of treatment is applied to the gallons of water intercepted to estimate avoided treatment costs. Local stormwater treatment rates are used to determine a cost per gallon, and this is used in the equation below to determine the avoided costs. The cost of water treatment per gallon in Norfolk is $0.0106.[8]

$$Total\ treatment\ cost\ (\$) = \$0.0106\ per\ gallon\ x\ gallons\ of\ runoff\ reduction$$

[7] *Unless otherwise noted, all equations used in this section are from the Green Infrastructure Guide published by the Center for Neighborhood Technology.*

[8] *City of Norfolk. Undated. Water and Sewer Rates. [Web page] Located at:* http://www.norfolk.gov/index.aspx?NID=654

Another benefit of stormwater storage is a reduction in energy used for treating wastewater. Because the cost of energy is already captured in the avoided treatment costs, the benefits of reduced energy use are translated to air quality and climate regulation benefits. These are indirect benefits associated with reduced water treatment, such as reduced pollutant emissions.

Air Quality- Reduced Criteria Air Pollutant Emissions

Direct Benefits

Criteria air pollutants impose a variety of health impacts, such as increased risk of bronchitis, asthma, and emphysema. Natural vegetation can absorb these air pollutants and reduce health risks in the surrounding population.

The annual uptake and avoided pollutant emissions captured by natural vegetation is a direct benefit. The annual pollutant uptake capacity for criteria air pollutants for trees, grasses, and shrubs was used with the area or amount of added vegetation to estimate total pollutant reduction. For this analysis, annual pollutant uptake figures for grasses and shrubs (Table 7) were obtained from research conducted in Chicago, Illinois, and annual pollutant uptake for trees (0.83 pound per tree) was obtained from the Piedmont Community Tree Guide.

Table IV.2.6 Annual Pollutant Uptake Capacity for Criteria Air Pollutants in Grams per Square Meter[9]

Type of Vegetation	Nitrogen Dioxide	Sulfur Dioxide	Particulate Matter	Ozone	Total
Grass	0.65	2.33	1.12	4.49	8.59
Herbaceous Plants	0.83	2.94	1.52	5.81	11.10

The value of this ecosystem service, pollutant reduction, was determined using the cost per pound of criteria air pollutants listed in Table 8. The value represented below is the marginal damage cost for different pollutants to meet air quality standards. The table lists the values provided by three different sources. The values were normalized[10] to current dollars, and the average was used to value benefits included in the benefit cost ratio.

[9] *Yang J., Yu Q., and Gong P. 2008. Quantifying air pollution removal for green roofs in Chicago. Atmospheric Environment. 42 7266-7273. 17 March.*

[10] *Values were converted from past dollars to current dollars using the Consumer Price Index Inflation Calculator located at: http://data.bls.gov/cgi bin/cpicalc.pl?cost1=2.84&year1=2010&year2=2015*

Table IV.2.7 Cost per Pound of Pollutant[11]

Pollutant	Piedmont Community Tree Guide	Green Infrastructure Guide	National Highway Traffic Safety Administration	Average Cost per Pound of Pollutant[12]
Ozone		$3.66		$3.66
Nitrogen Dioxide	$7.75	$3.66	$3.48	$4.96
Sulfur Dioxide	$2.26	$2.25	$20.58	$8.36
Particulate Matter	$2.73	$3.11		$2.92
Small Particulate Matter			$159.29	$159.29
Volatile organic compounds	$7.37		$0.88	$4.13
Average				$30.55

The value of pollutant reduction was calculated as follows using the information provided above.

$$1{,}192\ trees * 0.83\ lbs\ per\ tree * \$30.55\ per\ lb = Value\ of\ air\ pollutant\ reduction\ (\$)$$

$$SF\ of\ grass\ or\ plant\ cover * grams\ of\ pollutant\ per\ square\ meter * 0.092903\ square\ meters\ per\ SF * average\ cost\ per\ lb\ of\ pollutant = Value\ of\ air\ pollutant\ reduction\ (\$)$$

Indirect Benefits

There are indirect benefits associated with reduced water treatment, such as reduced air pollutant emissions, due to reduced energy consumption for water treatment.

Reduced energy use is a product of reduced runoff and a standard energy consumption factor. EPRI's 2002 standard energy consumption factor for water treatment plants is 1,911 kilowatt hours (kWh) per million gallons.[13]

$$Reduced\ energy\ use\ (kWh) = million\ gallons\ x\ 1{,}911 kWh\ per\ million\ gallons$$

Emission factors are used to determine the reduction in criteria air pollutants. The emission factors for the Norfolk region are provided by the EPA eGRID for 2010 (Table IV.2.9). The eGRID does not provide emission factors for ozone, volatile organic compounds, or particulate matter. The pounds of reduced pollutants are multiplied by the cost per pound listed in *Table IV.2.8* to estimate the value of pollutant reduction. A summary of the calculation is provided below.

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[11] *E. Gregory McPherson, James R. Simpson, Paula J. Peper, Shelly L. Gardner, Kelaine E. Vargas, and Qingfu Xiao. 2006. The Piedmont Community Tree Guide. Benefits, Costs, and Strategic Planting. U.S. Department of Agriculture, U.S. Forest Service. Pacific Southwest Research Station. November.*

[12] *Normalize to current dollars using the Consumer Price Index (CPI) Inflation Calculator. Located at: http://data.bls.gov/cgi-bin/cpicalc.pl*

[13] *EPRI. 2002. Water Sustainability (Volume 4): U.S. Electricity Consumption for Water Supply and Treatment – The Next Half Century. Technical Report. Page I-4. March. Located at: http://www.epri.com/abstracts/Pages/ProductAbstract.aspx?ProductId=000000000001006787&Mode=download, projected for advanced ww treatment with nitrification*

$$Reduced\ energy\ use\ (kWh) * emission\ factor\ \left(\frac{lbs}{kWh}\right) * price\ per\ lb\ of\ pollutant$$
$$= Damage\ cost\ of\ criteria\ air\ pollutant\ (\$)$$

Table IV.2.8 Emissions Factor (lbs/kWh)

Air pollutant	Pounds per kWh	Pounds per mWh
Nitrogen Dioxide	0.0007997	0.7997
Sulfur Dioxide	0.0020387	2.0387

Climate Regulation- Reduced Carbon Dioxide Emissions

Carbon dioxide, a greenhouse gas, is a primary contributor to climate change. Climate change is expected to impose worldwide impacts, such as reduced human health and damage to property due to increased flooding and more intense storms. Carbon sequestration is an ecosystem service that helps to mitigate climate impacts. Natural vegetation captures and stores carbon in the atmosphere as it grows. Market values and social costs of carbon have been developed recently by the European Union, the United States Interagency Working Group on Social Cost of Carbon, and the Stern Review published by the British Government, and allow for the estimation of the economic value of carbon sequestration.

Direct Benefits

Analysts applied the rate of carbon sequestration for various types of natural vegetation, collected from the Piedmont Community Tree Guide and Earth Economics (summarized in Table 10), to the added trees, shrubs, and planted grasses resultant from the Project to estimate pounds of carbon sequestered. This ecosystem service was translated to dollar figures using the cost of carbon represented in Table 11. The European Union (EU) value is the market price of carbon set in the EU's Emission Trading System. The Stern Review, Tree Guide, and Executive Order 12866 values are an estimate of the social cost of carbon, which is the price the world has to pay if no action is taken on climate change for each ton of gas emitted. More specifically, it can be thought of as the monetary damage of emitting an extra unit of carbon at any point in time on the present value (at any time) of expected well-being. The social cost of carbon considers changes in net agricultural productivity, human health, property damages from increased flood risk, and changes in energy costs.[14] The cost per pound of carbon was normalized using the Consumer Price Index (CPI) Inflation Calculator.

Table IV.2.9 Annual Carbon Sequestration Based on Vegetative Type

Vegetative Cover	Sources	Pounds of Carbon per Year
Trees	Piedmont Community Tree Guide	128 (per tree)
Plants	Earth Economics	0.04 (per square foot)
Grass	Earth Economics	0.04 (per square foot)

Table IV.2.10 Cost per Pound of Carbon Dioxide

Estimate	Year	Cost per Pound[15]
Low Estimate		
EU Market Price	2010	$0.01
Tree Guide	2006	$0.01
Medium Estimate		
Executive Order 12866*	2012	$0.03

[14] *U.S. EPA. The Social Cost of Carbon. Web page. Located at: http://www3.epa.gov/climatechange/EPAactivities/economics/scc.html*

[15] *Normalized to current dollars using the CPI Inflation Calculator. Located at: http://data.bls.gov/cgi-bin/cpicalc.pl*

Estimate	Year	Cost per Pound[15]
Low Estimate		
High Estimate		
Stern Review	2007	$0.05
Average Price		$0.03

*EO 12866[16] provides different estimates of the price of carbon based on discount rate. The average of the estimates is presented here.

Using the information provided above and the average cost per pound of carbon, the value of climate benefits was calculated as follows.

$$128\ lbs\ per\ tree * 1{,}192\ trees * \$0.03 = Climate\ benefit\ of\ trees\ (\$)$$

$$SF\ of\ grass\ or\ plant\ cover * 0.04\ lbs\ per\ SF * \$0.03 = Climate\ benefit\ (\$)$$

Indirect Benefits

Indirect benefits are those associated with avoided power plant emissions for reduced water treatment needs.

The carbon dioxide emission factor for the Norfolk region provided by EPA eGRID (1.07365 lbs/kWh) is used in the equation below with the amount of energy reduction, previously calculated, and the cost per pound of carbon (Table IV.*2.11*) to estimate the cost of carbon dioxide emissions.

$$Reduced\ energy\ use\ (kWh) * 1.07365\left(\frac{lbs}{kWh}\right) * \$0.03\ per\ lb = Climate\ Benefit\ (\$)$$

Reduced Grey Infrastructure Costs

GI and natural vegetation reduces the amount of stormwater entering the sewer system, and this reduces the amount of conventional infrastructure (grey infrastructure) needed to manage stormwater. The EPA estimates that the conventional cost of stormwater storage infrastructure is $22.17[17] per cubic foot. The cubic feet of storage features and average retention rate was used in the following equation to determine avoided grey infrastructure costs.

$$\$22.17\ per\ cubic\ foot * total\ cubic\ feet\ of\ water\ retained\ by\ green\ infrastructure * \%\ retained = Cost\ savings\ (\$)$$

Limitations, Uncertainties, Assumptions, Sensitivities

- The Piedmont Community Tree Guide accounts for tree morbidity over time (33.95%). This assumption is factored into the figures provided by the Tree Guide; therefore, it is not included as a separate function in the calculation.
- It is assumed that added trees carry attributes similar to those provided in the Piedmont Tree Guide.
- It was assumed that the trees added are medium trees; therefore, the benefits were calculated for medium trees. It is possible that this will change later in the design phase.
- The results of previously conducted studies are applicable to the Target Area.

[16] *Located at: https://www.whitehouse.gov/sites/default/files/omb/inforeg/social_cost_of_carbon_for_ria_2013_update.pdf*
[17] *Center for Neighborhood Technologies. Undated. Green Values National Stormwater Management Calculator. Cost Sheet. [Web page]Located at: http://greenvalues.cnt.org/national/cost_detail.php*

Ecosystem Goods and Services Benefits

Ecosystem Goods and Services

Wetlands and riparian habitats comprise a multifunctional system that provides numerous ecosystem goods and services, as well as contribute to the resilience of coastal communities. Green and riparian spaces also provide a variety of ecosystem goods and services. A summary of these benefits and the studies FEMA used to determine standard values is provided in the Appendix F-8 through Appendix F-10.

FEMA used the benefits transfer method to develop standard values for various ecosystem services of certain types of vegetative areas (wetlands, riparian, and green open space) that can be used in FEMA-approved benefit cost analyses required in applications for federal funding. Benefits are be calculated by square foot; totals are provided in Table IV.2.12. The FEMA standard values provide a method to calculate benefits of natural capital (associated with new or improved green spaces, wetlands, and riparian areas), which have yet to be calculated in this analysis. First, analysts must consider the applicability of the values to the project site, benefits not yet captured by FEMA, and possible duplication of benefits if an alternative valuation method is available.

The following basic steps were taken to review and apply FEMA standard values:

1. Review studies from which FEMA estimated values
2. Determine applicable values, fill in missing ecosystem service values wherever possible, and consider possible duplication of benefits.
    a. Analysts determined that FEMA values for erosion control and pollination ($0.01 per square foot per year) can supplant the green infrastructure calculations for bioretention features and rain gardens.
    b. Analysts determined that FEMA values for erosion control and pollination ($0.01 per square foot per year) can supplant the green infrastructure calculations for improved park space and waterfront areas in Newton's Creek Watershed.

These additional benefits are the "adjusted FEMA values" in

    c. Table IV.2.13 and Table IV.2.14, and remove any duplication of benefit with GI values. The "adjusted FEMA values" are added to the GI benefits to provide "combined benefits".
3. Convert dollar value per acre per year to dollar value per square foot per year (See Appendix F-8 through F-10)
4. Normalize values using the Consumer Price Index (CPI) Calculator[18] (See Appendix F-8 through F-10). The CPI Calculator adjusts past dollars to current value using the average Consumer Price Index for a given calendar year. The Consumer Price Index data represents changes in prices of all goods and services purchased for consumption.
5. Value ecosystem good and service benefits using applicable FEMA value per square foot.

[18] *U.S. Bureau of Labor Statistics. Undated. CPI Inflation Calculator. [Web page] Located at: http://www.bls.gov/data/inflation_calculator.htm.*

Table IV.2.11 Total Square Feet of Wetlands, Riparian Habitat, and Green Open Space

Feature	Newton's Creek Watershed (Square Feet)	Ohio Creek Watershed (Square Feet)	Elizabeth River (Square Feet)
New Park Space	1,206,612		
Improved Waterfront Amenities	335,902		
Living Shoreline[19]			13,500
New Inland Wetlands	2,813,976		
Wetland Protection and Restoration		658,170	
Conversion of Open Space to Park Space / Improved Park Space	933,398	501,520	
Grandy Village Open Space		41,000	
Total	5,296,788	1,207,290	13,500

Limitations, Uncertainties, Assumptions, Sensitivities

- The estimated value of ecosystem service from other studies is applicable to the Target Area.
- Environmental benefits related to the natural berm are not included in this analysis.

[19] 2,200 linear feet at 3 foot depth is 6,600 square feet; 2,300 linear feet at 3 foot depth is 6,900 square feet.

Detailed Results

Detailed Results

Annual benefits and net present value are provided in the tables below. The benefits are integrated with other benefits to determine total annual benefits, net present value, and the benefit cost ratio. The reduced grey infrastructure costs are a one-time avoided cost; therefore, they are added as a lump sum to the net present value. Annual benefits are converted to net present value using the net present value coefficient for a 50–year project useful life at a 7% discount rate.

Table IV.2.12 Ohio Creek Annual Benefits

Feature	Green Infrastructure Guide*	FEMA	Adjusted FEMA Benefits**	Combined Benefits
Improved Park Space		$10,030.40		$10,030.40
Wetland Protection and Restoration		$210,614.40		$210,614.40
Grandy Village Open Space		$820.00		$820.00
Bioretention Features	$2,371,679.63	$238,880.16	$7,465.00	$2,379,144.63
Permeable Pavement	$18,054.31	$23,272.00	-	$18,054.31
Rain Gardens	$1,608.69	$2,073.60	$64.80	$1,673.49
Total	$2,391,342.63	$485,690.56	$7,529.80	$2,620,337.23

*GI benefits are water quality, air quality, and climate regulation. GI values presented do not include avoided infrastructure costs.
**Value for erosion control and pollination benefits. FEMA values that are captured by the GI are removed to avoid a duplication of benefits

Table IV.2.13 Newton's Creek Annual Benefits

Feature	Green Infrastructure Guide*	FEMA	Adjusted FEMA Benefits**	Combined Benefits
New Park Space		$24,132.24		$24,132.24
Improved Park Space	$1,011,600.72	$9,333.98	$4,666.99	$1,016,267.71
Improved Waterfront Areas	$285,122.03	$3,359.02	$1,679.51	$286,801.54
New Inland Wetlands		$900,472.32		$900,472.32
Trees	$66,744.60			$66,744.60
Total	$1,363,467.35	$937,297.56	$6,346.50	$2,294,418.41

*GI benefit for park space and waterfront area are air quality and climate regulation. GI benefit for trees includes water quality, air quality, and climate regulation. GI values presented don't include avoided infrastructure costs
**Value for erosion control and pollination benefits. FEMA values that are captured by the GI are removed to avoid a duplication of benefits

Table IV.2.14 Elizabeth River Annual Benefits

Feature	FEMA
Living Shoreline	$14,538.96

Table IV.2.15 Total Benefits

Feature	Ohio Creek			Newton's Creek		Elizabeth River		Total Benefits
	Reduced Grey Infrastructure Costs*	Combined Annual Benefits	Net Present Value	Combined Annual Benefit	Net Present Value	Annual Benefit	Net Present Value	
New Park Space				$24,132.24	$333,042.91			$333,042.91
Improved Park Space		$10,030.40	$138,427.00	$1,016,267.71	$14,025,252.52			$14,163,679.52
Improved Waterfront Areas				$286,801.54	$3,958,075.19			$3,958,075.19
Living Shoreline						$14,538.96	$200,648.49	$200,648.49
Wetland Protection and Restoration		$210,614.40	$2,906,635.84					$2,906,635.84
New Inland Wetlands				$900,472.32	$12,427,189.77			$12,427,189.77
Grandy Village Open Space		$820.00	$11,316.61					$11,316.61
Bioretention Features	$24,331,521.06*	$2,379,144.63	$32,833,970.74					$57,165,491.80
Permeable Pavement	$4,998,620.59*	$18,054.31	$249,162.94					$5,247,783.53
Rain Gardens	$445,391.01*	$1,673.49	$23,095.40					$468,486.41
Trees				$66,744.60	$921,125.21			$921,125.21
Total	$29,775,532.66	$2,620,337.23	$36,162,608.53	$2,294,418.41	$31,664,685.60			$97,803,475.29

*Lump sum value added to net present value of other benefits to determine total benefits

3.0 Social and Recreational Values

Social Value

Literature has revealed that urban parks help improve the quality of life and social sustainability of cities by providing recreational opportunities and aesthetic enjoyment, promoting physical health, contributing to psychological well-being, enhancing social ties, and providing opportunities for education.[1] Time spent outdoors has proven to have a positive effect on life expectancy, health, and well-being, and this is reflected in society as a whole. Accessibility to parks and green space is especially important for the elderly, children, and people with disabilities. The availability of safe recreation spaces for children supports healthy physical and psychological development, and access to open space is associated with greater longevity for seniors due to increased physical activity and reduced risk of depression.[2] Furthermore, these types of spaces foster social interaction and promote social cohesion within diverse communities. Research has shown that communities with stronger social networks improve the resiliency of vulnerable populations against hazards, as social ties within communities are critical to the ability to sustain shocks and stresses, as well as recover effectively.[3] Lastly, maintained green spaces can encourage more use of city spaces, and therefore increased social monitoring of public spaces, “eyes on the street”, sometimes referred to as crime prevention through environmental design (CPTED).[4] Key elements of the conceptual design of Norfolk’s Coastal Adaptation and Community Transformation Plan will enhance the health and well-being of nearby residents, increase social capital, and improve quality of life in the greater community.

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[1] *Zhou, X. and M.P. Rana. 2011. Social benefits of urban green space. A conceptual framework of valuation and accessibility measurements. Management of Environmental Quality: An International Journal.*

[2] *California State Parks. 2005. The Health and Social Benefits of Recreation. California State Parks, Sacramento.*

[3] *Center for American Progress. Social Cohesion. The Secret Weapon in the Fight for Equitable Climate Resilience. May 2015. Located at: https://cdn.americanprogress.org/wp-content/uploads/2015/05/SocialCohesion-report.pdf*

[4] *Wolfe, M.K., and J. Mennis. 2012. “Does Vegetation Encourage or Suppress Urban Crime? Evidence from Philadelphia, PA.” Landscape and Urban Planning 108 (2–4): 112–122.*

Recreational Benefits

Recreational Benefit

Norfolk's Coastal Adaptation and Community Transformation Plan will add new and improved park space, bicycle and pedestrian trails, as well as community gathering and recreation spaces and amenities, which will give residents and visitors opportunities to participate in a variety of activities such as walking, jogging, bicycling, and playground use. There are two benefits related to recreation that are quantified in this section: 1) increased outdoor recreation and 2) health benefits related to increased activity due to the availability of new recreation space.

Table IV.3.1 outlines the type and scale of new and improved recreation space being proposed within Norfolk's Coastal Adaptation and Community Transformation Plan. For more details and conceptualized renderings of the proposed improvements see Section 2.0 of this BCA Report.

Table IV.3.1 New and Improved Park and Recreation Space

Feature	Newton's Creek Watershed (Square Feet)	Ohio Creek Watershed (Square Feet)	Elizabeth River (Square Feet)
New Park Space	1,206,612		
Conversion of Open Space to Park Space / Improved Park Space	933,398	501,520	
Improved Waterfront Amenities	335,902		
Increased Bike and Pedestrian Paths / Neighborhood Bike Path	211,150		
New Inland Wetlands	2,813,976		
Living Shoreline			13,500
Wetland Protection and Restoration		658,170	
Bio-retention Features		746,500	
Permeable Pavement		72,725	
Rain Gardens		6,840	
Grandy Village		41,000	
Total	**5,289,888**	**2,026,755**	**13,500**

Sources

Earth Economics and the Federal Emergency Management Agency's (FEMA's) Final Sustainability Benefits Methodology Report provide different, but related, approaches to value benefits. Data sources include the following:

- **Recreation Use Values Database, Randall S. Rosenberger, Oregon State University.**[5] This database provided analysts with the Consumer Surplus Values used to calculate recreational values.
- **City of Norfolk Geographic Information Systems Department, Area of Existing Park Space.** The areas provided within this data layer offered analysts the park square footage used in recreation analysis.
- **Virginia Department of Recreation, Virginia Statewide Comprehensive Outdoor Recreation**

[5] *Rosenberger, R. 2015. College of Forestry Recreation Use Database. Oregon State University. [Web page] Located at: http://recvaluation.forestry.oregonstate.edu/*

Plan (SCORP).[6] The analysts used statewide recreation participation estimates provided within this plan to determine overall recreation benefits.

- **University of Virginia Weldon Cooper Center for Public Service, Demographics and Workforce Group.** The report developed from this team provided population projections used in current and future analysis of the Target Area.
- **Outdoor Recreation Demand for Virginia:** An Analysis Using 2011 Virginia Outdoors Survey Data by Terance Rephann.[7] Activity days and projected activity days were obtained from the article and used during analysis.

Detailed Approach

There are two methods that can be used to quantify recreation benefits (Table IV.3.2), Earth Economics or FEMA. Earth Economics uses participation rates based on statewide recreation activity, collected through an Outdoors Demand Survey, to estimate benefits in the Target Area. FEMA quantified recreational benefits based on the square footage of added or improved recreational space. Both methods and results are presented in this section to illustrate a range of benefits.

Table IV.3.2 Summary of Methods to Value Benefits

Parameter	FEMA	Earth Economics		
Recreation	Low Value	Medium Value		High Value
Health Benefits of Recreation	-	Low Value	Medium Value	High Value

Earth Economics

Statewide participation rates were used to estimate future recreational activity resulting from Norfolk's Coastal Adaptation and Community Transformation Plan. The Virginia Department of Conservation and Recreation maintains the Virginia Outdoors Plan, and an element of this plan is the Outdoors Demand Survey. The survey estimates participation in and demand for a wide variety of recreation activities throughout Virginia, and the results of the survey are used to estimate statewide activity days for the current population and projected population in 2020.[8] Activity days are the total number of days during which an activity is performed within a year for a given population. Projected activity days in 2020 based on two methods: Regional Method and Cohort Component. Rephann T., page 29, "The regional method estimates average resident activity levels for each activity by region. Resident activity levels are determined by multiplying mean participation proportions by median person-days of activity per household member (total household person-days involved in activity divided by the household size) for each activity. The local activity levels by recreation activity are applied to local area population estimates and projections to obtain aggregate local-area activity levels…The cohort component method estimates rates statewide for 28 demographic groups categorized by age. Mean participation rates were multiplied by median activity levels for each category. Local aggregate activity levels were obtained by multiplying the demographic group activity levels by the corresponding local area demographic group population and projections."

The ratio of statewide activity days to the total state population was applied to the total population in the Target Area to determine the total number of activity days for certain recreation activities within a given year.

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[6] *Virginia Department of Conservation and Recreation. 2013. Virginia Statewide Comprehensive Outdoor Recreation Plan (SCORP).*

[7] *Rephann, Terrance. 2012. Outdoor Recreation Demand for Virginia: An Analysis Using 2011 Virginia Outdoors Survey Data. February 27.*

[8] *Rephann, Terrance. 2012. Outdoor Recreation Demand for Virginia: An Analysis Using 2011 Virginia Outdoors Survey Data. February 27.*

Consumer surplus values[9] were used to value the annual increase in recreation participation (activity days). The results (value of increased recreation participation) are distributed across the total acreage of new and existing park space (59.2 acres) to obtain a value per acre. Currently, there are 13.6 acres of park space, and Norfolk's Coastal Adaptation and Community Transformation Plan intends to add 45.6 acres of manicured parks, sports fields, waterfront promenade space, and converted open to recreation space. To account for outdoor recreation activity that may already be occurring, the recreation value for 13.6 acres is subtracted from the total benefits.

FEMA

FEMA provides a recreation value per acre per year for green open space, wetlands, and riparian habitat using the benefit transfer method. See Appendix F-8 through Appendix F-10 for more detail on the studies used to determine the recreation value per square foot. The benefit transfer method applies the results of previously conducted primary studies to another geography. For more detail on benefit transfer, see the Environmental Benefits Section of this Attachment F Part 5.0 BCA. The recreation value was converted from acres to square feet and (based on the vegetative cover) applied to the total area of new and improved park space resulting from Norfolk's Coastal Adaptation and Community Transformation Plan to estimate the recreation value of such spaces. The half of the total value was used for improved park space, as there could be existing recreational use of the space.

Limitations, Uncertainties, Assumptions, Sensitivities

Limitations, uncertainties, assumptions, and sensitivities of the **Earth Economics** approach include:

- It is assumed that the current amount of recreation area does not fully meet the needs of residents in the Target Area.
- It is assumed that the ratio of activity days to persons within a year is the same in Norfolk as it is statewide.
- Recreational amenities will be added throughout the Target Area; therefore, it is assumed that the entire population contributes to the number of activity days per activity.
- An increase in population is considered by calculating benefits for the population in 2020, using projected activity days (based on population projections) at certain points in time. Population growth is considered until 2020, as projected activity days are provided only for 2020.

Limitations, uncertainties, assumptions, and sensitivities of the **FEMA** methodology include:

- The results of previously conducted studies are applicable to the Target Area. The FEMA value relies on studies, which are limited in scope, but are considered applicable nationwide. This approach does not consider location specific factors known to impact the results of studies that value recreational benefits, such as population density, age, and income distribution.[10]

Detailed Results

The results of the above methods are presented in Table IV.3.3 through Table IV.3.10 below. Annual results are projected over a 50-year project useful life at a 7% discount rate to determine net present value. The FEMA values represent low results, Earth Economics average results for the total population in 2010 represent medium range results, and Earth Economics average results for the population in 2020 represent high results. The low, medium, and high annual results were incorporated in the low, medium, and high benefit cost ratio, respectively.

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[9] *Rosenberger, R. 2015. College of Forestry Recreation Use Database. Oregon State University. [Web page] Located at: http://recvaluation.forestry.oregonstate.edu/.*

[10] *Brander, L.M. and M.J. Koetse. 2011. The Value of Urban Open Space: Meta-analyses of contingent valuation and hedonic pricing results. Journal of Environmental Management. 92 (2011) 2763-2773. October*

Table IV.3.3 Earth Economics Method Annual Benefits for Newton's Creek Watershed Transformation Project

Activity	Regional Method		Cohort Component Method		Average	
Year	2010	2020	2010	2020	2010	2020
Walking for pleasure	$3,805,883.22	$4,245,545.05	$3,700,359.36	$3,984,340.17	$3,753,121.29	$4,114,942.61
Jogging/running	$7,909,818.29	$8,886,690.82	$5,497,095.78	$5,879,849.85	$6,703,457.03	$7,383,270.33
Fitness trail	$318,665.92	$356,224.37	$379,078.54	$388,422.47	$348,872.23	$372,323.42
Using a playground	$1,940,987.71	$2,176,816.66	$2,363,634.93	$2,922,151.36	$2,152,311.32	$2,549,484.01
Picnicking away from home	$156,244.55	$173,395.14	$155,652.15	$164,976.44	$155,948.35	$169,185.79
Visiting natural preserves	$267,355.67	$300,178.93	$212,911.71	$242,195.08	$240,133.69	$271,187.00
Visiting parks	$1,028,721.83	$1,156,333.03	$520,107.65	$555,100.25	$774,414.74	$855,716.64
Softball	$205,041.90	$227,996.72	$223,629.75	$246,133.53	$214,335.83	$237,065.13
Baseball	$356,575.43	$398,795.36	$238,621.85	$252,955.43	$297,598.64	$325,875.40
Soccer	$590,531.17	$661,846.82	$888,420.07	$943,317.96	$739,475.62	$802,582.39
Football	$341,586.79	$384,411.28	$300,242.00	$319,465.85	$320,914.40	$351,938.56
Visiting historic areas	$585,059.85	$655,615.04	$467,673.88	$509,482.96	$526,366.87	$582,549.00
Bird watching	$84,679.47	$93,631.56	$106,487.58	$119,219.60	$95,583.52	$106,425.58
Total Benefit	$17,591,151.81	$19,717,480.78	$15,053,915.26	$16,527,610.94	$16,322,533.53	$18,122,545.86

Table IV.3.4 Earth Economics Method Annual Benefits Ohio Creek Watershed Transformation Project

Activity	Regional Method		Cohort Component Method		Average	
Year	2010	2020	2010	2020	2010	2020
Walking for pleasure	$794,734.52	$886,543.54	$772,699.30	$831,999.43	$783,716.91	$859,271.49
Jogging/running	$1,651,707.44	$1,855,695.39	$1,147,889.07	$1,227,814.77	$1,399,798.25	$1,541,755.08
Fitness trail	$66,542.98	$74,385.84	$79,158.18	$81,109.36	$72,850.58	$77,747.60
Using a playground	$405,311.94	$454,557.13	$493,568.03	$610,195.96	$449,439.99	$532,376.54
Picnicking away from home	$32,626.58	$36,207.92	$32,502.87	$34,449.95	$32,564.72	$35,328.93

Activity	Regional Method		Cohort Component Method		Average	
Year	2010	2020	2010	2020	2010	2020
Visiting natural preserves	$55,828.51	$62,682.57	$44,459.66	$50,574.54	$50,144.08	$56,628.56
Visiting parks	$214,814.99	$241,462.42	$108,607.51	$115,914.57	$161,711.25	$178,688.50
Softball	$42,816.31	$47,609.68	$46,697.78	$51,396.96	$44,757.04	$49,503.32
Baseball	$74,459.14	$83,275.40	$49,828.39	$52,821.49	$62,143.77	$68,048.44
Soccer	$123,313.16	$138,205.11	$185,517.54	$196,981.17	$154,415.35	$167,593.14
Football	$71,329.26	$80,271.75	$62,695.74	$66,710.02	$67,012.50	$73,490.88
Visiting historic areas	$122,170.66	$136,903.81	$97,658.43	$106,388.89	$109,914.54	$121,646.35
Bird watching	$17,682.54	$19,551.90	$22,236.46	$24,895.12	$19,959.50	$22,223.51
Total Benefit	$3,673,338.02	$4,117,352.44	$3,143,518.96	$3,451,252.22	$3,408,428.49	$3,784,302.33

Table IV.3.5 Earth Economics Method Annual Benefits Elizabeth River Project

Activity	Regional Method		Cohort Component Method		Average	
Year	2010	2020	2010	2020	2010	2020
Saltwater Fishing	$657,771.83	$742,077.77	$792,206.81	$966,580.68	$724,989.32	$854,329.22

Table IV.3.6 Earth Economics Method Net Present Value for Newton's Creek Watershed Transformation Project

Activity	Regional Method		Cohort Component Method		Average	
Year	2010	2020	2010	2020	2010	2020
Walking for pleasure	$52,524,027.69	$58,591,688.81	$51,067,719.70	$54,986,866.67	$51,795,873.69	$56,789,277.74
Jogging/running	$109,161,393.11	$122,642,962.82	$75,864,022.57	$81,146,314.25	$92,512,707.84	$101,894,638.54
Fitness trail	$4,397,827.39	$4,916,162.07	$5,231,566.68	$5,360,519.78	$4,814,697.03	$5,138,340.93
Using a playground	$26,787,078.35	$30,041,693.86	$32,619,925.35	$40,327,868.76	$29,703,501.85	$35,184,781.31
Picnicking away from home	$2,156,291.36	$2,392,982.27	$2,148,115.75	$2,276,797.89	$2,152,203.56	$2,334,890.08
Visiting natural preserves	$3,689,707.66	$4,142,693.15	$2,938,340.44	$3,342,472.77	$3,314,024.05	$3,742,582.96

Activity	Regional Method		Cohort Component Method		Average	
Year	2010	2020	2010	2020	2010	2020
Visiting parks	$14,197,128.72	$15,958,258.38	$7,177,873.60	$7,660,797.60	$10,687,501.16	$11,809,527.99
Softball	$2,829,731.24	$3,146,524.83	$3,086,257.37	$3,396,826.38	$2,957,994.30	$3,271,675.61
Baseball	$4,921,006.97	$5,503,673.53	$3,293,159.59	$3,490,973.62	$4,107,083.28	$4,497,323.58
Soccer	$8,149,770.64	$9,133,979.83	$12,260,859.71	$13,018,491.60	$10,205,315.17	$11,076,235.71
Football	$4,714,152.58	$5,305,162.42	$4,143,563.61	$4,408,867.03	$4,428,858.09	$4,857,014.72
Visiting historic areas	$8,074,262.39	$9,047,976.62	$6,454,248.42	$7,031,244.88	$7,264,255.41	$8,039,610.75
Bird watching	$1,168,639.83	$1,292,185.44	$1,469,607.98	$1,645,319.35	$1,319,123.90	$1,468,752.40
Net Present Value	$250,280,623.72	$280,588,048.27	$216,799,674.93	$239,128,554.81	$233,540,149.32	$259,858,301.54

Table IV.3.7 Earth Economics Method Net Present Value for Ohio Creek Watershed Transformation Project

Activity Days	Regional Method		Cohort Component Method		Average	
Year	2010	2020	2010	2020	2010	2020
Walking for pleasure	$10,967,929.23	$12,234,962.25	$10,663,826.82	$11,482,212.78	$10,815,878.02	$11,858,587.51
Jogging/running	$22,794,794.81	$25,609,980.72	$15,841,725.53	$16,944,759.77	$19,318,260.17	$21,277,370.24
Fitness trail	$918,342.74	$1,026,580.02	$1,092,441.99	$1,119,369.63	$1,005,392.36	$1,072,974.83
Using a playground	$5,593,607.20	$6,273,227.45	$6,811,606.96	$8,421,159.42	$6,202,607.08	$7,347,193.43
Picnicking away from home	$450,271.09	$499,696.26	$448,563.88	$475,434.94	$449,417.48	$487,565.60
Visiting natural preserves	$770,475.04	$865,066.28	$613,576.52	$697,966.37	$692,025.78	$781,516.32
Visiting parks	$2,964,607.06	$3,332,361.51	$1,498,864.67	$1,599,707.59	$2,231,735.86	$2,466,034.55
Softball	$590,897.03	$657,049.03	$644,464.14	$709,316.35	$617,680.58	$683,182.69
Baseball	$1,027,591.72	$1,149,262.62	$687,668.92	$728,975.92	$857,630.32	$939,119.27
Soccer	$1,701,813.66	$1,907,333.63	$2,560,280.45	$2,718,487.15	$2,131,047.06	$2,312,910.39
Football	$984,396.93	$1,107,810.05	$865,248.05	$920,648.01	$924,822.49	$1,014,229.03
Visiting historic areas	$1,686,046.22	$1,889,374.66	$1,347,759.17	$1,468,246.05	$1,516,902.70	$1,678,810.36
Bird watching	$244,032.29	$269,830.76	$306,879.67	$343,571.26	$275,455.98	$306,701.01
Total	$52,262,941.14	$58,591,657.77	$45,271,537.53	$49,934,195.46	$48,767,239.33	$54,262,926.61

Table IV.3.8 Earth Economics Method Net Present Value Elizabeth River Project

Activity	Regional Method		Cohort Component Method		Average	
Year	2010	2020	2010	2020	2010	2020
Saltwater Fishing	$1,568,136.12	$10,241,226.76	$10,933,044.93	$13,339,534.43	$10,005,393.42	$11,790,380.59

Table IV.3.9 FEMA Method Ohio Creek Watershed Transformation Project

Category*	Description	Square Feet	Recreation Value per SF per Year	Recreation Value per Section per Year	Net Present Value
Green Open Space	Conversion of Open Space to Rec Outdoor Space***	501,520	$0.13	$32,598.80	$449,887.76
Wetlands	Wetland Protection and Restoration	658,170	$0.01	$6,581.70	$90,832.37
Green Open Space	Permeable Pavement	72,725	$0.13	$9,454.25	$130,475.70
Green Open Space	Grandy Village	41,000	$0.13	$5,330	$73,557.98
	Total	1,273,415		$53,964.75	$744,753.81

*Feature categorized to determine a standard recreation value per square foot per year.
**Bio-retention Features and Rain Gardens do provide a recreational benefit, and thus, are not included in the results above.
***Half of the total benefit is included because recreational use may already be occurring.

Table IV.3.10 FEMA Method Newton's Creek Watershed Transformation Project

Category*	Description	Square Feet (SF)	Recreation Value Per SF per Year	Recreation Value per Section per Year	Net Present Value
Green Open Space	New Park Space - Naturalized Upland Areas	1,206,612	$0.13	$156,859.56	$2,164,778.95
Green Open Space	Improved Park Space - Manicured Parks/Sports Fields***	933,398	$0.13	$60,670.87	$837,303.27
Green Open Space	Improved Waterfront Areas - Waterfront Promenade***	335,902	$0.13	$21,833.63	$301,320.38

Category*	Description	Square Feet (SF)	Recreation Value Per SF per Year	Recreation Value per Section per Year	Net Present Value
Green Open Space	Added Bike and Pedestrian Paths - Concrete Walkways	211,150	$0.13	$27,449.50	$378,823.58
Wetlands	New Inland wetland development	2,813,976	$0.01	$28,139.76	$388,349.68
	Total	5,501,038		$294,953.32	$4,070,575.86

*Feature categorized to determine a standard recreation value per square foot per year.
***Half of the total benefit is included to consider recreational use that may already be occurring.

Table IV.3.11 FEMA Method Elizabeth River Project

Category*	Description	Square Feet (SF)	Recreation Value Per SF per Year	Recreation Value per Section per Year	Net Present Value
Riparian	Living Shoreline	13,500	$0.37	$10,101.00	$139,401.34

Health Benefits

Health Benefits of Recreation

Regular exercise strongly influences an individual's health. Generally, people who are physically active live longer and are at lower risk for heart disease, stroke, type 2 diabetes, depression, some cancers, and obesity[11]. The National Center for Chronic Disease Prevention and Health Promotion (Centers for Disease Control [CDC]) estimates that for adults, 150 minutes of exercise weekly and muscle training bi-weekly is necessary to maintain proper health. Adequate, safe, and community-scale space for outdoor recreation can influence physical activity behavior among residents. Studies have found that access to outdoor recreation can increase the rate of exercise for a surrounding population by 48%.[12] Increased exercise improves health, and therefore, reduces health care costs and increases work productivity. The benefits valued here are avoided health care costs of medical bills and compensation payments due to an increase in physical activity, as well as lost productivity costs due to poor physical health. These benefits are not duplicative of the recreational benefits calculated above, which is the benefit a consumer derives from the recreational service provided by park space. These benefits also do not duplicate the lost productivity costs as a result of increased mental illness post-disaster, which are quantified in the Human Impacts section.

Sources

Earth Economics, studies conducted by the Trust for Public Land, and the East Carolina University Physical Inactivity Cost Calculator provided resources to quantify benefits, and the data necessary to complete the analysis was obtained from the CDC and American Community Survey 2013 5-year estimates.[13] Population projections were obtained from the University of Virginia Weldon Cooper Center for Public Service, Demographics and Workforce Group.[14]

Detailed Approach

State level data on physical fitness was used to determine the number of people that would meet physical fitness guidelines if the Norfolk's Coastal Adaptation and Community Transformation Plan were implemented.[15] Therefore, the total number of residents in the Target Area is adjusted based on the percentage of the population that meets physical fitness guidelines (both 150-minute aerobic exercise and muscle strengthening requirements). In Virginia, this percentage is 22.7% for adults and 23.8% for children that meet aerobic exercise requirements.[16] The increase in the number of residents meeting physical fitness guidelines is related to an increase in physical activity (48%) associated with added recreation space.[17] Thus, the number of residents meeting physical fitness guidelines is adjusted based on this percentage to determine the additional number of residents meeting fitness guidelines due to added recreation space. Health care cost savings per person per year, determined using the Physical Inactivity Cost Calculator, were applied to the increased number of residents meeting physical fitness guidelines to determine avoided health care costs due to increased physical activity. To provide low, medium and high estimated benefits and to account for population growth, benefits are calculated for the projected population at certain points in time.

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[11] National Center of Chronic Disease Prevention and Health Promotion. 2014. State Indicator Report on Physical Activity. Page 1.

[12] *Sherer, P. 2006. The Benefits of Parks: Why America Needs More City Parks and Open Space. San Francisco: The Trust for Public Land.*

[13] *United States Census. 2013 American Community Survey 5-year estimates. Located at: https://www.census.gov/programs-surveys/acs/data.html*

[14] *Population Estimates. Undated. Located at: http://www.coopercenter.org/demographics/virginia-population-estimates*

[15] National Center of Chronic Disease Prevention and Health Promotion. 2014. State Indicator Report on Physical Activity.

[16] *National Center of Chronic Disease Prevention and Health Promotion. 2014. State Indicator Report on Physical Activity. Page 18.*

[17] *Sherer, P. 2006. The Benefits of Parks: Why America Needs More City Parks and Open Space. San Francisco: The Trust for Public Land.*

Limitations, Uncertainties, Assumptions, and Sensitivities

- The percentage of people meeting physical fitness guidelines in the Target Area is the same as the percentage of people within the State of Virginia meeting physical fitness guidelines.
- The population will grow over time; therefore, benefits will increase. These additional benefits were captured using population projections through 2040, the latest projections available to analysts.
  - Population projections were available for Norfolk City for 2020 and 2040. To determine population growth in the Target Area, it was assumed the share of population in the Target Area as compared to Norfolk City will remain constant over time.
  - Age distribution will remain the same over time.
- People working in the Target Area may also benefit from the added recreation space, but these benefits are not included in the analysis.
- Conceptual designs show added recreation space and amenities throughout the Target Area; therefore, it is assumed that the entire population residing within the Target Area will benefit.

Detailed Results

The low, medium, and high results are presented in Table IV.3.12 below, and are based on the population in 2013, 2020, and 2040, respectively. Results have been integrated with other benefits to determine total annual benefits, net present value, and the benefit cost ratio. The net present value was determined using a net present value coefficient for a 50-year project useful life at a 7% discount rate.[18]

Table IV.3.12 Health-Related Benefits of Increased Recreational Activity

Watershed	Ohio Creek	Newton's Creek	Total Benefits
2013 Population			
Annual Benefits-Population Under 18	$97,871.24	$454,251.94	$552,123.18
Annual Benefits-Population Over 18	$156,194.38	$725,582.07	$881,776.45
Total Annual Benefits	$254,065.62	$1,179,834.01	$1,433,899.63
Net Present Value	$3,506,295.00	$16,282,589.55	$19,788,884.56
2020 Population			
Annual Benefits-Population Under 18	$126,705.33	$491,396.68	$618,102.02
Annual Benefits-Population Over 18	$202,211.21	$784,913.82	$987,125.02
Total Annual Benefits	$328,916.54	$1,276,310.50	$1,605,227.04
Net Present Value	$4,539,293.62	$17,614,037.03	$22,153,330.65
2040 Population			
Annual Benefits-Population Under 18	$131,007.61	$508,082.05	$639,089.66
Annual Benefits-Population Over 18	$209,077.28	$811,565.55	$1,020,642.83
Total Annual Benefits	$340,084.89	$1,319,647.59	$1,659,732.48
Net Present Value	$4,693,425.22	$18,212,121.22	$22,905,546.44

[18] *Association of Floodplain Managers. 2008. Discount Rate. Page 3. Located at: http://www.floods.org/PDF/WhitePaper/ASFPM_Discount_%20Rate_Whitepaper_0508.pdf*

Aesthetic Benefits

Aesthetic Benefits

Norfolk's Coastal Adaptation and Community Transformation Plan will provide a litany of benefits that will render the Target Area more appealing to existing and future residents and businesses, in turn resulting in a positive effect for residents and the local economy. Attractive views and reduction of flood risk are just two contributing factors to this positive effect that can be quantified. There are two methods that can be used to quantify such benefits: FEMA calculates aesthetic benefit based on the square footage of added space that may be considered an aesthetic amenity; while Earth Economics provides an approach that evaluates potential impacts to property values. Impacts to property values that were considered include the location of property near well-maintained green spaces and attractive views, in addition to the reduction in perceived risk of flooding. Property value benefits are presented for high, medium, and low scenarios. Both FEMA and Earth Economics provide methods to value benefits, but Earth Economic values are incorporated into the benefit-cost ratio to avoid a duplication of benefits. Nevertheless, it is important to recognize the benefits produced by FEMA's methodology as to illustrate a range of benefits. For reader facilitation, FEMA's approach to calculate aesthetic benefits are presented first, followed by a more detailed discussion of impacts to property values and benefits incorporated into the benefit-cost ratio.

Sources

FEMA's Final Sustainability Benefits Methodology Report[19] provided the method to value the square footage of added space that may be considered aesthetic. Earth Economics[20] and *The Value of Green Infrastructure: A Guide to Recognizing Its Economic, Environmental, and Social Benefits* (The Green Infrastructure Guide) developed by the Center of Neighborhood Technology[21] and various sources of literature provided the research needed to estimate an increase in property value for both proximity to aesthetic resources and reduction in flood risk. The value of real estate in the Target Area was obtained from the City of Norfolk Real Estate Assessor data.[22]

Detailed Approach

There are two methods that can be used to quantify aesthetic benefits (Table IV.3.13) - Earth Economics or FEMA. Earth Economics adjusts nearby property values by a percentage that is based on a compilation of literature that reveals property value increases due to aesthetic improvements, as well as other factors described later. FEMA quantifies aesthetic benefits based on the square footage of added or improved spaces. Both methods and results are presented in this section to illustrate a range of benefits. Ultimately, the Earth Economic low, medium, and high estimates have been integrated into the low, medium, and high benefit cost ratio.

Table IV.3.13 Methods to Value Aesthetic Benefits

Parameter	FEMA	Earth Economics		
Aesthetic Benefit	Low Value	Low Value	Medium Value	High Value

[19] *Federal Emergency Management Agency. 2012. Final Sustainability Benefits Methodology Report. HSFEHQ-10-D-0806. August 23.*

[20] *Earth Economics. 2014. Earth Economics Homepage. [Web page]. Located at: http://www.eartheconomics.org/.*

[21] *Center for Neighborhood Technology. 2011. The Value of Green Infrastructure: A Guide to Recognizing Its Economic, Environmental and Social Benefits. January 21.*

[22] *Web page: http://www.norfolk.gov/assessor/*

FEMA Approach to Aesthetic Benefit

The same FEMA-based approach used to estimate recreation value was used to determine aesthetic value. To summarize the approach, FEMA provides an aesthetic value per acre per year for a number of features that are considered aesthetic amenities. Analysts converted the values from acres to square feet, and applied the value per square foot to the total added area of new and improved aesthetic space to yield the estimated aesthetic value of such spaces. The features that Norfolk's Coastal Adaptation and Community Transformation Plan will contribute to aesthetic quality, FEMA's aesthetic value per square foot for those features, and the resulting benefits are presented in Table IV.3.14 and Table IV.3.15 below. As discussed previously, these benefits are not included in the benefit-cost ratio.

Table IV.3.14 Added and Improved Spaces Contributing to Aesthetic Quality – Newton's Creek Watershed Transformation Project

Feature	Added Square Feet (SF)	Aesthetic Value per SF per Year	Aesthetic Value per Feature per Year	Net Present Value
New Park Space - Naturalized Upland Areas	1,206,612	$0.04	$48,264.48	$666,062.86
Improved Park Space - Manicured Parks/Sports Fields	933,398	$0.04	$37,335.92	$515,245.78
Improved Waterfront Areas - Waterfront Promenade	335,902	$0.04	$13,436.08	$185,421.53
Increased Bike and Pedestrian Paths - Concrete Walkways	211,150	$0.04	$8,446.00	$116,557.08
New Inland wetland development	2,813,976	$0.04	$112,559.04	$1,553,345.14
		Total	$220,041.52	$3,036,632.39

Table IV.3.15 Added and Improved Spaces Contributing to Aesthetic Quality – Ohio Creek Watershed Transformation Project

Description	Square Feet (SF)	Aesthetic Value per SF per Year	Aesthetic Value per Feature per Year	Net Present Value
Conversion of Open Space to Rec Outdoor Space	501,520	$0.04	$20,060.80	$276,844.46
Wetland Protection and Restoration	658,170	$0.04	$26,326.80	$363,316.95
Bio-retention Features	746,500	$0.04	$29,860.02	$412,076.06
Permeable Pavement	72,725	$0.04	$2,909.00	$40,144.99
Rain Gardens	6,480	$0.04	$259.20	$3,577.03
Grandy Village	41,000	$0.04	$1,640	$22,633.22
		Total	$81,055.82	$1,118,592.71

Table IV.3.16 Improvements Contributing to Aesthetic Quality – Elizabeth River Project

Description	Square Feet (SF)	Aesthetic Value per SF per Year	Aesthetic Value per Feature per Year	Net Present Value
Living Shoreline	13,500	$0.01	$66	$910.00

Earth Economics Approach to Property Value Benefits

Research indicates that property values increase from a reduction in flood risk and an increase in aesthetic value; these benefits are mutually exclusive and thus may be quantified without any duplication.

Aesthetic value related to green spaces can be determined from what consumers are willing to pay for this value in the housing market.[23] Literature[24] indicates that green spaces can increase property values by 3% to 20%[25]; a summary of this literature is provided in Appendix F-20. Research also shows that property value increases 2% to 5% on average for marginal reductions in flooding; because increases are based on visible improvements, this is considered a conservative estimate.[26] The reduction in flood risk may also be realized in the reduction of flood insurance premiums. Streiner and Loomis (1995), using hedonic pricing, found that flood damage reduction added 3% to 5% to mean residential property value.[27] Bin et al. (2008) found that, in areas where there is a high level of risk awareness in the community due to regulatory standards, homes located in the floodplain experience a 7% reduction in price. [28]

Ranges of property value increases as a result of both proximity to aesthetic amenities and reduction in flood risk call for presentation of benefits in high, medium, and low scenarios. The approach presented below was followed for each of these scenarios, using 10%, 5%, and 3% increases in property value for proximity to aesthetic amenities, and 5%, 3.5%, and 2% increases for flood risk reduction.

The assessed value of structures that were appropriate to include in each analysis was determined from the City of Norfolk 2014 Real Estate Assessor data. The assessed value must be converted to market value. An assessed value is the valuation placed on a property by a public tax assessor for purposes of taxation, while fair market value is the agreed upon price between a willing and informed buyer and seller under usual and ordinary circumstances. In other words, market value is the best estimate of the price the property will bring when offered for sale on the open market. Tax assessors often apply an 80% multiplier to the fair market value to determine the assessed value (meaning the assessed value is 80% of the market value).[29] Thus, to convert assessed value to market value, the below equation is used.

$$Increase\ in\ Property\ Value = (Assessed\ Value * Percent\ Increase)/0.8$$

The applicable percentage increase in property value was then applied to the structure assessed value. The added value calculated using the equation above must then be converted to an annual figure. To do so, Earth Economics suggests that a reasonable estimate is 1% of the overall property value increase is realized per month; therefore, the added value is multiplied by 12% to obtain an annual added value using the following equation:

$$Increase\ in\ Property\ Value * 0.12 = Added\ Value\ Per\ Year$$

It is important to note that for this analysis, the increase in property value represents a cap for which the added value per year should not exceed. For example, it may take 10 years of added value to reach the increase in property value identified using the above equations. The annual value is used to project benefits each year

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[23] *Earth Economics. Located at: http://www.eartheconomics.org/*

[24] *Referenced literature is a combination of that referenced by Earth Economics, as well as independent research completed by Arcadis.*

[25] *Sadeghian M. and Vardanyan Z. 2013. The Benefits of Urban Parks, a Review of Urban Research. Journal of Novel Applied Sciences. 2 (8): 231-237.; Haq S. 2011. Urban Green Spaces and an Integrative Approach to Sustainable Environment. Journal of Environmental Protection. 2, 601-608. May 3.; Wise, S., Braden, J., Ghalayini, D., Grant, J., Kloss, C. MacMullan, E., Morse, S., Montatto, F., Nees, D., Nowak, D., Peck, S., Shaik, S. and C. Yu. 2010. Integrating Valuation Methods to Recognize Green Infrastructure's Multiple Benefits: Low Impact Development. pp. 1123-1143. DOI: 10.1061/41099(367)98.*

[26] *Johnston, D.M. and J.B. Braden. 2004. Downstream Economic Benefits from Storm Water Management: A Comparison of Conservation and Conventional Development. DOI: 10.1061/(ASCE)0733-9496(2004)130:6(498).*

[27] *Streiner, C.F., and Loomis, J.B. 1995. "Estimating the benefits of urban stream restoration using the hedonic price method." River, 5(4), 267–278.*

[28] *Bin, O., Brown Kruse, J., and C.E. Landry. 2008. Flood Hazards, Insurance Rates, and Amenities: Evidence from Coastal Housing Market. Journal of Risk and Insurance. Vol. 75 No. 1. Pp. 63-82*

[29] *Duncan, J. 2013. Assessed Value vs Market Value: Understanding the Difference. Movoto Blog. [web page] Located at: http://www.movoto.com/blog/homeownership/assessed-value-vs-market-value/. April 3.*

until the total added value is reached.

Limitations, Uncertainties, Sensitivities, and Assumptions

Limitations, uncertainties, assumptions, and sensitivities of the FEMA approach include:

- It is assumed that the results of previously conducted studies, used by FEMA to determine standard values, are applicable to the Target Area.

Limitations, uncertainties, assumptions, and sensitivities of the Earth Economics approach include:

- The benefits that result from perceived flood risk reduction and proximity to aesthetic amenities are not considered a duplication of benefits because the estimated increase in property value is considered conservative for both benefits. Moreover, such benefits are mutually exclusive.
- Benefits are realized financially when a property is sold on the open market. Nevertheless, the property value increase is a quantification of the increased value to residents and prospective buyers in the area; date of sale is neither known nor relevant to the benefits calculated.
- Aesthetic improvements and added spaces are located throughout the Target Area; therefore, it is assumed that all property values within the Target Area will increase as a result of Norfolk's Coastal Adaptation and Community Transformation Plan. Figure IV.3.1 below illustrates the conceptual design for the Ohio Creek Open Space.
- Perceived flood risk reduction is expected to only be realized in structures that flood during the 10% annual chance scenario, which is closest to the flooding that was experienced during Hurricane Irene. Structures evaluated for an increase in property value are those that meet such criteria.

Figure IV.3.1 Target Area Open Space Conceptual Design

Detailed Results

The results of the Earth Economics methodology (for property value increases as a result of aesthetic amenity and reduction in perceived flood risk) are presented below. These scenario results are integrated with other losses avoided and added benefits to determine total annual benefits, net present value, and the benefit cost ratio.

As demonstrated in Table IV.3.17 and Table IV.3.18, the total added value per year for the medium scenario is $11.7 million in Newton's Creek, $2.6 million in Ohio Creek, and $27,848.68 for the Elizabeth River Project. Based on the total increase in market value and the total added value per year, it is estimated that it will take 8.3 years after project implementation for the increase in property values to be fully realized.

Table IV.3.17 Scenario Results for Added Property Values: Aesthetic Value and Reduction in Flood Risk

Target Area	Scenario	Aesthetic Value			Reduction in Flood Risk (10% Annual Chance)		
		Increased Property Value (20%, 10%, 5%)	Increased Market Value	Added Value per Year	Increased Property Value (5%, 3.5%, 2%)	Increased Market Value	Added Value per Year
Newton's Creek	High	$151,305,324.27	$189,131,655.34	$22,695,798.64	$3,797,120.00	$4,746,400.00	$569,568.00
	Medium	$75,652,662.14	$94,565,827.67	$11,347,899.32	$2,657,984.00	$3,322,480.00	$398,697.60
	Low	$37,826,331.07	$47,282,913.84	$5,673,949.66	$1,18,848.00	$1,898,560.00	$227,827.20
Ohio Creek	High	$33,024,820.01	$41,281,025.01	$4,953,723.00	$1,443,520.00	$1,804,400.00	$216,528.00
	Medium	$16,512,410.00	$20,640,512.50	$2,476,861.50	$1,010,464.00	$1,263,080.00	$151,569.60
	Low	$8,256,205.00	$10,320,256.25	$1,238,430.75	$577,408.00	$721,760.00	$86,611.20
Elizabeth River	High	$371,315.72	$464,144.65	$55,697.36	-	-	-
	Medium	$185,657.86	$232,072.32	$27,848.68			
	Low	$92,828.93	$116,036.16	$13,924.34			

Table IV.3.18 Total Results for Added Property Values

Target Area	Scenario	Total Increased Property Value	Total Increased Market Value	Total Added Value per Year
Newton's Creek	High	$155,102,444.27	$193,878,055.34	$23,265,366.64
	Medium	$78,310,646.14	$97,888,307.67	$11,746,596.92
	Low	$37,826,331.07	$49,181,473.84	$5,901,776.86
Ohio Creek	High	$34,468,340.01	$43,085,425.01	$5,170,251.00
	Medium	$17,522,874.00	$21,903,592.50	$2,628,431.10
	Low	$8,833,613.00	$11,042,016.25	$1,325,041.95
Elizabeth River	High	$371,315.72	$464,144.65	$55,697.36
	Medium	$185,657.86	$232,072.32	$27,848.68
	Low	$92,828.93	$116,036.16	$13,924.34

4.0 Economic Revitalization

Economic Revitalization Benefits

The Norfolk Proposed Project consists of several economic revitalization efforts targeted towards various locations within the Target Areas. These efforts include the following:

1) Redevelopment of public housing sites within the Newton Creek watershed, specifically the Tidewater Gardens, Young Terrace, Calvert Square, and Harbor Park revitalization districts. The revitalization efforts are planned to consist of additional retail and office space, new residential units, and more hospitality opportunities in those districts. Currently, plans to redevelop these districts are phased and presented in high-, medium-, and low-density scenarios. Figure IV.4.1 below presents a drawing of Newton's Creek watershed's medium-density scenario.
2) Creating an Acceleration Center within the Newton Creek watershed that will partner with education organizations throughout Norfolk to focus revolutionary water management solutions and workforce training for the water management industry.
3) Redevelopment of Grandy Village, a public housing district in the Ohio Creek watershed. The revitalization effort is planned to replace obsolete public housing units with improved, energy-efficient units. The plans also include construction of a community center and use of green space for gathering and play space.

The economic benefits of the aforementioned revitalization efforts can be measured by anticipated added economic output and employment compensation for those industries. This methodology quantifies such benefits by implementing an approach similar to FEMA's Hazus 2.1 software methodology. Hazus is capable of using IMPLAN data to estimate economic and employment impacts due to flooding; therefore, it is appropriate that a similar approach is used to estimate impacts of additional innovation, recreation, retail, office, residential, and hospitality space. Overall, this analysis involves average output and employment compensation values per square foot for industries within the City of Norfolk's Target Area that are expected to be impacted by the proposed revitalization efforts, which are then multiplied by the square footage of added new space for each corresponding industry.

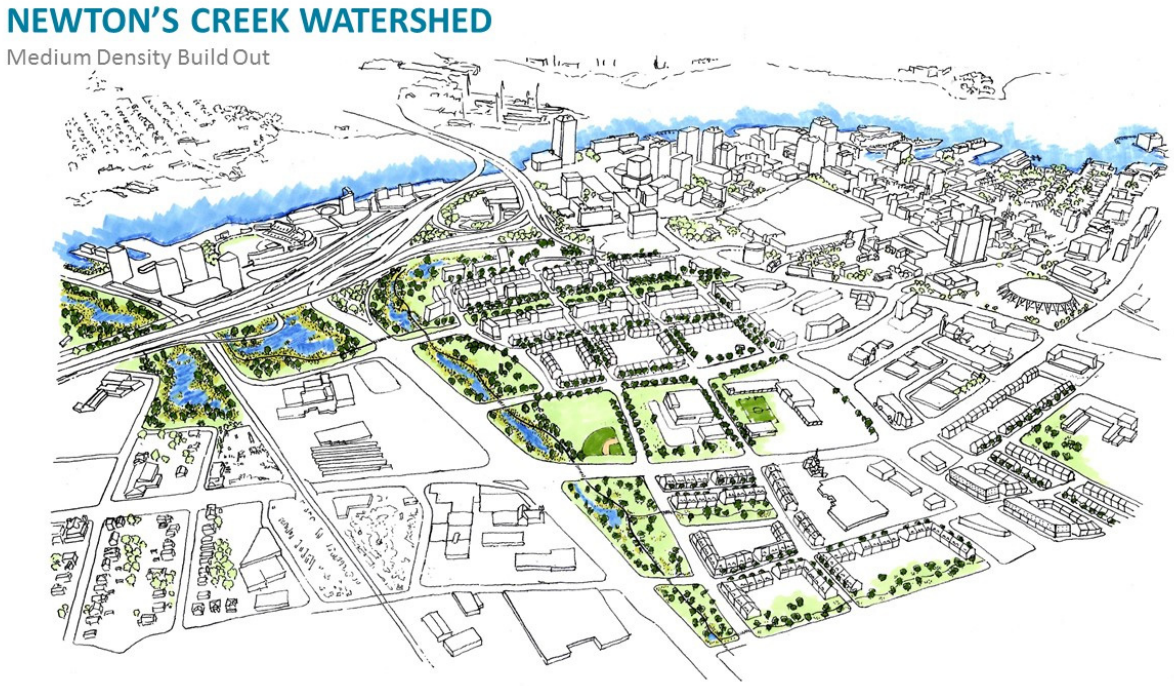

Figure IV.4.1. Newton's Creek Watershed Medium Density Scenario

Data Sources

The main data sources necessary to identify economic revitalization benefits include 2014 Real Estate building data for Norfolk and 2013 IMPLAN data for the City of Norfolk, which provides industry annual economic output data and annual employment compensation data. IMPLAN is a private economic data provider that offers data sourced from federally collected datasets. IMPLAN data were used to determine employment compensation and output per square foot data for retail, office, residential, and hospitality industries. 2014 Real Estate building data maintained by Norfolk's Real Estate Assessor provided the square footage of structures throughout the City.

Detailed Approach

FEMA's Hazus software methodology uses national output per square foot data to estimate economic losses. IMPLAN data are often incorporated into Hazus software and uses employment/output ratios to estimate economic and employment losses. Although the benefits described in this section are not a function of economic loss, the basic approach to estimating economic loss in Hazus may be applied to estimate economic gains.

In following the Hazus approach, Norfolk 2013 industry output and employment compensation values provided by IMPLAN are broken down to yield an average output and employment compensation value per square foot for the City. IMPLAN defines output as the value of industry production; for retail sales, this is considered gross margin. Gross margin represents the total sales revenue a company retains after incurring direct costs. Employment compensation may be defined as the payroll cost of employees paid by an employer, including wages and benefits. IMPLAN also provides employment data per industry; although unable to include in the benefit-cost ratio, analysts have included added employment to this analysis in order to provide an additional measure of the value of economic revitalization[1]. Economic data obtained from IMPLAN are considered complete, current, and can be used to represent economic industries at specifically defined scales; therefore, they are the best available data for this analysis.

The following steps were taken to calculate output and employment compensation per square foot. Table 1 summarizes the results of these steps.

1. Relate retail, office, residential, hospitality, innovation, and recreation industries from IMPLAN to structure class codes in the Norfolk 2014 Real Estate dataset. The mapping results for those industries is provided in Appendix F-15.
2. Calculate the average annual output, employment compensation, and jobs per square foot for each of the four industries. This was accomplished by calculating the total annual output and employment compensation for each industry, divided by the total square footage of structures that would fall under that industry category. The equation below provides an example of the calculation used.

$$Output\ per\ square\ foot = \frac{Total\ Annual\ Output}{Total\ Industry\ Square\ Feet}$$

[1] *As defined by IMPLAN, jobs include both full-time and part-time positions.*

Table IV.4.1 Summary of Output and Employment Compensation

Industry	Total Annual Output	Total Annual Employment Compensation	Total Annual Jobs	Total Square Feet of Space	Average Annual Output per SF	Average Annual Employment Compensation per SF	Average Annual Employment per Square Foot
Retail	$914,584,193	$342,913,363	12,324	11,902,386	$76.84	$28.81	0.001
Office	$4,490,502,284	$319,777,386	31,946	15,000,662	$299.35	$21.32	0.002
Residential	$1,960,032,763	$105,402,934	5,597	115,839,683	$16.92	$1.76	0.000
Hospitality	$783,400,982	$291,175,401	13,584	4,873,197	$160.76	$59.75	0.002
Innovation	$2,657,077,112	$1,154,171,816	15,627,054	18,924.60	$170.03	$73.86	0.001
Recreation	$13,700,160	$5,787,547	235.2	117,703.29	$116.40	$49.17	0.001

After the average annual output and employment compensation per square foot are determined for each industry, the example equation below is used to calculate the economic benefits of added retail, office, residential, hospitality, innovation, and recreation space.

$$Added\ Output\ per\ year = Average\ Annual\ Output\ per\ Square\ Foot * \ Added\ Space\ (SF)$$

Limitations, Uncertainties, Assumptions, and Sensitivities

For the purposes of this analysis, the approach does not account for inflation over time, nor does it consider business turnover, vacancy rates, introduction of new industries, and changes in future land use designations for these revitalization areas. Moreover, the relationships between industries and structure uses that already exist within Norfolk are not at a one-to-one relationship: there are many structure uses that comprise one industry. Analysts also assume that the revitalization plans provide a net addition of space per industry. Therefore, results are considered a broad estimate of future economic gains in these districts, based on the current conditions of Norfolk's economy. This results in a static analysis that does not account for changes in Norfolk's real estate market nor the success of revitalization efforts.

Detailed Results

The results of the analysis for each effort are summarized below.

Annual benefits are projected over a 50-year project useful life. Applicable high-, medium-, and low-density development scenarios are included as results for the public housing revitalization efforts in Newton's Creek watershed. Table IV.4.2 through Table IV.4.4 provide detailed results for each of the public housing revitalization density scenarios; Table IV.4.5 provides detailed results for the additional revitalization efforts: the Acceleration Center and Grandy Village.

Table IV.4.2. Added Output and Employment Compensation for Revitalization Districts – Low Density Scenario

District	Industry	Added SF	Added Annual Output	Added Employment Compensation	Added Jobs	Added Output (NPV)	Added Employment Compensation (NPV)
Tidewater Gardens	Retail	35,000	$2,689,414.27	$1,008,366.21	36.24	$37,115,923.23	$13,916,205.97
	Office	20,000	$5,987,071.98	$426,351.02	42.59	$82,626,059.64	$5,883,962.12
	Residential Units	502,500	$8,502,409.86	$882,656.54	46.87	$117,335,551.78	$12,180,898.63
	Total (TG)	*557,500*	$17,178,896.11	$2,317,373.78	125.70	$237,073,404.64	$31,980,383.79
Young Terrace	Retail	10,000	$768,404.08	$288,104.63	10.35	$10,604,549.49	$3,976,058.85
Calvert Square	Retail	5,000	$384,202.04	$144,052.32	5.18	$5,302,274.75	$1,988,029.42
Harbor Park	Retail	10,000	$768,404.08	$288,104.63	10.35	$10,604,549.49	$3,976,058.85
Total Benefits – Low Density Scenario		**1,140,000**	**$19,099,906.30**	**$3,037,635.36**	**151.59**	**$263,583,863.98**	**$41,920,188.07**

Table IV.4.3 Added Output and Employment Compensation for Revitalization Districts – Medium Density Scenario

District	**Industry**	**Added SF**	**Added Annual Output**	**Added Employment Compensation**	**Added Jobs**	**Added Output (NPV)**	**Added Employment Compensation (NPV)**
Tidewater Gardens	Retail	50000	$3,842,020.39	$1,440,523.16	51.77	$53,022,747.47	$19,880,294.25
	Office	30000	$8,980,607.97	$639,526.53	63.89	$123,939,089.47	$8,825,943.18
	Residential Units	1,095,000	$18,527,639.41	$1,923,400.83	102.13	$255,686,426.26	$26,543,450.74
	Total (TG)	1,175,000	$31,350,267.76	$4,003,450.52	217.79	$432,642,159.62	$55,248,698.06
Young Terrace	Retail	15000	$1,152,606.12	$432,156.95	15.53	$15,906,824.24	$5,964,088.27
	Residential Units	168333	$2,848,236.80	$295,682.62	15.70	$39,306,436.91	$4,080,500.04
	Total (YT)	183333	$4,000,842.92	$727,839.57	31.23	$55,212,712.51	$10,044,382.61
Calvert Square	Retail	10000	$768,404.08	$288,104.63	10.35	$10,604,549.49	$3,976,058.85
	Residential Units	125,000	$2,115,027.33	$219,566.30	11.66	$29,187,948.20	$3,030,074.29
	Total (CS)	135,000	$2,883,431.41	$507,670.94	22.01	$39,792,131.94	$7,005,996.00
Harbor Park	Retail	30000	$2,305,212.23	$864,313.90	31.06	$31,813,648.48	$11,928,176.55
	Office	40000	$11,974,143.95	$852,702.04	85.19	$165,252,119.29	$11,767,924.24
	Hospitality	40000	$6,430,284.04	$2,390,015.56	111.50	$88,742,716.81	$32,983,997.65

District	Industry	Added SF	Added Annual Output	Added Employment Compensation	Added Jobs	Added Output (NPV)	Added Employment Compensation (NPV)
	Residential Units	1040000	$17,597,027.38	$1,826,791.65	97.0	$242,843,729.05	$25,210,218.06
	Total (HP)	1150000	$38,306,667.61	$5,933,823.15	324.75	$528,642,355.84	$81,888,361.55
Total Benefits – Medium Density Scenario		**5,286,666**	**$76,541,209.69**	**$11,172,784.17**	**595.78**	**$1,056,289,359.92**	**$154,187,438.21**

Table IV.4.4 Added Output and Employment Compensation for Revitalization Districts – High Density Scenario

District	Industry	Added SF	Added Annual Output	Added Employment Compensation	Added Jobs	Added Output (NPV)	Added Employment Compensation (NPV)
Tidewater Gardens	Retail	100000	$7,684,040.77	$2,881,046.32	103.54	$106,045,494.94	$39,760,588.49
	Office	50000	$14,967,679.94	$1,065,877.55	106.48	$206,565,149.11	$14,709,905.30
	Residential Units	2,797,143	$47,328,268.70	$4,913,266.56	260.89	$653,142,886.65	$67,804,405.15
	Total (TG)	*2,947,143*	*$69,979,989.41*	*$8,860,190.43*	*470.91*	*$965,742,748.48*	*$122,273,020.21*
Young Terrace	Retail	30,000	$2,305,212.23	$864,313.90	31.06	$31,813,648.48	$11,928,176.55
Calvert Square	Retail	20,000	$1,536,808.15	$576,209.26	20.71	$21,209,098.99	$7,952,117.70
Harbor Park	Retail	50,000	$3,842,020.39	$1,440,523.16	51.77	$53,022,747.47	$19,880,294.25
Total Benefits- High Density Scenario		**5,994,286**	**$77,664,030.18**	**$11,741,236.75**	**574.46**	**$1,071,784,585.82**	**$162,032,237.33**

Table IV.4.5 Added Output and Employment Compensation for the Acceleration Center and Grandy Village

Revitalization Effort	Industry	Added SF	Added Annual Output	Added Employment Compensation	Added Jobs	Added Output (NPV)	Added Employment Compensation (NPV)
Acceleration Center	Innovation	1,500	$255,045.88	$553,929.66	5*	$3,519,701.95	$7,644,378.81
Grandy Village	Recreation	1,500	$174,593.60	$73,755.97	3	$2,409,438.76	$1,017,852.35

**The Acceleration Center is expected to employ five people. The value of these 5 jobs are based on average annual employment compensation values for the innovation industry.*

Incorporation into the Benefit-Cost Ratio

An additional important assumption of this analysis is that the revitalization plan for the public housing developments will be phased; this includes the Tidewater Gardens, Young Terrace, Calvert Square, and Harbor Park districts. It is expected that the City will not engage in redevelopment of more than one district at a time, and that each district will be broken down into sub-phases of redevelopment so that the full benefit of the Proposed Project within one district will be realized within 5 years of the start of implementation.
The full annual benefit then continues to be realized throughout the useful life of the project. Therefore, the results of the analysis for those four revitalization projects are presented in a phased fashion for each density scenario; the medium density scenario is demonstrated in

Figure IV.4.2. This phased format was integrated into the benefit-cost ratio. Note that the Acceleration Center and Grandy Village are not assumed to be phased projects, so these benefits are assumed to be realized the year of implementation and were incorporated into the benefit-cost ratio as such.

	Tidewater Gardens	Young Terrace	Calvert Square	Harbor Park	Total
Year 1-5					
Year 6-10					
Year 11-15					
Year 16-20					
Year 20-50					
Year 50-55					
Year 55-60					
Year 60-65					

Figure IV.4.2 Phasing Assumptions for Revitalization Plans – Medium Density Scenario

Economic Impacts Avoided

Economic Impacts Avoided

Modeled economic impacts for the Proposed Project are presented within this portion of the methodology. These economic impacts are based on expected economic impacts due to various business interruptions and losses resulting from flooding. Additional economic impacts resulting from Proposed Project expenditures are presented in Part V Benefits not Included in the Benefit Cost Ratio.

For the presentation of the economic results, output refers to the value of industry production, which varies by industry[1]. For example, the output of the service sector is measured in sales, hospital output is measured in the total service package that a patient receives during their entire length of stay, and output for non-profit organizations is based on the cost of production or the expenses that the organization must incur to operate[2]. The industry output value is significant because it supports the understanding of the relationships among industries that comprise the overall economy within a geographic region[3].

Indirect economic losses as a result of natural disasters, which demonstrate the economic disruption or ripple effects that follow from direct losses, may be quantified in several ways including lost output, retail sales, wages and work time; utility disruptions; lost tourism; and increased financial market volatility[4]. Measuring change in industry output as a result of some stimulus or impact is considered one of the most efficient and straightforward methods to evaluate the relationships among industries in any given economy. Moreover, it demonstrates the reverberating effects of natural disasters on that economy.

This methodology describes the approach to calculating lost economic output as a result of expected flood damage under various flood scenarios. The analysis accounts for all structures and assets expected to benefit from project implementation. The results of expected loss of economic output are analyzed within the Metropolitan Statistical Area (MSA) and presented as such.

Lost economic output may be used as a benefit in the Proposed Project's BCA, as the proposed flood protection system will prevent damage and disruption from storms within the Target Area. This analysis uses lost economic output by industry and input-output modeling software to calculate the direct effects of output loss within an industry, as well as the effects of loss on supporting industries and spending patterns in the economy (also known as indirect effects). This section will present expected direct and indirect economic impacts within the Target Area, present limitations and assumptions included in the analysis, and provide results by flood scenario.

Sources

The principle calculation used to determine the loss of output (direct effects) is sourced from the Hazus 2.1 Flood Technical Manual (TM) Direct Economic Losses Chapter 14. This calculation is described in more detail in the Detailed Approach section of this methodology. The output loss and economic impact approach uses the results of other analyses completed for this application as inputs, namely the Direct Physical Damage evaluation and Displacement methodologies. Respectively, they provide important information on the extent of future damage expected under specific flood scenarios within the Target Area and economic loss of function (ELOF) time expected due to such damage.

Output loss results are calculated based on ELOF and then imported into input-output software that models the

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[1] MIG IMPLAN. The controlled vocabulary of IMPLAN-specific terms. [web page] located at: http://www.implan.com/index.php?option=com_glossary&Itemid=1865.
[2] Swick, R., Bathgate, D., and M. Horrigan. 2006. Services Producer Price Indices: Past, Present, and Future. U.S. Bureau of Labor Statistics. Located online at: http://www.bls.gov/bls/fesacp1060906.pdf. May 26.
Mead, C.I., McCully, C.P., and M.B. Reindsdorf. 2003. Income and Outlays of Households and of Nonprofit Institutions Serving Households. U.S. Bureau of Economic Analysis. Located at: http://www.bea.gov/scb/pdf/2003/04April/0403household.pdf. April.
[3] Bureau of Economic Analysis. 2014. Frequently Asked Questions. [Web page] Located at: http://www.bea.gov/faq/index.cfm?faq_id=1034. April.
[4] Kliesen, K.L. 1994. The Economics of Natural Disasters. Federal Reserve Bank of St. Louis. [Web page] Located at: https://www.stlouisfed.org/Publications/Regional-Economist/April-1994/The-Economics-of-Natural-Disasters April.

expected effects of such losses on Norfolk's economy. Analysts used IMPLAN software for this portion of the analysis. IMPLAN software is produced by the Minnesota IMPLAN Group of MIG, Inc. and licensed to users for the purpose of measuring the effect of a change or activity that takes place in a particular local or regional economy. MIG, Inc. licensed IMPLAN Version 3.0 economic impact assessment software system to the analyst team. The software uses an input-output methodology of analysis, in combination with social accounting matrices and economic multipliers, to estimate the result of changes or activities in the economic study area. IMPLAN data sets can create a complete set of balanced social accounting matrices (SAMs) for every zip code, county, and state. The SAMs provide a complete picture of the economy, and are used to generate multipliers, which measure the total change throughout the economy from one unit change for a given sector to estimated economic impacts. IMPLAN incorporates data from many sources, including the U.S. Bureau of Economic Analysis (BEA), the U.S. Bureau of Labor Statistics (BLS), and the U.S. Census Bureau. Analysts used the city-level data available in the Virginia Beach-Norfolk-Newport News MSA dataset to estimate output impacts. These impacts were then input into the IMPLAN software to model the relationships of these impacts throughout the MSA. Greater regional and national consequences are not accounted for in the model. These implications are discussed in Part V Qualified Benefits.

Analysts took the following principle steps to identify lost industry output and assess cascading economic impacts:

1. Identify displacement time (see methodologies for Displacement and Direct Physical Damages (Buildings) expected to occur in 10%, 2%, 1%, and 0.2% annual chance flood scenarios.

2. Translate business interruption into output (e.g., sales) losses using Hazus methods.

3. Input these output losses by industry sector into IMPLAN to model the direct and indirect effects of such losses.

Detailed Approach

FEMA's Hazus software methodology uses national output per square foot data to estimate economic losses. IMPLAN data are often incorporated into Hazus software and uses employment/output ratios to estimate economic and employment losses. Although the benefits described in this section are not a function of economic loss, the basic approach to estimating economic loss in Hazus may be applied to estimate economic gains.

In following the Hazus approach, Norfolk 2013 industry output and employment compensation values provided by IMPLAN are broken down to yield an average output and employment compensation value per square foot for the City. IMPLAN defines output as the value of industry production; for retail sales, this is considered gross margin. Gross margin represents the total sales revenue a company retains after incurring direct costs. Employment compensation may be defined as the payroll cost of employees paid by an employer, including wages and benefits. IMPLAN also provides employment data per industry; although unable to include in the benefit-cost ratio, analysts have included added employment to this analysis in order to provide an additional measure of the value of economic revitalization[5]. Economic data obtained from IMPLAN are considered complete, current, and can be used to represent economic industries at specifically defined scales; therefore, they are the best available data for this analysis.

The following steps were taken to calculate output and employment compensation per square foot. Table 1 summarizes the results of these steps.

1. Relate retail, office, residential, hospitality, innovation, and recreation industries from IMPLAN to structure class codes in the Norfolk 2014 Real Estate dataset. The mapping results for those industries is provided in Appendix F-15: Code Mapping.

[5] *As defined by IMPLAN, jobs include both full-time and part-time positions.*

2. Calculate the average annual output, employment compensation, and jobs per square foot for each of the four industries. This was accomplished by calculating the total annual output and employment compensation for each industry, divided by the total square footage of structures that would fall under that industry category. The equation below provides an example of the calculation used.

$$Output\ per\ square\ foot = \frac{Total\ Annual\ Output}{Total\ Industry\ Square\ Feet}$$

Data Sources

As referenced in the introduction to this section, the calculation used to determine industry output loss as a result of economic loss of function was sourced from the Hazus Flood TM. The data necessary to complete those calculations were gathered from the sources identified below:

- **Direct Physical Damages (Buildings)**. Analysts modeled flood impacts at various recurrence intervals to determine which structures are expected to flood and the depth of flooding within those structures. Building damage, contents and inventory loss, and relocation costs were evaluated for each structure. The output loss analysis used this information to gather appropriate square footage of damaged structures to use in the calculations.

- **Displacement Values**. Once flood impacts were modeled and structure damage was identified, the ELOF was calculated for damaged structures using expected displacement time based on the U.S. Army Corps of Engineer's (USACE's) depth-damage function (DDF) in addition to multipliers provided by Hazus in order to differentiate displacement time from ELOF time.

- **Industry Output**. Existing industry output for the Target Areas was sourced from the IMPLAN base model for the City of Norfolk, which uses 2013 data. For the purposes of this analysis, output was identified at the city level so that the most appropriate and accurate measure of economic output by industry could be identified.

- **Norfolk Real Estate Data**. 2014 Real Estate building data for Norfolk were used to determine the building use, designated land use, and square footage of both damaged and undamaged structures in the Target Area.

- **NAICS Codes.** IMPLAN software uses 440 IMPLAN sectors, which are derived from North American Industry Classification System (NAICS) codes.

Detailed Approach

Information Gathering

1. **Identify impacted structures**. Analysts first identified which structures in the Target Areas are expected to incur ELOF time, as identified by the three flood scenarios.

2. **Identify economic industry output in the Target Areas.** Using IMPLAN data at the city level, analysts were able to identify the industries located within the Target Areas. The output for these industries is reported as annual output. For the purpose of this analysis, the annual output was converted to daily output per industry.

3. **Develop a Norfolk Real Estate Data-IMPLAN-Resiliency Occupancy Class Crosswalk.** Analysts assigned Norfolk Real Estate Data class codes to appropriate IMPLAN NAICS codes and Occupancy

Class Codes. Proper identification of damaged structures and their associated economic industries is essential to the analysis, as many assumptions inherent to the analysis are based on industry type. Please refer to Appendix F-15: Code Mapping for the results of the crosswalk.

It should be noted that code mapping correlations do not always occur in a one-to-one ratio. There are instances where several Norfolk Real Estate Data class codes relate to one IMPLAN NAICS and vice versa. This was particularly the case for Norfolk Real Estate Data codes defined simply as 'office buildings'. For such situations, analysts assigned an average Output/Day/SF for related industries that may correlate to a single or multiple Norfolk Real Estate Data codes. It was also necessary to appropriately assign square footage of damaged structures to industries rather than dividing the square footage equally among industries. This was accomplished by calculating the percentage of output that each industry contributes to the aggregation and applying that percentage to the damaged square footage. This appropriately modifies damage to each industry to reflect the approximate presence of the industry in the economy.

4. **Calculate Output per Day per Square Foot (Output/Day/SF) for all impacted industries.** Once analysts were able to identify which structure types correlated with the most appropriate industry, analysts divided an industry's daily output by the total square footage of all structures assigned to one industry within the City.

Data Processing

1. **Output Loss Calculations.** Hazus Flood TM[6] provides calculations to evaluate the expected loss of industry output in the Target Areas. Minor revisions were made to the original calculation, as discussed in the Assumptions section of this methodology. The calculation presented below was run for each flood scenario included in the analysis.

$$YLOS_i = \Sigma\, FA_{ij} * INC_i * LOF_{i,j}$$

Where:

$YLOS_i$	=	Output losses
FA_{ij}	=	Floor area of impacted occupancy class
INC_i	=	Output/Day/SF for industry
$LOF_{i,j}$	=	Business loss of function time (in days)

Completing the Analysis

1. **IMPLAN Analysis.** The output loss per industry within the Target Areas was input in IMPLAN. While the output loss was calculated based on the City of Norfolk's economic data, the entire City of Norfolk MSA was used as the geography for to complete the IMPLAN analysis so that economic effects on output losses within the Target Areas could be measured throughout all of the Virginia Beach-Norfolk-Newport News MSA. Within the model, each Target Area had one activity for each annual chance event; each activity had several events indicating each industry's output loss. Analysts ran three models for each of the Target Areas: one for each flood scenario.

2. **Collect Data.** Analysts collected the following data for each economic impact model:

    1. Total Impact Summary. This table provides the total direct, indirect, induced, and total effect of the modeled activities on employment, labor income, value added, and output throughout all of

[6] *Pages 14-33 of the Direct Economic Loss Chapter*

Norfolk

2. Top 10 Industries Affected
3. Employment Loss
4. Output Loss
5. Labor Income

Assumptions, Uncertainties, Sensitivities, and Limitations

In appropriately calculating output loss without duplicating benefits associated with business relocation and other costs, the following assumptions were made:

- Structures that are not expected to be impacted during the storm, and industries represented by features that will not be protected by the Proposed Project (such as shipyards), were excluded from this analysis.
- The square footage of mixed-use structures, such as mixed residential and commercial buildings, was divided among the mixed industries based on number of stories and square footage. It was assumed in these mixed-use structures that the first floor will consist of non-residential space.
- If the expected flood depth within the structure is less than 10 feet, the area of the first floor is used to calculate output loss.
- The original output loss calculation provided by the Hazus Earthquake TM incorporates a recapture factor, which represents output losses that can be recouped to some extent by working overtime after the event. The Hazus Earthquake TM provides a recapture factor for each Occupancy Code. These recapture factors have not been included in the output loss calculation. The analysis assumes that, as soon as a business relocates or reopens after a disaster, it is able to return immediately to pre-storm output. Recapture factors are not appropriate for use because they do not consider opportunity costs.
- Seasonal variation in economic output of various sectors included in the analysis was not considered due to data limitations.
- Output/Day/SF was calculated using square footage of an industry within the Target Geography using 2014 Real Estate building data for Norfolk. It is assumed that these data are accurate.
- The results display the economic impacts anticipated to be experienced within the Virginia Beach-Norfolk-Newport News MSA as a result of expected output loss in the Target Areas. Therefore, these impacts are considered to be conservative, as the local economy for the Target Areas has economic linkages that impact areas beyond the Virginia Beach-Norfolk-Newport News MSA.
- Results are presented in 2015 dollars.
- IMPLAN does not account for price elasticities or changes in consumer/industry behavior based on a direct effect, such as changes in spending patterns within sectors not related directly to activity changes. Therefore, the analysis assumes a static economy.
- The IMPLAN data used for this analysis are from 2013. The implications of the timing of the collection and release of these data have not been explored.
- As described in Displacement, displacement values and economic loss, although closely related, are considered two independent costs of disaster impacts. The reason for this is the function of time used

in the two analyses; restoration time and ELOF. It is imperative that the length of time attributed to each of these functions is not duplicated. As detailed in Displacement, appropriate steps were taken to ensure that such duplication is not present in this analysis.

- Economic impacts as a result of lifeline damage (e.g., transportation, utilities) may be modeled in IMPLAN. Care must be taken to ensure that there is no duplication of benefits, with loss of function values calculated based on service population impacts. As a result, direct output loss and impacts to labor income were not calculated for lifelines as part of this analysis.

Detailed Results

The results of the output loss calculations and the IMPLAN economic analyses are presented below by Target Area for the total Proposed Project.

Newton's Creek Economic Impact Results

The results presented for Newton's Creek include those for each of the three flood scenarios analyzed, reporting the direct, indirect, induced, and total impacts for employment loss, loss of labor income, and loss of output. Moreover, the top ten industries that will be impacted by the event are provided.

In Newton's Creek, a 1% annual chance flood scenario is expected to mainly impact limited-service restaurants, local government enterprises, and real estate. For the same flood scenario, a total of 200 jobs, $7.8 million in labor income, and $27.3 million in industry production (or sales) is estimated to be lost for the year of the natural hazard.

Table IV.1.5.1 Total Impact Summary of Output Loss in Newton's Creek

Recurrence Interval	Impact Type	Employment	Labor Income	Output	Total
10% annual chance	Direct Effect	-15.6	$796,910	$3,365,507	$4,162,417
	Indirect Effect	-8.5	$426,833	$1,376,302	$1,803,135
	Induced Effect	-9.3	$385,913	$1,210,080	$1,595,993
	Total Effect	-33.4	$1,609,656	$5,951,890	$7,561,546
2% annual chance	Direct Effect	-88	$2,820,798	$10,449,187	$13,269,985
	Indirect Effect	-25	$1,245,338	$4,048,744	$5,294,082
	Induced Effect	-30.5	$1,267,976	$3,976,422	$5,244,398
	Total Effect	-143.5	$5,334,112	$18,474,353	$23,808,465
1% annual chance	Direct Effect	-117.5	$4,084,565	$15,468,605	$19,553,170
	Indirect Effect	-37.4	$1,859,299	$5,993,242	$7,852,541
	Induced Effect	-44.7	$1,860,558	$5,834,567	$7,695,125
	Total Effect	-199.5	$7,804,421	$27,296,414	$35,100,835

Table IV.1.5.2 Newton's Creek Top Industries Affected by Output Loss for the 1% Annual Chance Flood Scenario

Sector	Description	Employment	Labor Income	Output	Total
502	Limited-service restaurants	-79.2	$1,534,305	$4,184,766	$5,719,071
526	Other local government enterprises	-7.6	$571,741	$2,247,398	$2,819,139
440	Real estate	-7.6	$182,664	$1,520,337	$1,703,001
410	Water transportation	-7.1	$1,170,023	$6,489,742	$7,659,765
497	Fitness and recreational sports centers	-6.4	$103,357	$281,742	$385,099
512	Other personal services	-5.8	$204,874	$447,692	$652,566
464	Employment services	-3.6	$129,063	$190,983	$320,046
395	Wholesale trade	-3	$187,221	$611,688	$798,909
405	Retail - General merchandise stores	-2.9	$75,946	$200,050	$275,996
400	Retail - Food and beverage stores	-2.6	$65,542	$158,646	$224,188

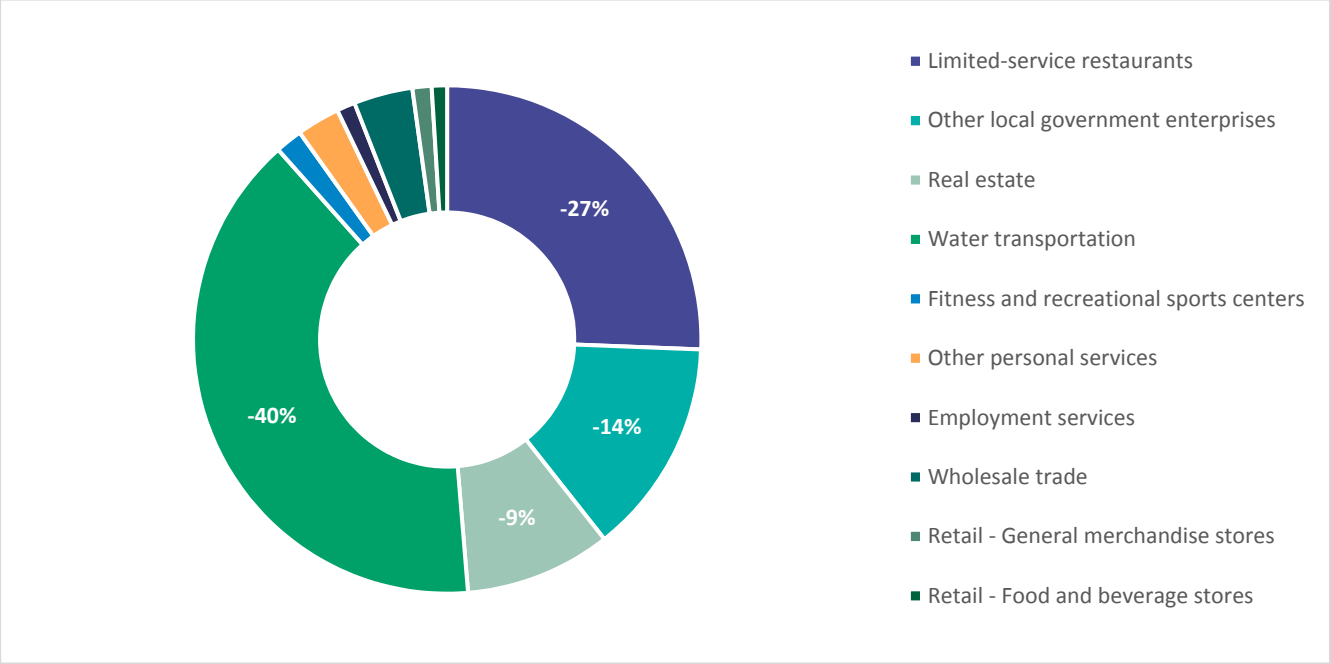

Figure IV.5.1 Newton's Creek Top 10 Impacted Industries for the 1% Annual Chance Event

Ohio Creek Economic Impact Results

The Ohio Creek results are broken down similar to the Newton's Creek results. For Ohio Creek, a 1% flood scenario is expected to mainly impact real estate, wholesale trade, and local government enterprises. For the same flood scenario, a total of 211 jobs, $9.6 million in labor income, and $44.5 million in industry production (or sales) is estimated to be lost for the year of the event. These values indicate just how much economic activity is currently generated in Norfolk, and how much of that economic activity is vulnerable to flood risks.

Table IV.1.5.3 Total Impact Summary of Output Loss in Ohio Creek

Recurrence Interval	Impact Type	Employment	Labor Income	Output	Total
10% annual chance	Direct Effect	-10.9	$603,270	$2,856,208	$3,459,478
	Indirect Effect	-6.3	$322,009	$958,937	$1,280,946
	Induced Effect	-7.4	$310,649	$973,521	$1,284,170
	Total Effect	-24.6	$1,235,928	$4,788,665	$6,024,593
2% annual chance	Direct Effect	-56.2	$2,815,914	$16,574,654	$19,390,568
	Indirect Effect	-36.9	$1,809,765	$5,437,099	$7,246,864
	Induced Effect	-39.4	$1,650,240	$5,168,522	$6,818,762
	Total Effect	-132.5	$6,275,918	$27,180,276	$33,456,194
1% annual chance	Direct Effect	-88.7	$4,076,245	$27,574,715	$31,650,960
	Indirect Effect	-60.7	$2,914,396	$8,809,198	$11,723,594
	Induced Effect	-62.1	$2,605,397	$8,156,766	$10,762,163
	Total Effect	-211.5	$9,596,038	$44,540,679	$54,136,717

Table IV.1.5.4 Ohio Creek Top Industries Affected by Output Loss for the 1% Annual Chance Event

Sector	Description	Employment	Labor Income	Output	Total
440	Real estate	-49.4	$1,190,933	$9,912,297	$11,103,230
395	Wholesale trade	-23.8	$1,505,185	$4,917,735	$6,422,920
526	Other local government enterprises	-19.5	$1,459,452	$5,736,812	$7,196,264
464	Employment services	-7.1	$253,893	$375,702	$629,595
62	Maintenance and repair construction of nonresidential structures	-6.3	$402,791	$1,164,879	$1,567,670
468	Services to buildings	-5	$126,144	$275,318	$401,462
502	Limited-service restaurants	-4.1	$78,682	$214,603	$293,285
517	Private households	-3.7	$63,188	$63,522	$126,710
501	Full-service restaurants	-3.6	$74,120	$172,226	$246,346
63	Maintenance and repair construction of residential structures	-3.5	$225,559	$690,548	$916,107

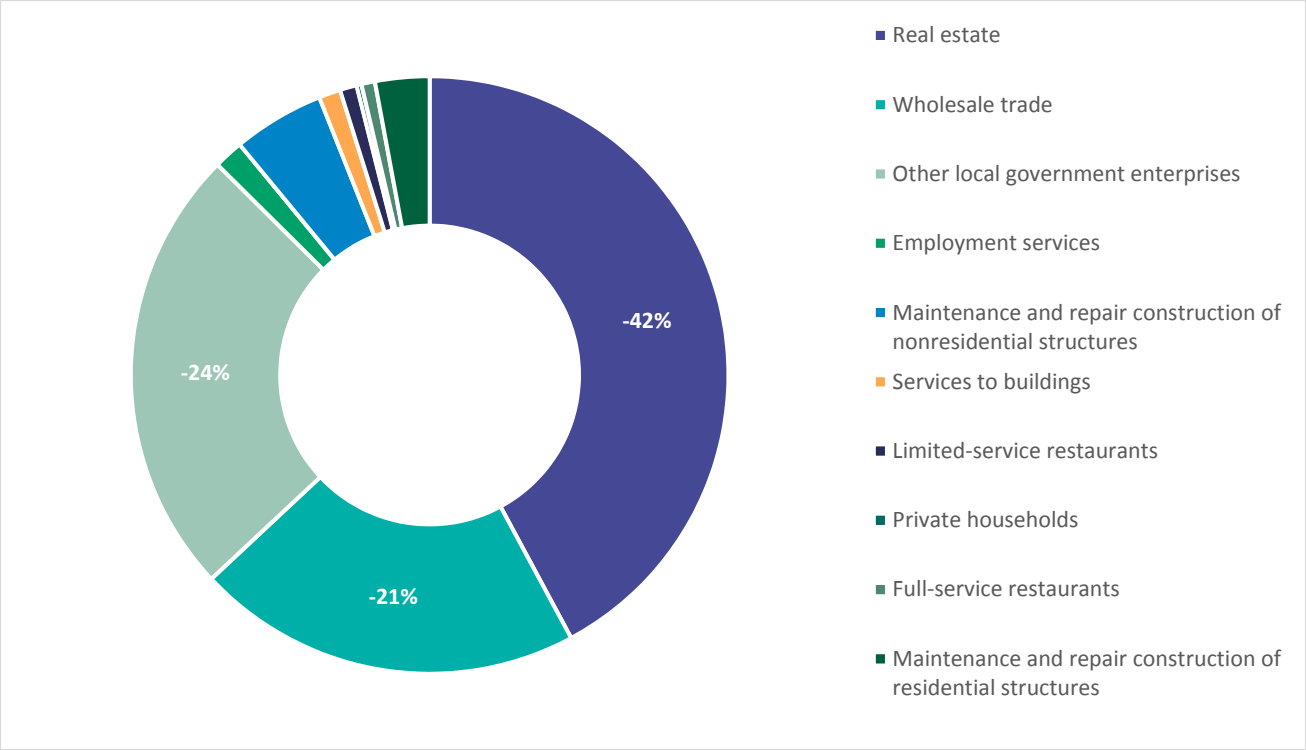

Figure IV.1.5.2 Ohio Creek top 10 Industries Affected by the 1% Annual Chance Event

Total Economic Impact Results

Naturally, the total project results presented in this methodology demonstrate the complete expected economic impact in Norfolk should another flood event occur. These impacts appear to be quite extensive; a 1% flood scenario is expected to mainly impact real estate, water transportation, and owner-occupied dwellings. For the same flood scenario, a total of 411 jobs, $17.4 million in labor income, and $71 million in industry production (or sales) is estimated to be lost for the year of the event.

Table IV.1.5.5 Total Impact Summary of Output Loss for 1% Annual Chance Flood Scenario

Recurrence Interval	Impact Type	Employment	Labor Income	Output	Total
10% annual chance	Direct Effect	-26.4	$1,400,180	$6,221,714	$7,621,894
	Indirect Effect	-14.9	$748,842	$2,335,240	$3,084,082
	Induced Effect	-16.7	$696,562	$2,183,601	$2,880,163
	Total Effect	-58	$2,845,584	$10,740,555	$13,586,139
2% annual chance	Direct Effect	-144.3	$5,636,711	$27,023,841	$32,660,552
	Indirect Effect	-61.9	$3,055,103	$9,485,843	$12,540,946
	Induced Effect	-69.9	$2,918,216	$9,144,944	$12,063,160
	Total Effect	-276	$11,610,030	$45,654,628	$57,264,658
1% annual chance	Direct Effect	-206.1	$8,160,809	$43,043,320	$51,204,129
	Indirect Effect	-98.1	$4,773,695	$14,802,441	$19,576,136
	Induced Effect	-106.8	$4,465,955	$13,991,332	$18,457,287
	Total Effect	-411	$17,400,459	$71,837,093	$89,237,552

Table IV.1.5.6 Top 10 Industries Affected by Output Loss for the 1% Annual Chance Flood Scenario

Sector	Description	Employment	Labor Income	Output	Total
502	Limited-service restaurants	-83.3	$1,612,987	$4,399,369	$6,012,356
440	Real estate	-56.9	$1,373,597	$11,432,634	$12,806,231
526	Other local government enterprises	-27.1	$2,031,193	$7,984,210	$10,015,403
395	Wholesale trade	-26.8	$1,692,407	$5,529,423	$7,221,830
464	Employment services	-10.7	$382,956	$566,684	$949,640
62	Maintenance and repair construction of nonresidential structures	-8.7	$554,594	$1,603,899	$2,158,493
410	Water transportation	-7.1	$1,174,980	$6,517,235	$7,692,215
497	Fitness and recreational sports centers	-6.7	$108,638	$296,137	$404,775
468	Services to buildings	-6.5	$163,570	$357,002	$520,572
512	Other personal services	-6.2	$220,401	$481,621	$702,022

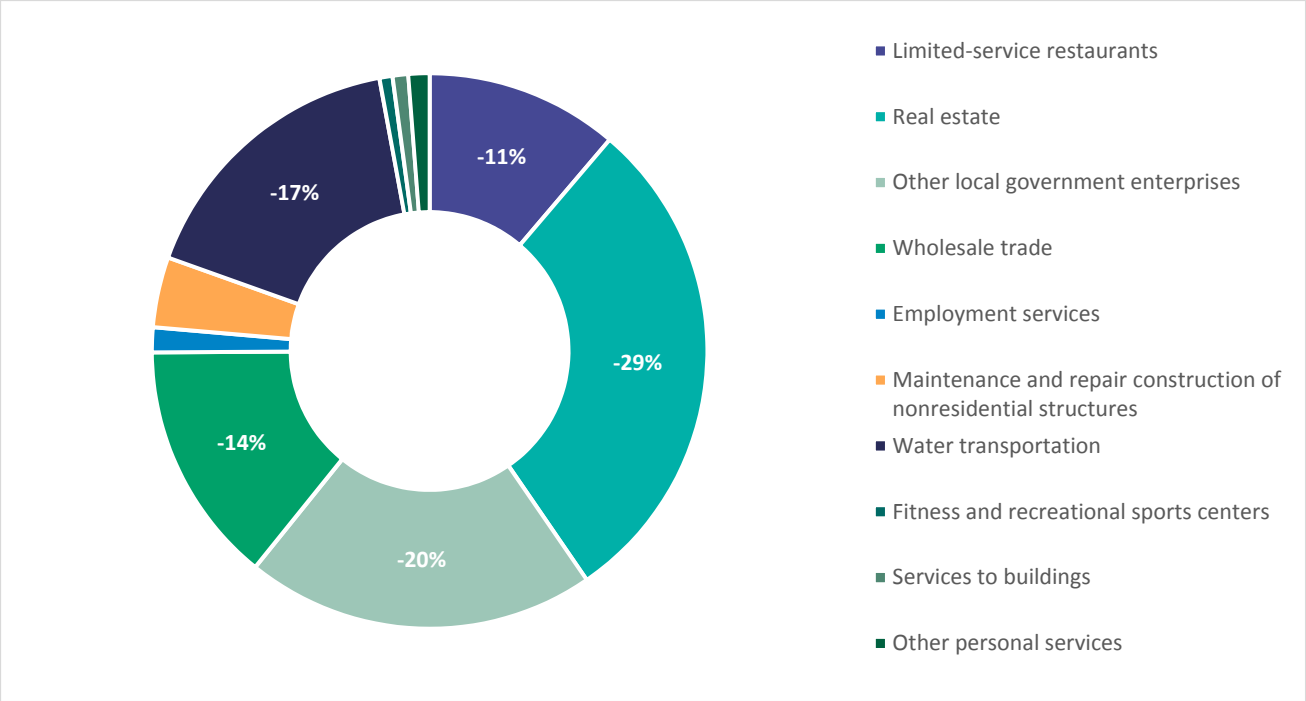

Figure IV.1.5.3 Top Industries Affected by Output Loss for the 1% Annual Chance Flood Scenario

Table IV.1.5.7 Net Present Value and Annualized Benefits for Economic Impacts

Output and Labor Income Loss by Percent Annual Chance Flood Scenario				Benefits	
Target Area	10%	2%	1%	Annualized	Net Present Value
Newton's Creek	$7,561,546	$23,808,465	$35,100,835	$1,583,332.25	$21,850,412.55
Ohio Creek	$6,024,593	$33,456,194	$54,163,717	$1,812,950.35	$25,019,204.33
Total	$13,586,139	$57,264,658	$89,237,552	$3,396,282.58	$46,869,616.60

PART V
QUALITATIVE BENEFITS

Qualitative Benefits

Additional benefits can be derived from installation of the measures in the Target Area, but quantifying these benefits is not possible for one of the following reasons: 1) there is currently no defensible or feasible methodology available to develop quantifiable measures; 2) the developed values may be considered a duplication of benefits; or 3) it is not practical to incorporate the benefit into the benefit cost analysis. With that stated, it is still important that these benefits are considered and incorporated into the full project analysis for the proposed projects in Norfolk's Coastal Adaptation and Community Transformation Plan.

Affordable Housing

Research indicates that building an estimated 100 affordable housing units for families through Low-Income Housing Tax Credit programs can support as many as 30 new jobs in the local economy. These employment effects are on-par with building comparable market-rate units.[1] The availability of affordable housing not only attracts employers but could also increase the amount of disposable income to be reinvested into the local economy.

Many employers have reported that a lack of affordable housing makes it more difficult – and thus more costly – to recruit and retain employees. In a national survey of more than 300 companies, 55% of the largest respondents acknowledged an insufficient level of affordable housing in their proximity and two-thirds of these respondents believed that this shortage negatively affected their ability to hold onto qualified employees.[2] From an employer's perspective, a lack of affordable housing may put a local economy at a competitive disadvantage.

In regard to the resiliency of the community as a whole, if families within these households are required to spend a smaller percentage of their income in housing, assumptions can be made that these populations would be able to allocate these resources more heavily in disaster response, action, and recovery. Therefore, by protecting affordable housing from future flood events, the Target Area can preserve the economic benefits that affordable housing provides, encourage and retain current and future LMI employers, and increase disposable income expenditures in the local economy.

Although research does exist with regard to the potential benefits of affordable housing within an economy, the research methodologies established during the development of this project limits the ability to quantify these benefits. However, it is clear that the loss of irreparable affordable housing due to a future flood event would greatly impact the populations within the Target Area.

Stormwater Management

Most of Norfolk collects stormwater from streets and surrounding areas in a dedicated stormwater drainage system. The stormwater network in the project areas is designed to collect rainwater runoff and route it towards the Elizabeth River. During extreme flood events, the outfalls of these systems are closed to prevent tidal waters from backing up into the system up through the inlets causing flooding in city streets and surrounding areas.

Analysts used geographic information systems (GIS) to determine the potential areas of stormwater inundation of the Target Area. The analysts calculated the total volume of water for the 20% annual chance, 24-hour rain event and compared this volume to two rain-driven flooding scenarios:[3]

1. Estimated flood depths given blockage of stormwater system (depression storage), and
2. Estimated flood depths given failure of stormwater storage and removal systems with the proposed flood walls in place.

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[1] Cohen, Rebecca and Wardrip, Keith (2011). The Economic and Fiscal Benefits of Affordable Housing. The Planning Commissioners Journal.
[2] Urban Land Institute (2007). Lack of Affordable Housing near Jobs: A Problem for Employers and Employees.
[3] Results from a transient model of stormwater runoff over the City surface and through the stormwater system, while desirable, were not available given the short duration of the application.

Depression Storage (Scenario 1)

Analysts estimated the expected direct physical damages based on the following scenario conditions:

- 10% annual chance, 24-hour rain event
- Inlets that collect stormwater are blocked and/or the drainage network is at capacity due to closure of the network outlets, as would be the case with a level in the receiving body of water at approximately 6.6 feet NAVD88 (this corresponds to approximately a 2.8 % annual chance coastal flood event or approximately a 46% chance coastal flood event with 2.5 feet sea level rise)
- Water collects in local depressions and water in excess of depression storage flows offsite to the coast with no incremental flooding impacts assumed.

Depression Storage (Scenario 2)
Analysts calculated expected direct physical damages based on the following scenario conditions:

- 10% annual chance, 24-hour rain event
- Outfalls that are able to release stormwater in excess of system capacity are closed, as would be the case with a level in the receiving body of water at approximately 6.6 feet NAVD88 (this corresponds to approximately a 2.8% annual chance coastal flood event or approximately a 46% chance coastal flood event with 2.5 feet sea level rise)
- The proposed pump stations in the project areas are at capacity and unable to manage the excess stormwater

It's important to note that the boundary flood protection neither creates nor resolves the stormwater flooding issue associated with combined surge and rain events. Nevertheless, the conditions associated with stormwater flooding differ depending upon whether the storm scenario includes or does not include coastal boundary protection. The pumping portion of the stormwater solution proposed relies, in part, on the presence of the boundary protection in order to function fully. As such, the stormwater flood scenario incorporates the proposed coastal boundary protection.

Based on the model, flooding from the scenario is expected to concentrate in low lying areas, but also against the coast, damaging assets most vulnerable to coastal flood events.

It should be noted that flooding in these scenarios do not account for water that flows overland. Such overland flow would require a transient stormwater flow model that was beyond the current scope of this evaluation. The development of such a model is strongly recommended in future phases of work to facilitate stormwater and resiliency design and evaluation. Also, backup into basements, though anticipated, is not presented in these figures. The damages calculated for these scenarios are considered to be captured already within the coastal flood damages calculated and were not added within the BCA to avoid duplication of benefits. These losses have been compared to the losses for the recurrence interval for this coincident rain and surge scenario and are confirmed to have been captured within the BCA's Resiliency Values.

Norfolk's Coastal Adaptation and Community Transformation Plan will provide green stormwater management techniques throughout the Target Area. These measures—on-site parcel retention such as rain gardens, bioswales and rain barrels on both public and private properties—green and blue street improvements, enhanced and newly created wetlands, dry-day parks, above and below-ground retention areas, and other techniques are expected to provide a good measure of stormwater detention that will attenuate the delivery of stormwater during and immediately after a rain event. Because the project design is not complete, however, specific volumes cannot be quantified at this time.

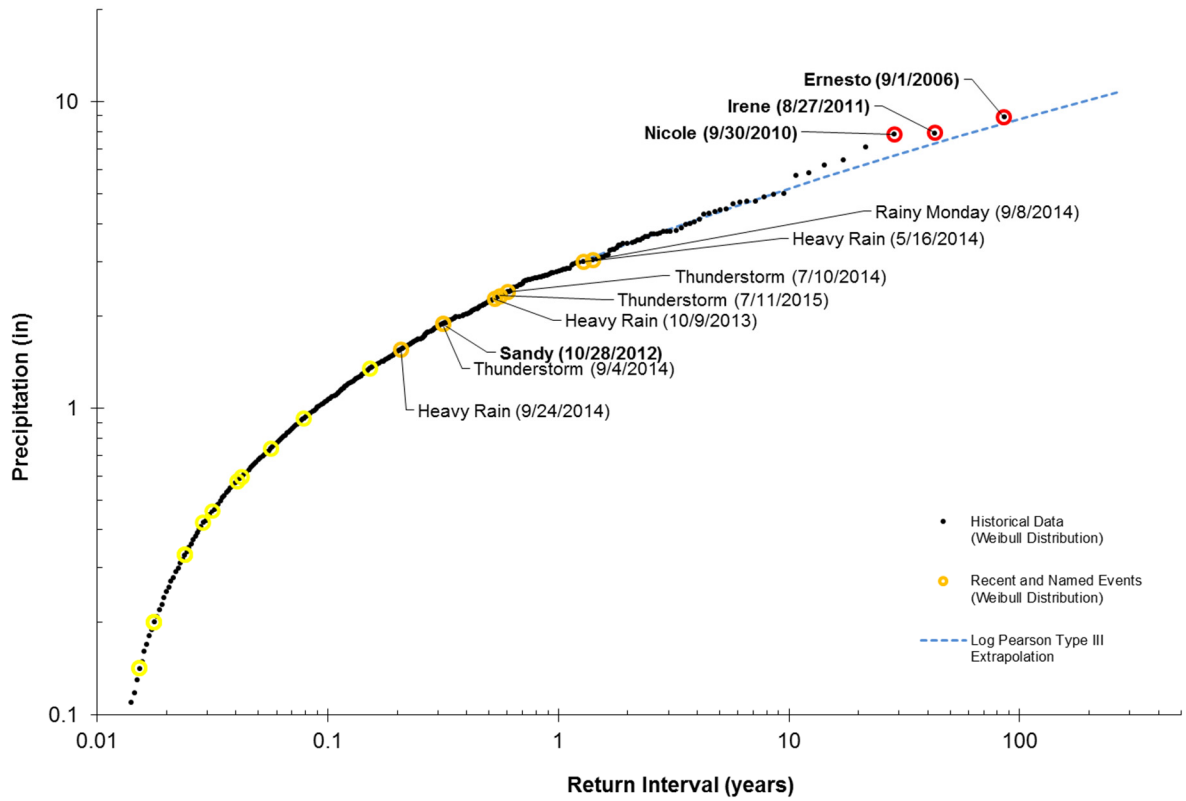

Figure V.1 Estimated flood depths given 2.5 ft SLR and proposed improvements – 1% annual chance

Workforce Benefits

One amenity in the Newton's Creek Watershed includes the development of an "Acceleration Center"—a nexus for technological, organizational and conceptual innovation around identified regional resilience issues including increased flooding, economic vitality and equity of opportunity. This center will have national implications for research and best practices in addressing sea level rise and leveraging economic development opportunities related to coastal communities. The Department of Housing & Community Development's initiative seeks to revitalize the regional economy by focusing on efforts that will generate high-paying, satisfying jobs and includes workforce development, export expansion, identifying and supporting existing business clusters and developing regional civic leadership talent.

Although the Center expects to employ 5 FTE staff in year 1, the number of industry workers trained and exported from this initiative is unknown at this time. Therefore no quantitative benefits could be derived from the amenity. For more about this element, see the project description found in this BCA report, Part 2.

Historic Preservation

The proposed Target Area contains a number of historic structures that would benefit directly from the installation of the protection measures. The Ohio Creek Watershed encompasses the Chesterfield Heights Historic District, a district that was placed on the National Register of Historic Places in June 2003.[4] The District comprises 401 residential structures and three non-residential buildings and stands out as one of the largest

[4] *National Park Service. Undated. National Register of Historic Places Program: Chesterfield Highlands Historic Places Program. [web page] Located at: http://www.nps.gov/nr/feature/places/13000540.htm*

and earliest planned suburbs in the City of Norfolk. The Newton's Creek Watershed is home to seven historic structures including the Attucks Theatre and six churches, one of which dates back to 1739 and remains Norfolk's oldest building.[5] Though the building/content replacement value of these structures is not inherently higher when compared to non-historic buildings; the social, cultural, and historic loss of these structures would have a much greater impact on the community as a whole. Potential benefits of having a Historic Designation structure within the Target Area are discussed below.

Increase in Property Values

Historic preservation is often cited as a tool for urban neighborhood revitalization due to a potential to increase property values. The rise in property value is one chief claim usually associated with locally and nationally designated historic preservation districts. In a study conducted in Pennsylvania, the authors found immediate and sizeable increases (15 to 63%) in house prices of historic districts the year following historic designation and annual appreciation rates of 3 to 4% points higher than those of the average in surrounding non-historic neighborhoods.[6] In New Jersey, it was found that, "Properties listed on the national, state, or local historic registers have a market value of $6 billion, of which about $300 million can be attributed to the value-enhancing effort of historic designation."[7] *Table V.1* below indicates property values in designated historic districts compared to similar undesignated neighborhoods in the same communities.

Table V.1 Property Values in Designated Historic Districts Compared to Similar Undesignated Neighborhoods in the Same Communities

Study Area	Data Interval	Average Value Difference (%)	Annual Rate (%)
Athens, GA	1976-1996	+14	+.7
Denver, CO	1993-2000	+3.6	+.4-1.2
Durango, CO	1993-2000	+.7	+.1
Galveston, TX	1975-1991	+8-360	+5.3-22.5
Memphis, TN	1998-2002	+14-23	+3.5-5.7
New York, NY	1975-2002	+13	+.5
Rome, GA	1980-1996	+10	+.6
San Diego, CA	2000-2005	+16	+3.2
Savannah, GA	1974-1997	+264-588	+11.5-25.6
Tifton, GA	1983-1996	+2	+.2
Tucson, AZ	1987-2007	+15	+.7

Source: John Mabry, Ph.D. 2007. Benefits of Residential Historic District Designation for Property Owners. June 7.

An analysis of property values within the Target Area indicates similar results. Residential structures contained within the Chesterfield Heights Historic District maintained an average value approximately 27% higher than structures located directly outside of the district. In an area with high poverty rates, the loss of these historic structures due to flooding would likely lower property values and exacerbate poverty in the area.

[5] *National Park Service. Undated. National Register of Historic Places Program [web page] Located at: http://www.nps.gov/nr/research/*
[6] *Pennsylvania Historical and Museum Commission. 2011. Economic Benefits of Historic Preservation Activities in Pennsylvania. December.*
[7] *New Jersey Historic Trust. 2005. Economics and Historic Preservation: A Guide and Review of the Literature.*

Social & Cultural Benefits

Though monetary values from historic preservation are derived with regard to number of visits and ticket sales, there is also the idea that historic preservation benefits social and cultural vitality. People may attach a value to the conservation of such resources for a number of reasons – without ever using or visiting them. There may be a selfless feeling that others are enjoying cultural heritage, or there may be motivation behind the desire to conserve these resources for future generations. There could also be benefit in the knowledge that cultural resources are being preserved in one's community. Although these are considered nonmarket values, the inherent benefit of having these resources within a community is a qualitative benefit that should be considered.

Water Quality Benefits

Although reduced costs for stormwater treatment are being included as benefits in the quantitative portion of this analysis, there is no clear way to ascertain a value for overall water quality at this time, such as Total Maximum Daily Loads (TMDLs) that are expected to be reduced though these projects. TMDLs represent the total amounts of pollution that a water body can receive and still meet EPA standards for water quality. The Virginia Department of Environmental Quality submits the "Reduction of Toxics in State Waters Report" to the House Committees on Conservation and Natural Resources and the Chesapeake and Its Tributaries, and to the Senate Committee on Agriculture, Conservation and Natural Resources each year in January. From the January 2015 report's Appendix I-3 "State of the Elizabeth River Scorecard 2014", we read:

"The Eastern Branch [of the Elizabeth River] *earns a D, indicating urgent need behind a new plan for this branch. Scientists found disturbingly high levels of bacteria in Broad Creek and Indian River tributaries and extremely low dissolved oxygen in Broad Creek. The Elizabeth River Project has just completed a draft comprehensive strategy for community-wide efforts to improve the Eastern Branch, with a priority focus on Broad Creek and Indian River."* (page 3)

The scorecard measures nine characteristics, including dissolved oxygen, bacteria from both human sources and from shellfish, nitrogen and phosphorus. A grade of D was given in 2014 to the following measured elements: bottom health (abundance and diversity of life on the riverbed), polycyclic aromatic hydrocarbons (PAH), phosphorus, and polychlorinated biphenyls. Again from the Report:

"The Elizabeth River Project in 2014 engaged diverse stakeholders to complete a comprehensive action plan, Eastern Branch Environmental Restoration Strategy, currently in final draft form. Though this branch traverses three cities (Norfolk, Chesapeake and Virginia Beach), it has the lowest public profile and also some of the lowest scores for environmental health of any of the Elizabeth's five branches, especially with regard to troubling scores in Broad Creek and Indian River tributaries to the Eastern Branch.

The main channel of this branch, toward its mouth in downtown Norfolk, is the healthiest in terms of water quality. Nonetheless, partners are focusing on an area of bottom contamination there at the former location of a wood treatment facility."[8]

The goals of the Elizabeth River Project work are to: 1) Improve acceptability of living shorelines by demonstrating their value with diverse participants in a low-income neighborhood. 2) Establish living shorelines as the accepted practice, at all levels of the community, for abating impacts of sea level rise while restoring habitat for bay fisheries including the Atlantic and Short-nosed Sturgeons, endangered species. 3) Restore a living shoreline on the Elizabeth River, reducing flooding, erosion and other impacts of sea level rise while restoring ecologically connected habitat of the Elizabeth River for bay fisheries.

While these project goals do not include the specific reduction of TMDLs, these practices are consistent with overall water quality improvement measures, and are expected to provide the benefits of cleaner, healthier river water and tidal ecosystems in the Target Area.

The project will restore marsh and oyster reefs with the potential to create resilient habitat for the Atlantic Sturgeon (Acipenser oxyrinchus), endangered in the Chesapeake Bay; and the following fish found in the Elizabeth River and managed under the Magnuson-Stevens Fisheries Conservation and Management Act:

8 "State of the Elizabeth River Scorecard 2014", Nov. 17, 2014. Page 10

Spiny Dogfish (Squalus acanthias), Summer Flounder (Paralichthys dentatus), Black Sea Bass (Centropristis striata), Squid (Lolliguncula brevis), Butterfish (Poronotus triacanthus) and Atlantic Bluefish (Pomatomus saltatrix). Another key species managed under National Marine Fisheries Service that will use these habitats is the Striped Bass (Morone saxatilis).

Urban Heat Island Mitigation

Urban areas are more vulnerable to the effects of temperature increase and precipitation pattern changes because of the heating and cooling processes of building roofs and cars, as well as the emission of greenhouse gases.[9] The City of Norfolk is vulnerable to the Urban Heat Island (UHI) effect, as it maintains a relatively dense urban environment to the surrounding regions and contains a large amount of impervious paved surfaces that trap and absorb heat. In a 2014 study, Norfolk ranked fifth in the nation as having the fastest growing overnight urban heat island with temperatures heating in the city faster than in rural areas.[10] Norfolk has identified as part of the PlaNorfolk 2030 that a result of several actions identified in the plan will "serve to reduce the effect of reflected energy on temperatures (the urban heat island effect), as well as increase the tree canopy cover and reduce the amount of paved surface."[11] Research has indicated that the installation of green space, such as rain gardens, bio-retention features, and permeable pavements, cause a reduction in temperature variations.[12]

The proposed Target Area will contribute towards reducing UHI effects by planting trees, expanding park spaces, installing bio-retention features, incorporating rain gardens into existing landscapes, and installing permeable pavement throughout. These project features will not only create more inviting spaces for the public but provide new shaded areas, assist in cooling surface temperatures, and reduce greenhouse gases from the atmosphere by absorption.

The improvements made in the Target Area will also allow for water, air, and water vapor to filtrate naturally through the soil rather than through the stormwater collection system. This ability to filtrate naturally will greatly reduce energy needs required to treat wastewater and therefore reduce the amount of greenhouse gases emitted from the treatment plants. Additionally, the capability to decrease the UHI effect could indirectly save electrical energy costs. The Lawrence Berkeley Lab Heat Island Group estimates that each one degree Fahrenheit increase in peak summertime temperature leads to an increase in peak demand of 225 megawatts, costing ratepayers $100 million annually.[13] Figure 2 illustrates warming rates since 1970.

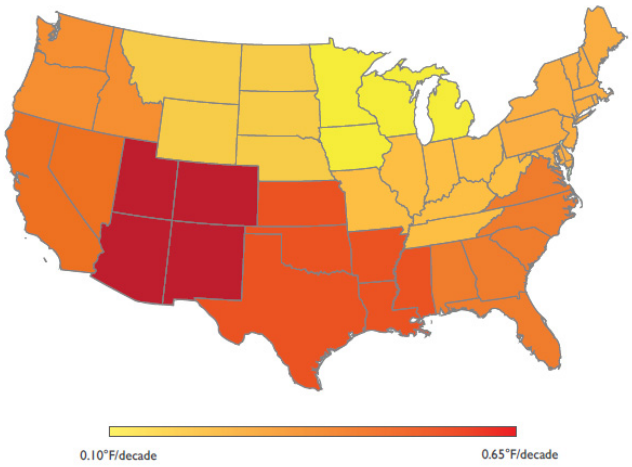

Figure V.2 Regional Summer (June-July-August) Warming Rates Since 1970

9 Choi, Hyun-Ah (2012). Determining the Effect of Green Spaces on Urban Heat Distribution Using Satellite Imagery.
10 Climate Central (2014). Summer in the City: Hot and Getting Hotter
11 City of Norfolk (2015). PlaNorfolk 2030, page 6-13.
12 Choi, Hyun-Ah (2012). Determining the Effect of Green Spaces on Urban Heat Distribution Using Satellite Imagery.
13 Chang, S. (2000). Energy Use. Lawrence Berkeley Lab Heat Island Group.

Emergency and Recovery Efforts

After Hurricane Irene, flooded roadways and out-of-service transportation services impeded travel throughout the Target Area. Although no lives were lost due to this situation, flooded roads could in the future prevent effective emergency response vehicles such as police cars, ambulances or firefighting equipment from reaching victims in time. The protection of these areas from flooding will serve to reduce emergency response times and give adequate access to crews that typically deal with fallen trees, downed power lines or other disaster incidents. Flood risk reduction will also favorably impact post-disaster recovery efforts, allowing residents and property owners to return from evacuation safely in order to address possible damages and begin the return to "blue skies" life. This reduction in the need for and cost of emergency services is not able to be quantified at this time, however, due to a lack of data from previous flood events.

Injuries

Injuries that may be experienced during and immediately after a future flood event have not been quantified in the Benefit Cost Analysis due to lack of data from past storms. It should be noted, however, that in New York's "Hurricane Sandy After Action" report, the City stated that "tens of thousands were injured, temporarily dislocated or entirely displaced by the storm's impact."[14] According to the CDC, injuries sustained within the first week of Hurricane Sandy recovery were from evacuation, cleanup, or repair of a damaged/destroyed home. The most common injuries were arm/hand cuts, followed by back strain/sprain, and leg cuts. Twenty-five % of people with an injury received treatment from a hospital, emergency department (ED), or doctor's office, though this varied by household.[15]

Again, due to a lack of data regarding injuries from past storms in the Norfolk area, this element has not been included in the BCA assessment and ratio. Although it would have been possible to apply knowledge of Hurricane Sandy injuries to Norfolk, the level of uncertainty in such an analysis warranted exclusion of such benefits from the Benefit-Cost Ratio.

Regional Benefits

Although there are no known considerations for base relocation and closures (BARC) for the Hampton Roads area, the region is responsive to concerns by its largest employer and gross regional product initiator, the federal military. Naval activities, the Virginia Port Authority, and other water-based industries in the area such as ship building and ship repair facilities provide considerable employment; the ability for these employees to get to and from work each day is paramount to the region's economic success. The protection afforded by the proposed projects will positively impact the lives of these employees, in turn helping to maintain a steady productivity in the region. This benefit is unquantifiable at this time with regard to the Target Area, as the measurable impact of flooding is greater than the project areas.

Light Rail Infrastructure

Norfolk is the smallest city in America to have built a light rail system. Work week ridership for the first six months of operation averaged 4,650 a day – exceeding the original projection of 2,900 trips per day.[16] The total cost of the light rail makes it the least expensive system built on a per mile basis in the country. Norfolk has already experienced over $1.2 billion in investment along the 7.4 mile light rail alignment since it was announced. In fact, the last 10 years of downtown development has been along The Tide's right-of-way. The light rail system is part of a larger plan to develop a multi-modal transportation network to sustain Norfolk's position as the business, cultural, educational, and medical center of Hampton Roads.

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[14] New York City, "Hurricane Sandy After Action Report," May 2013. Page 1.
[15] Brackbill, R.M., Caramanica, K., Maliniak, M., Stellman, S.D., Fairclough, M.A., Farfel, M.R., Turner, L., Maslow, C.B., Moy, A.J., Wu, D., Yu, S., Welch, A.E., Cone, J.E., and Walker, D.J. 2014. Nonfatal Injuries 1 Week after Hurricane Sandy – New York City Metropolitan Area, October 2012. Morbidity and Mortality Weekly Report. Centers for Disease Control. 63(42); 950-954. October 24.
[16] PlaNorfolk 2030 (2013). City of Norfolk

During the Hurricane Irene event, light rail transportation was suspended Saturday, August 27th and was scheduled to resume approximately 35 hours later at 11 am on Sunday, August 28th. [17] Ray Amoruso, Chief Planning and Development Officer of Hampton Roads Transit, stated, "Our Operators are instructed never to risk their equipment if the waters rise while they are in route and call into dispatch for detour instructions." It is important to recognize that Hurricane Irene was considered a 17 year event based on recurrence interval analysis. Therefore, it is safe to assume that much more significant impacts would occur during the 100-year event plus 2.5 feet of SLR being analyzed.

The Tide light rail system ridership is significantly dependent on the system as nearly half of all trips on the system are home based work trips. Loss of service impacts as a result of flooding have large impacts on the community as it affects people's ability to get to and from work. It can be assumed under the scenario which incorporates SLR, stated above and within the BCA results, the light rail system if impacted could be out of service for an extended period of time. Many light rail systems have delicate electronic systems which, when exposed to floodwater, has high likelihood of severe damage. For repair of damaged light rail components, loss of service for the rail line can be a number of weeks. It is assumed that under significant flood scenarios such as those modeled for Norfolk, this loss of service would be substantial and have severe negative impacts to riders.

If it was assumed that the light rail received would receive similar impacts as the roadway systems during natural hazard impacts, which is likely considering the tracks' proximity to the water, the analysts believe significant impacts could be experienced. The proposed project will provide benefits to transportation infrastructure including the light rail system by protecting these assets against future natural hazard impacts related to storm surge and flooding thereby reducing shocks and stresses on the community.

[17] *http://gohrt.com/news_release/transit-services-suspended-for-saturday/*