2018 Update

City of Baltimore

Disaster Preparedness and Planning Project (DP3)

A combined all hazard mitigation and climate adaptation plan

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Introduction

Summary of Changes

- New information on related plans, including the 2018 Sustainability Plan
- Discussion of public outreach and plan development process in 2018, including details on the meetings of the Advisory Committee and the community engagement efforts

Regulatory Checklist

A1. Does the plan document the planning process, including how it was prepared and who was involved in the process for each jurisdiction? 44 CFR 201.6(c)(1)

A2. Does the plan document an opportunity for neighboring communities, local and regional agencies involved in hazard mitigation activities, or agencies that have the authority to regulate development, as well as other interests, to be involved in the planning process? 44 CFR 201.6(b)(2)

A3. Does the plan document how the public was involved in the planning process during the drafting stage? 44 CFR 201.6(b)(1) and 201.6(c)(1)

A4. Does the plan document the review and incorporation of existing plans, studies, reports, and technical information? 44 CFR 201.6(b)(3)

C1. Does the plan document each jurisdiction's existing authorities, policies, programs and resources, and its ability to expand on and improve these existing policies and programs? 44 CFR 201.6(c)(3)

C6. Does the plan describe a process by which local governments will integrate the requirements of the mitigation plan into other planning mechanisms, such as comprehensive or capital improvement plans, when appropriate? 44 CFR 201.6(c)(4)(ii)

D1. Was the plan revised to reflect changes in development? 44 CFR 201.6(d)(3)

D2. Was the plan revised to reflect progress in local mitigation efforts? 44 CFR 201.6(d)(3)

Project Overview

Introduction

Baltimore takes a comprehensive approach to hazard mitigation planning, recognizing the City's vulnerability to the impacts of severe hazard events and the need to increase our resilience to disaster. Baltimore's Disaster Preparedness and Planning Project (DP3) was first produced by the Department of Planning in 2013[1] to address both existing hazards and the predictions of the impacts of climate change on these natural hazards, including but not limited to heat waves, sea level rise, increased precipitation, and flooding.

The 2018 update addresses changes in priorities that have taken place since the plan was created 5 years ago and includes the latest science. It also highlights the most recent climate-related disasters the city has faced and features many new strategies and actions to help Baltimore continue moving forward with hazard mitigation and community preparedness. Community outreach to help inform this update was conducted through multiple interviews and the creation and widespread distribution of a survey intended to gauge community perspectives on hazard risk.

Hazard mitigation is the process of developing strategies that will reduce or eliminate loss of life and/or property damage resulting from natural hazard events. The 2018 DP3 identifies the natural hazards the City faces and assesses the potential risks and vulnerabilities associated with those hazards. It also addresses how climate change is expected to make many of the natural hazards Baltimore faces more dangerous and unpredictable. Regardless of how quickly or stringently cities are able to reduce greenhouse gas (GHG) emissions, impacts related to climate change will continue to be felt, as extreme precipitation events become more frequent and other impacts intensify.

Hazard mitigation planning is a continuous process for the City of Baltimore. This 2018 update fulfills Federal requirements to regularly update our formal plans, but the City includes additional elements it plans to develop over the next 2-3 years. In addition to resuming and expanding the community engagement work, the City will begin crafting an equity lens for future work and implementation of the plan. Hazard mitigation plans can also include man-made hazards; at this time, the DP3 does not, but a review of the feasibility of doing so has been initiated. Work will also proceed on food resilience, community resiliency planning, and a hazard mitigation planning strategy for the city's historic resources.

Scope and Vision of the Plan

The 2018 DP3 incorporates strategies to increase the City's adaptive capacity to withstand the impacts of more frequent and intense extreme weather events and quickly bounce back from any disruptions. This approach has several benefits. Most significantly, preemptive action offers cost savings. Federal efforts to strengthen a city's preparedness for hazards, for instance, costs only a fraction of what governments typically spend to repair the damage from a hazard after the event. In fact, for every dollar spent on mitigation projects, losses from future disasters can be reduced by at least $3[2]. For Baltimore to become more resilient, the City should improve essential infrastructure and buildings, protect people and property, and embrace and enhance its natural systems. Most importantly, Baltimore must not wait for a crisis before acting. Implementing the strategies and actions detailed in this plan will take time; and it is vital that the City act today to ensure a future for Baltimore that is sustainable and growing.

The DP3 addresses and reviews the natural hazards affecting the City. The planning process has included:

- Profiles and historic occurrences of hazard events;
- An assessment of geographic extent and Baltimore's risk and vulnerability for each hazard;
- Hazard-specific loss estimations in terms of economic damage.

Climate-related impacts are already affecting Baltimore, so the DP3 also identifies opportunities to better prepare Baltimore to adapt to new climate conditions[3]. Heat waves, sea level rise, and flooding due to more extreme precipitation events are all projected to affect the City's environmental, social, and economic systems more intensely than in the past. Building adaptation into this plan will allow Baltimore City to reduce risks associated with natural hazards and increase overall resiliency.

VISION

Baltimore will be a city whose daily activities reflect a commitment shared by government, business, and citizens to reduce or eliminate impacts from current and future natural hazards.

GOALS

- Protect the health, safety and welfare of Baltimore City residents and visitors
- Prevent damage to structures, infrastructure, and critical facilities
- Build resilience and disaster prevention and planning into all programs, policies, and infrastructure (public and private)
- Enhance the City of Baltimore's adaptive capacity and build institutional structures that can cope with future conditions that exceed past experience
- Promote hazard mitigation and climate adaptation awareness and education throughout the City of Baltimore
- Provide support to increase efforts toward a better Community Rating System (CRS) community rating

Changes from 2013 DP3

The Disaster Mitigation Act of 2000 (DMA 2000) was created to reduce the damages associated with natural hazards. Under the DMA, the Federal Emergency Management Agency (FEMA) requires that every local jurisdiction in the United States develop and adopt an All Hazards Mitigation Plan (AHMP) as a condition to be eligible for disaster-related assistance. FEMA also requires that local governments update their AHMPs every 5 years.

Baltimore's past hazard mitigation plans were completed in 2006, 2011, and 2013. With this current update, the 2018 DP3 reflects the progress made over the last 5 years in our local efforts to mitigate hazards and the changes in development. Successes since 2013 include adoption of the new zoning code with an open space designation, progress toward creation of four pilot Resiliency Hubs,

significant progress toward funding needed stream restoration and other flood-minimizing projects, and the adoption of a Landscape Manual.

Each chapter includes a summary of changes made with the current update. Overall, these changes include:

- New Hazard Identification and Risk Assessment (Ch 3)
- Updated vulnerability assessment with integration of data, mapping products, and results from HIRA and related planning initiatives (Ch 4)
- Updated mitigation strategies and actions with new prioritization ranking, the addition of many new actions, and the consolidation of repetitive actions (Ch 5)
- Updated monitoring, evaluation, and implementation plans, including community engagement aspects; new table on potential funding sources (Ch 6)
- Documentation of community engagement and technical updates, with a vision for moving forward (Ch 7)

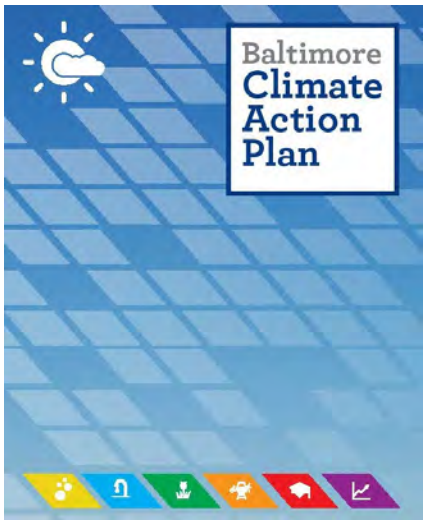
Connection to the Sustainability Plan

Baltimore's first Sustainability Plan was adopted in March 2009. It was created as a guide for the City in its sustainability efforts and identified various goals and strategies. The 2009 plan has seven chapters, 29 goals, and 132 strategies—93 percent of which have been initiated or completed by residents, faith-based institutions, nonprofits, city agencies, and businesses.

Recognizing that there is more work to be done, the City began the process to update its Sustainability Plan in 2016. The new Plan is expected to be finalized in early 2019 and will include new topics to more intentionally address all three prongs of sustainability. The community engagement for the 2018 Sustainability Plan update was extensive. One hundred and twenty-five (125) Sustainability Ambassadors were recruited (68 percent of whom are African-American, which reflects the demographic composition of the City), and they surveyed over 1,200 residents. There were 22 stakeholder meetings–attended by more than 500 people–for industry leaders and professionals to discuss their visions for a sustainable future in their fields. There were two public gatherings, averaging 300 attendees each. Comments were also gathered during the public comment period in April/May 2018.

Two aspects of the 2018 Sustainability Plan are noteworthy. The first is that it will likely form the basis of the City's next comprehensive plan update, in part due to the extensive community outreach. The second is the addition of a "Community Preparedness" section to help neighborhoods and people prepare to withstand and recover quickly from extreme weather and other emergencies. This chapter sets several goals for preparing for disasters, connecting the work of the 2018 DP3 to the broader sustainability efforts of the City. At the 2018 Sustainability Town Hall, attendees had the opportunity to directly provide comments on the "Community Preparedness" section of the plan.

Connection to the Climate Action Plan



The City of Baltimore adopted and released the Baltimore Climate Action Plan (CAP) in 2012 with the goal of achieving a 15-percent emissions reduction by 2020. Chapter 4 of the CAP focuses on climate adaptation. It explores ways that Baltimore can efficiently manage risks and protect vulnerable populations from the anticipated impacts of climate change. Key recommendations from the CAP include integration of climate adaptation into the DP3, in addition to conducting vulnerability and risk assessments. The 2013 DP3 provides further detail on the implementation steps for CAP measures related to both hazard mitigation and climate adaption. Measures that address energy savings and conservation, land-use and transportation, and the protection of Baltimore's natural systems are explicitly highlighted in the CAP as having the co-benefit of supporting climate adaptation.

Connection to the Baltimore Green Network Plan

The Baltimore Green Network Plan (BGN) is one component of the Sustainability Plan and was formally adopted by the City in September of 2018. The BGN promotes urban resiliency through land-use equity and connects Baltimore residents to a system of healthy, vibrant, and resilient places. Rooted in a triple bottom-line approach (people, prosperity, and environmental sustainability), the BGN transforms vacant properties into green community assets. It also connects these spaces to schools, homes, retail districts, and other activity centers. Community benefits of the Green Network Vision include improved public safety, increased economic growth, a better neighborhood quality of life, and a cleaner and healthier environment. This last benefit connects to the 2018 DP3 update as efforts to improve water quality can also impact water quantity during storms and the green infrastructure components of BGN projects are expected to mitigate flooding. BGN projects should also reduce the urban heat island effect and improve local air quality, serving to help reduce the City's overall vulnerability to extreme heat. Developed in collaboration with diverse stakeholders, this plan details strategies and recommendations for the City and its community partners to direct resources to the most underinvested neighborhoods.

Connection to TRANSFORM Baltimore

In December 2016, Baltimore passed a new, more modern zoning code to replace the 1971 Zoning Code. Called TRANSFORM Baltimore, it is intended to simplify and streamline development review and provide an easy-to-understand set of rules, while fostering growth and development and maintaining neighborhood character. TRANSFORM now includes an open space designation, which was a recommendation in the 2013 DP3.

Hazard Mitigation Planning and Emergency Operations Planning

Emergency Operations Plans (EOPs) designate the responsibilities and authority of agencies and individuals before, during, and immediately after an emergency. Alongside local hazard mitigation plans, which help to facilitate Federal funding and actions during and after hazard events, EOPs are tools for establishing a framework to execute emergency response activities.

Baltimore's EOP, maintained by the Mayor's Office of Emergency Management, includes annexes for each hazard and for all Emergency Support Functions (ESFs). ESFs represent services, or sets of services, that are likely to be needed during a hazard event or incident (the Baltimore City Police Department, the Baltimore City Fire Department, etc.). The services provided by ESFs are coordinated with—and incorporate—all other City plans, policies, and procedures that pertain to emergency response and recovery, including the 2013 DP3 and the previous hazard mitigation plans.

Connections with Surrounding Counties and Cities

The City of Baltimore has strong partnerships at the local, State, and Federal level and understands the importance of collaboration with surrounding communities to achieving its mitigation and adaptation goals. As part of this planning process, City staff discussed the development of the hazard mitigation plan with various jurisdictions within the region, including but not limited to the following:

- Baltimore UASI (Urban Area Security Initiative, which covers City of Baltimore and City of Annapolis as well as Anne Arundel, Baltimore, Carroll, Hartford, and Howard Counties): multiple meetings
- Maryland Resiliency Partnership (which includes several Maryland State agencies, the City of Annapolis, and the Maryland Association of Floodplain and Stormwater Managers): April 17, 2018
- Presented at "Resilience Prioritization: Sharing Best Practices Across Sectors" (attendees included government staff and business representatives from the region): July 30, 2018

In addition, DP3 planners participate in the Maryland Climate Change Commission efforts and actively participate in sustainability, resiliency, and climate networks such as the Urban Sustainability Directors Network (USDN).

Overview of Methodology

Planning Process

The DP3 project has utilized the following process throughout plan development:

- Identify and profile existing hazards.
- Conduct an inventory that identifies all assets such as hospitals, schools, etc.
- Utilize modeling to identify risk from existing hazards and predicted climate impacts.
- Complete a vulnerability analysis of identified assets and critical facilities. Identify exposure, sensitivity and adaptive capacity.
- Identify actions and recommendations to deal with existing hazards and predicted impacts.
- Develop implementation plans for these actions, as well as recommendations for stakeholder involvement and funding strategies.

To integrate the hazard mitigation and adaptation processes, the City of Baltimore has used FEMA's Local Multi-Hazard Mitigation Planning Guidance and Crosswalk planning tool (see Figure 1).

Figure 1: Planning Tool

2018 DP3 Process Documentation

Advisory Committee

In the time since the 2013 DP3 was approved, Baltimore has regularly reported on progress made on the plan's strategies and actions[4]. The planning process for the 2018 DP3 followed these assessments and more formally began in 2017. Grants were secured to establish multiple Resiliency Hubs, to begin work on new elements of the DP3 (Coastal Zone Management Act grant[5]), and to conduct a risk assessment of high-priority historic areas and buildings that are significantly impacted by flooding (Maryland Historic Trust/NPS Hurricane Sandy Relief Grant program)[6].

As part of these grants, the technical work and the community engagement was initiated, and the relevant City agencies began the needed collaboration to update the 2018 DP3. Early meetings took place between staff of the Mayor's Office of Emergency Management and the Department of Planning (April 23 and June 12, 2018), with the Department of Public Works (July 7, 2017 and March 7, 2018), and with Resiliency Hubs and City agencies (December 11 and 12, 2017). A presentation on the 2018 DP3 update was given to the interagency Homeland Security Preparedness Committee on June 11, 2018.

Starting in 2018, the Mayor's Office of Emergency Management (MOEM) and the Department of Planning (DOP) assembled a group of experts from around the City and State to help gather essential data and draft recommendations for the DP3 plan. The purpose of the Advisory Committee was to bring together stakeholders from key agencies, institutions, businesses, and neighborhoods to identify actions and recommendations for the plan. Director David McMillan (MOEM) and Director Thomas Stosur (DOP) co-chaired the meetings.

The Advisory Committee consisted of City directors and staff from agencies such as the Department of Public Works, Baltimore City Health Department, Fire Department, and Department of General Services, as well as representatives from the community, business leaders, Maryland Emergency Management Agency, the Port of Baltimore, and Baltimore Gas & Electric. The Advisory Committee met three times during the summer of 2018. Additionally, members participated in subcommittees based on their specific areas of expertise. These subcommittees–Strategies, and Equity and Outreach–also communicated regularly by email before and after the in-person meetings. The Advisory Committee membership (included all who were invited to attend) is included in Table 1 and additional information on the meetings of the Committee is in Table 2 and in Appendix 1-1: Advisory Committee Meetings.

Table 1: Advisory Committee Membership

Name	Affiliation	Name	Affiliation
Tom Stosur (Co-chair)	Baltimore City Department of Planning	Jen Sparenberg	Maryland Historical Trust
David McMillan (Co-chair)	Mayor's Office of Emergency Management	Tracy Williams	KCI Technologies, Inc.
Kimberly Morton	Baltimore City Mayor's Office	Phil Lee	Moffatt & Nichol, Inc.
Peter Hammen	Baltimore City Mayor's Office	Bill Phillips	Moffatt & Nichol, Inc.
Leana S. Wen	Baltimore City Health Department	Barbara McMahon	Maryland Port Administration
Kimberly Eshleman	Baltimore City Health Department	Terry Horrocks	Maryland Port Administration
Patrick Campbell	Baltimore City Fire Department	Craig Purcell	BCT Architects
James Wallace	Baltimore City Fire Department	John Quinn	Baltimore Gas and Electric Co
Gary Tuggle	Baltimore City Police Department	Dale Hargrave	Community Leader
Mark Howe	Baltimore City Police Department	Inez Robb	Community Leader
Frederick Gilbart	Baltimore City Police Department	Laurie Schwartz	Waterfront Partnership of Baltimore
Rob Smith	Baltimore City Police Department	Eileen Singleton	Baltimore Metropolitan Council
Albert DellaRocco	Baltimore City Police Department	Edward Strouse	Mayor's Office of Emergency Management
Brian Hopkins	Baltimore City Police Department	Lisa McNeilly	Baltimore Office of Sustainability
James Price	Baltimore City Department of Public Works	Stephanie Smith	Baltimore Department of Planning
Dale Thompson	Baltimore City Department of Public Works	Aubrey Germ	Baltimore Office of Sustainability

Name	Affiliation	Name	Affiliation
Ryan McByrne	Baltimore City Department of Public Works	Victor Ukpolo	Baltimore Office of Sustainability
Michelle Pourciau	Department of Transportation	Anne Draddy	Baltimore Office of Sustainability
Jason Orozco	Department of General Services	Sarah Buzogany	Baltimore Office of Sustainability
Husam Albattrawi	Department of General Services	Rachelle Wood	Mayor's Office of Emergency Management
Craig Keenan	Department of General Services	Stacy Montgomery	Baltimore Historical and Architectural Preservation
Dennis Chojnowski	Department of General Services	Lauren Schiszik	Baltimore Historical and Architectural Preservation
Marwan Alkarajat	Department of General Services	Mark James	Michael Baker International
JaLeesa Tate	Maryland Emergency Management Agency	Virginia Smith	SP&D
Jihane Ambroise	Maryland Emergency Management Agency	Nicolette Louissaint	HealthCare Ready
Mari Radford	Federal Emergency Management Agency	Sarah Baker	HealthCare Ready
Mary Jo Rogers	Maryland Insurance Administration	Sasha Land	Maryland Department of Natural Resources

Table 2: Advisory Committee Meetings

Date	Committee	Location	Purpose	Target Audience	Agencies Represented
06.22.2018	DP3 Advisory Committee	DoP: 417 E Fayette St, 8th Floor, with Livestream Access	Kick-off meeting; introduce committee members to planning process	DP3 Advisory Committee Members	DoP, BoS, DGS, MOEM, BMC, DPW, MEMA, BGE, BCHD, MIA, Moffatt & Nichol, Maryland Port Administration, Waterfront Partnership
07.18.18	DP3 Advisory Committee	DoP: 417 E Fayette St, 8th Floor, with Livestream Access	Introduce preliminary HIRA results, discuss necessary strategy and action updates, overview community survey that was created, receive feedback	DP3 Advisory Committee Members	DoP. BoS, BCFD, MOEM, DPW, MIA, USACE, WD CRC, Moffatt & Nichol, BPD, BMC, CHAP, MDE, WPM, BGE, BCHD
08.01.2018	DP3 Advisory Committee	DoP: 417 E Fayette St, 7th Floor	Review hazard assessment, vulnerability analysis, and strategies and actions; provide update on equity and outreach survey	DP3 Advisory Committee Members	DoP, BoS, MHT (MDP), Moffatt & Nichol, DPW, MOEM, BCFD, BCHD, BGE, CHAP, Maryland Port Administration

Date	Committee	Location	Purpose	Target Audience	Agencies Represented
07.11.18	Equity and Outreach Subcommittee	DoP: 417 E Fayette St, 8th Floor	Establish goals and methods of equitable engagement.	Equity and Outreach Subcommittee Members	Department of Planning, Office of Sustainability, Resiliency Hubs, Healthcare Ready
08.07.18	Equity and Outreach Subcommittee	DoP: 417 E Fayette St, 8th Floor	Review preliminary community survey results and discuss engagement progress	Equity and Outreach Subcommittee Members	Department of Planning, Office of Sustainability, Resiliency Hubs, Mayor's Office of Emergency Management, Healthcare Ready
07.26.2018	Strategy Subcommittee	DoP: 417 E Fayette St, 8th Floor	Review list of strategies for needed updates and additions	Strategy Subcommittee Members	Department of Planning, Office of Sustainability, Department of Health, Office of Emergency Management, Department of General Services, Department of Transportation, BG&E, Moffatt& Nichol, Michael Baker Int.

The Department of Planning also engaged three consultants to assist in the update of the 2018 DP3. Funded through the Hazard Mitigation Grant Program (a sub-award from the Maryland Emergency Management Agency), the consultants began work in the summer of 2018. Michael Baker International and Smith Planning & Design led the hazard identification, risk assessment, vulnerability analysis, and mitigation strategy components. HealthCare Ready (HCR) led the community engagement for the update. After contracts and scopes of work were finalized, the team met weekly to review progress and set next steps. Documentation of these meetings, including the status of key plan components, is included in Appendix 1-2: Team Meetings.

Public Meetings and Community Outreach

Throughout plan development, community input was solicited and encouraged. Baltimore and HealthCare Ready developed a community engagement plan. In the initial phases, the strategy was to capitalize on existing meeting structures within the community, convene regularly with chosen organizations, and continue communication with and utilization of Resiliency Hubs. The overall goal was to ensure an explicit understanding of the necessity and parameters of equitable policies, create meaningful tools and practices for community involvement in Baltimore's DP3 updates, and, when appropriate, bring in academic perspectives through engagement of the local universities.

The community engagement is seen as a continuation of ongoing work by the Department of Planning to solicit input and work directly with the residents of Baltimore and relevant experts. In November 2016, Baltimore began work on the update for the DP3 through a Coastal Zone Management Act

grant. That grant described new elements for this plan, such as the incorporation of an equity lens in the plan update process. It also outlined additions for future DP3 updates.

In addition, the Office of Sustainability held a series of public and other meetings to solicit input (see Table 3). At the April 2018 Sustainability Town Hall, attendees had the opportunity to comment directly on the "Community Preparedness" section of the 2018 Sustainability Plan. Comments on that chapter were also gathered during the public comment period for that Plan in April/May 2018. Other recent meetings with key community members include those with the Resiliency Hubs and City agencies in December 2017. These meetings were held in partnership with the Mayor's Office of Emergency Management (MOEM) with the support of the Institute for Sustainable Communities and the Clean Energy Group. The first one was at City Hall (12/11/2017) with our Deputy Mayor and representatives from Planning, DPW, DOT, Health, Police, Fire, General Services and the Energy Office to brief them on the Resiliency Hub initiative, update them on our progress, and engage them as partners. The second meeting (12/12/2017) was held at one of our hubs and attended by 35 people including MOEM, Health, all Hub and community representatives, and solar / storage representatives. The DP3 Update was included in the agenda of the April 2018 Homeland Security Preparedness Commission, the June 2018 and October 2018 Sustainability Commission meetings, and the November Planning Commission meeting. Additional information (including agendas and meeting notes) from these meetings are included in Appendix 1-5: Public and Other Meetings.

A draft of the 2018 DP3 was shared for public comment and made available online for viewing and comments at bmoresustainable.civicomment.org from August 28 until September 7, 2018. The City also hosted a public meeting on August 29, 2018 to solicit comments on the draft.

Table 3: Public and Other Meetings

Date	Event	Location	Purpose	Target Audience	Agenda
12.11.2017	Resiliency Hubs – City Agencies	City Hall	Briefing on progress on Resiliency Hubs	Deputy Mayor; representatives from Planning, DPW, DOT, Health, Police, Fire, General Services and the Energy Office	Focused on and how to support Hubs in planning and operation, gathering input on role of Hubs during natural disasters
12.12.2017	Community Resiliency Hubs Stakeholder Meeting	Living Classrooms UA House 316 South Caroline Street	Provide an opportunity for city staff and Resiliency Hub leaders to meet and share their experiences to date. Identify common challenges in the development and implementation of Resiliency Hubs to inform city staff and	35 people attended including MOEM, Health, all Hub and community representatives, and solar / storage representatives	Attendees discussed common challenges, and identified shared needs.

Date	Event	Location	Purpose	Target Audience	Agenda
			support partners.		
04.10.2018	2018 Town Hall	War Memorial Building	Public review of draft 2019 Sustainability Plan; resource fair featuring local non-profits, free trees, and more.	City-wide (around 350 attended)	Multiple chapters of Sustainability Plan (including "Community Preparedness") were displayed, and attendees could share comments directly on posters; multiple organizations informational tables
04.19.2019	Homeland Security Preparedness Committee	City Hall	Quarterly meeting	City agency staff, representing MOEM, Fire, Police, Health, DPW	Share process for DP3 Update; solicit input
06.20.2018	Sustainability Commission	Curtis Bay Recreation Center: 1630 Filbert St, Curtis Bay	Monthly meeting of Sustainability Commission	City-wide (around 40 attended)	Share process for DP3 Update; received input on including man-made hazards.
08.29.2019	Community meeting	Community Room, 29th Street Community Center, 300 E 29th St	Solicit community input	City-wide (12-15 attended)	Presentation on draft DP3 update; open discussion with comments received incorporated into draft DP3 submitted for approval.
10.24.2017	Sustainability Commission	Department of Planning, 417 E. Fayette Street	Monthly meeting of Sustainability Commission	City-wide (around 30 attended)	Approval of DP3 (subject to final State and Federal review) by Sustainability Commission
11.01.2018	Planning Commission	Department of Planning, 417 E. Fayette Street	Regular meeting of Planning Commission	City-wide (around 25 attended)	Approval of DP3 (subject to final State and Federal review) by Planning Commission

Community Engagement Methodology and Activities

The City of Baltimore is committed to incorporating equitable policies in its planning efforts. The incorporation of an equity lens in the plan update required broad engagement of the widest swath of Baltimore residents and community organizations. The engagement for this plan focused on three core activities: the creation of an Equity and Outreach Subcommittee; targeted outreach to identified priority vulnerable populations; and a survey designed to collect the perspectives of community members and organizations on risks.

Equity and Outreach Subcommittee of DP3 Advisory Committee

A subcommittee of the DP3 Advisory Panel, known as the Equity and Outreach Subcommittee, was formed to: (1) define the equity lens and ensure its implementation throughout the plan update and in plan content, (2) foster robust community engagement in the update, and (3) collect baseline data to inform the additions identified for future DP3 updates, such as perceived community vulnerabilities to man-made hazards. Members convened twice to develop and assist in executing an equitable engagement strategy for this update. Members included:

- Director, Office of Sustainability
- Sustainability Coordinator, Office of Sustainability
- Climate and Resilience Planner, Office of Sustainability
- Coastal Resources Planner, Office of Sustainability
- Floodplain Manager, Office of Sustainability
- Assistant Director for Equity, Engagement and Communications, Department of Planning
- Director for Preparedness, Mayor's Office of Emergency Management
- Director, Resiliency Hub (First Mount Calvary Baptist Church)

A shared commitment to equity in planning among the Department of Planning, the Mayor's Office of Emergency Management, the Health Department, and Community Resiliency Hub Leaders allowed for a diverse, engaged subcommittee.

The subcommittee identified populations most vulnerable to the natural hazards listed in the DP3, identified community leaders to provide community-level perspectives, and performed regular check-ins on the outreach progress. The subcommittee was supported by HealthCare Ready (HCR), a non-profit organization with expertise in community resilience and disaster preparedness, through funding from the Hazard Mitigation Grant Program (HMGP). HCR's vision is to build the resiliency of communities to support health and create economic strength so that if disaster strikes, quality of life can rebound as quickly as possible.

Targeted Outreach and Interviews to Identified Priority Populations

The subcommittee consulted local subject-matter experts on equity and sustainability in Baltimore City and used historical context, as well as their own experience, to identify key populations vulnerable to likely events. Initial priority populations included the homeless, elderly, children, and structurally/economically disadvantaged groups.

In alignment with the City's commitment to equity, planners conducted targeted outreach to these populations to learn their concerns and experiences with the identified hazards. The goal was to capture and reflect these perspectives in the recommended strategies.

Groups engaged for input included:

- Senior centers
- Family and early life organizations
- Community organizations
- Faith-based organizations and churches
- Organizations supporting homeless populations
- Housing Authority of Baltimore City (Public Housing)

Anecdotes from interviews provided insights on future areas of focus, as described later in this chapter. Interviews also helped forge new and strengthen existing ties between community groups and the City. Many organizations expressed their pleasure to be contacted and engaged in the process, exclaiming that they were happy the City wanted to "hear their voice." A full list of the community outreach meetings and interactions is included in Appendix 1-3: Community Outreach.

Community-Based Risk Perspectives Survey

The primary mechanism for public engagement in this plan update was a survey. The survey was designed to collect the public's concern and experience with specific hazards.

The survey was organized into three sections:

- Concern and experience with natural hazards identified in DP3
- Concern and experience with man-made hazards
- Concern for vulnerable populations

Questions in the natural hazard section allowed planners to compare community concern for the hazards identified in the DP3 with the risk and vulnerability assessments within the DP3. Questions in the man-made hazards section were designed to collect baseline information for new hazards relevant to Baltimore, which will be introduced in future DP3s. Questions on vulnerable populations were designed to capture the perception of vulnerable populations and their anticipated needs during events. The survey was offered in both web-based and paper forms and was available in English and Spanish.

The survey was open from July 17 until August 15, 2018. During this window, it reached tens of thousands of people connected to the City, who ultimately submitted over 1,000 responses. Table 4 describes the dissemination channels and reach of the survey. Complete survey results are included in Appendix 1-4: Community Survey and are touched on in Chapter 3.

Table 4: Community Based Risk Perspective Survey Dissemination

Channels of Outreach	Reach
Baltimore Community Emergency Response Team (CERT) members	400
BRACE: The Baltimore Redevelopment Action Coalition for Empowerment Facebook group	3,000+
Greater Baltimore Urban League Email Distribution List	2,000+

Channels of Outreach	Reach
Health Clinics	Hundreds
Mayor's Commission on Disability	Hundreds
Mayor's Office of Emergency Management Twitter	14,000
Multiple City Council Members' Email Distribution Lists	1,000+
Nextdoor social network (via posts by Mayor's Office of Emergency Management and Individual Subcommittee Members)	60,000
Office of Sustainability Email Distribution List	700
Office of Sustainability Facebook and Twitter	3,000
Resiliency Hub Networks	100
Senior Centers (6)	Hundreds
Additional Subcommittee Members' Social Media Network	4,800
Other (Community associations, faith-based organizations, Headstart programs, etc.)	Unknown

Comprehensive community engagement in local planning is a moving target. The Equity and Outreach Subcommittee acknowledges that outreach and engagement efforts during this plan update have limitations that are important to recognize.

A primary issue was the condensed engagement period. There were expansive efforts to involve the public in the planning process, which did allow communities and residents to participate who may have otherwise been excluded. While many of these voices were not previously included in City planning efforts to date, additional effort is still required. Deep engagement is time-intensive and could not be accomplished under a compressed timeframe.

Despite subcommittee efforts, the composition of survey respondents underscored the need to expand outreach. There was a significant contrast between the racial and gender composition of the city and survey respondents. Going forward, planners recognize that a longer engagement period would allow planners to connect with more residents, especially those currently disconnected from these efforts. Additional engagement methods are a recognized gap, and identified methods for enhanced engagement are addressed in Chapter 7: Moving Forward.

Overview of the City of Baltimore

City Profile

History and Geography

The City of Baltimore, Maryland, is located on the eastern seaboard in the Mid-Atlantic region (also referred to as the Northeast, or Northeastern, region of the United States). Situated within the greater Chesapeake Bay Watershed, Baltimore surrounds a natural harbor near the mouth of the Patapsco

River. The City features 60 miles of waterfront within four local watersheds (Baltimore Harbor, Gwynns Falls, Jones Falls, and Herring Run watersheds). Baltimore City's 80 square miles of land comprise the most heavily developed area within the State of Maryland; the City is characterized by brick row houses, office centers, and university campuses, to name a few key features.

Founded in 1729, the City of Baltimore is a major U.S. seaport. Baltimore's port has been considerably successful. One particular economic advantage is that Baltimore is situated closer to major urban markets in the Midwest than any other major seaport on the East Coast. Additionally, the depth of Baltimore's harbor has continually provided access to the larger ships traveling from the Panama Canal. Today, Baltimore is one of only two East Coast port facilities that are deep enough to accommodate the substantially larger ships arriving due to the completion of the Panama Canal expansion in 2016. Baltimore's economic activity has largely centered on waterfront development and redevelopment. Baltimore's waterfront includes a wide variety of land uses, including industrial, commercial, recreational, and residential development.

Baltimore's Inner Harbor was once the second leading port entry for Immigrants to the United States and a major manufacturing center. After a decline in manufacturing industries in the 1970s and 80s, Baltimore shifted to a service sector-oriented economy. Now, Johns Hopkins University, Johns Hopkins Hospital, and the University of Maryland are the city's largest employers.

The port and waterfront remain extremely important assets in Baltimore, providing an abundance of job opportunities as well as some of the City's strongest property tax base. Today, the Inner Harbor is home to Harborplace, a festival marketplace that opened in 1980. Recognized as an international model for urban waterfront development and revitalization, Harborplace transformed Baltimore's Inner Harbor and is now a shopping, entertainment, and tourist destination that also features attractions like the National Aquarium and the Maryland Science Center. Daily visitors number in the hundreds of thousands, adding up to more than 20 million visitors each year. In fact, summer tourist season sometimes swells the City population to over 1 million.

Demographics and Development Trends

Baltimore is one of the nation's largest cities. According to Census Data, Baltimore reported a population of 620,961 residents in 2010. Since the 1950's, Baltimore has lost nearly one-third of its population due to the suburbanization of the region, among other factors. The latest Census data indicates that Baltimore's population is stabilizing somewhat. In 2012, the Census Bureau Population Estimates indicated that the City's population was 621,342, a small increase. However, a 2017 Census Bureau Population Estimate approximates Baltimore's population to be 611,648, equating a 1.5% decline since the 2010 Census. The upcoming 2020 Census will paint a clearer picture of where the City's population is heading.

In Baltimore, the median age is 34 years, and there are slightly more females (at 52.9 percent) than male residents. Data from the 2010 Census indicated that 64 percent of the population identifies as black and 29.4 percent as white. Both demographic groups, however, experienced a decline in numbers since 2000, while smaller demographic groups experienced significant increases. The percent of Baltimore's population that identify as Asian, for instance, increased 45.7 percent, while those who noted they were "some other race" increased by 159.1 percent. Additionally, the number of residents who indicated they were Hispanic increased 134.7 percent; with the largest increase — 161.9 percent — in Mexican Hispanic residents.

In 2010, there were 249,903 households in Baltimore City, 47.7 percent of which were owner-occupied (8.2 percent decrease since 2000). According to the 2010 ACS 1-Year Estimate, the Median Household Income grew to an estimated $50,046, up from just $39,368 in 2000 (2010 adjusted dollars). Also of note, 18 percent of family households were living below the poverty line between 2012-2016, with 33 percent of children in the city also living below the poverty line.

Development trends are showing an increase in residential development from decades past, with many new residential units coming online now and more expected in the future. Tax credits have encouraged the rehabilitation of many previously vacant townhomes, and new condominium/apartment towers are being constructed in the Central Business District as well as Harbor East and Harbor Point neighborhoods. Examples of recent development – including several in the floodplain and/or mixed use – include:

- Harbor Point (1300 Thames Street, other addresses): Multiple buildings (mixed use, some already finished including the Exelon Building) are part of Baltimore's largest downtown waterfront site currently under development. The Harbor Point site involved installing a geomembrane liner (part of the environmental cap) as part of a model brownfield revitalization in an urban waterfront setting and elevation of buildings for floodplain requirements.
- 414 Light Street: 44 stories of high-rise luxury apartments in Baltimore's inner harbor, this new residential building will be a LEED® Silver Certified building, and feature a minimized carbon footprint, compliance with stringent floodplain requirements, and carpool and public transit incentives (opened summer 2018).
- Bainbridge Federal Hill (1100 Key Highway): Apartment building opening in summer 2019 (outside of floodplain).
- Whitehall Mill (3300 Clipper Mill Road): A mixed-use redevelopment of an historic mill located on the Jones Falls featuring a 27 apartments, 18,000 square feet of rentable space, a 6,300-square-foot restaurant, and 2,300 square feet of office space, plus a one-story parking garage and a pedestrian bridge for emergency evacuation in case the Jones Falls floods. Electrical transformers will be built on stilts above the 100-year flood plain, as part of compliance with the City's floodplain code (opened 2016).

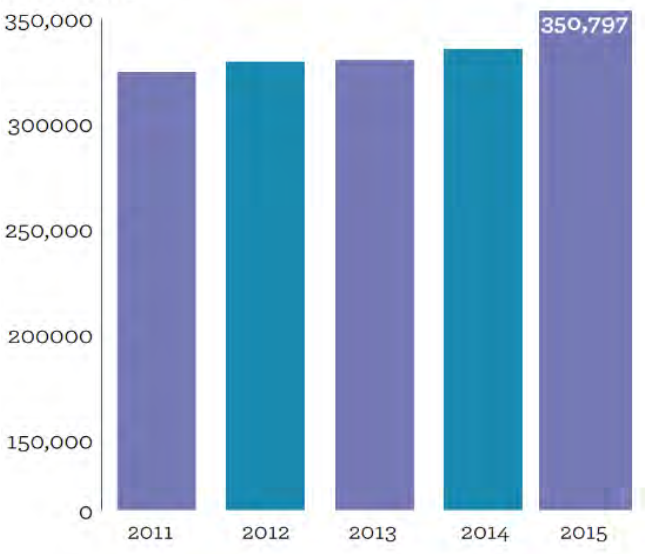
The 2017 State of Downtown Baltimore Report shows that demand for both rental and for-sale housing in downtown neighborhoods is solid and anticipates that the market can absorb around 7,000 new units over the next five years. Development in Port Covington, a privately-owned 235-acre parcel being transformed into a mixed-use neighborhood in South Baltimore, is expected to move forward, with its first set of buildings coming online in 2020. However, due to both Downtown Baltimore and Port Covington's locations along the waterfront, many of the new and renovated buildings are at risk for coastal hazards and flood events. Furthermore, the recent adoption of the Green Network Plan should create increased opportunity and energy around vacant property / infill redevelopment, equitable greenspace provision, and bike/pedestrian corridor development and enhancement.

In general, City expects to primarily see re-development, not necessarily "new" development, in the coming years. Since such areas were originally developed prior to modern building codes, redevelopment will be subject to these more stringent "modern" building codes, which take into consideration hazard loss and should result in increased resiliency and hazard resistant structures. The City expects continued noteworthy growth along its waterfront, but will maintain the new 'maritime industrial' zoning designation (which limits redevelopment to areas outside of deep water). Growth

in the Jones Falls Valley (where there has been past riverine flooding) should be more limited as well. Overall, planned growth is leaning toward densification and mixed-use development, which should result in less reliance on vehicles. The City will evaluate this as a factor in emergency evacuation planning.

Though the overall population of Baltimore has decreased slightly over the last few years, the total number of City jobs has seen an uptick between 2011 and 2015 (Figure 2). Baltimore is home to many high revenue-generating companies such as Abacus Corporation, the Baltimore Sun, Johns Hopkins University and affiliated hospitals/medical centers, University of Maryland Medical System, Kennedy Krieger Institute, and T Rowe Price Associates, to name a few. While these, and other leading industries, are dispersed across the City, some neighborhoods have high concentrations of these major employers. For instance, about 35 percent of Baltimore's major employers are located within the Inner Harbor and Downtown Baltimore neighborhoods, together, which are major economic centers in the City.

Figure 2: Total Jobs in Baltimore City, 2011-2015

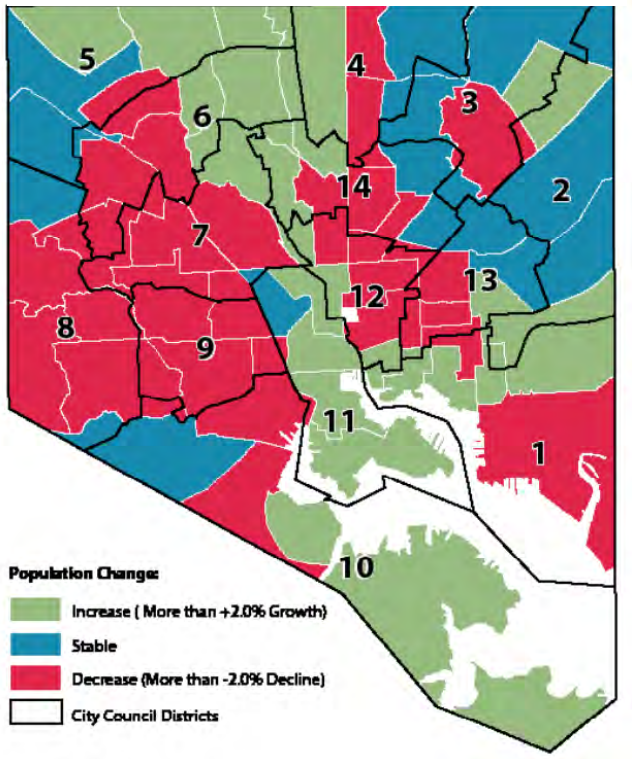


Source: BNIA 2016 Vital Signs Report

According to the ACS 2010 1-year Estimate, the top five largest industries in Baltimore are Education and Health Services (23.2 percent), Retail Trade (11.7 percent), Professional (10.6 percent), Manufacturing (10.4 percent), and the Arts (9.2 percent). In regard to the Manufacturing sector, Census data shows that the number of manufacturing businesses with the owner as a sole proprietor increased by 64% between 2003 and 2012. This suggests that entrepreneurship in the sector is on the rise.

Baltimore is often referred to as a "City of Neighborhoods" for its many unique districts and communities. While the overall population of Baltimore has been slowly declining, many neighborhoods have seen impressive growth over the last two decades (Figure 1-3). The characteristics of Baltimore's neighborhoods can vary greatly in terms of age, race, poverty status, educational attainment, etc. Concentrations of population groups with distinct demographic characteristics can lead to increased social and economic vulnerability. When coupled with the impacts from natural hazards, these neighborhoods and their residents are often impacted more significantly and with fewer resources to both withstand impact and recover. Environmental justice ensures the fair treatment and the equal protection of an individual — regardless of race, ethnicity, or income — from environmental and health hazards, as well as uniform access to planning and decision-making processes which provide residents with a healthy environment in which to live, earn, play, and learn. This plan attempts to provide disaster preparedness and planning opportunities in an equitable way that is inclusive of vulnerable and historically marginalized populations.

Figure 3: Population Change in Baltimore by Community Statistical Area (CSA), 2000-2010



Source: BNIA 2016 Vital Signs Report

Climate of Baltimore

Baltimore has a temperate climate and experiences four distinct seasons each year. Baltimore's winters are cool and dry, with limited snowfall. Summers are warm and humid, and the average annual rainfall is 40.72 inches. Average annual temperatures are 58.5°F, with average temperatures in the summer months ranging from 85°F to 89°F[7]. These averages do not always reflect the extremes the City can experience–in rainfall, heat waves, cold snaps, and extreme snow. According to the U.S. Environmental Protection Agency, average rainfall in the State of Maryland has already increased by around 5 percent, and the average temperature has risen 1-2 °F. The State has also seen an increase in sea levels at the rate of about 1 inch every 7 to 8 years[8].

These extremes are expected to increase due to climate change. The *Climate Science Special Report: Fourth National Climate Assessment (NCA4), Volume I* assesses the science and the projected impacts of climate change for the United States, including regional assessments. For the Northeast region, predicted impacts by mid-century include:

- 3.98°F to 5.09°F increase in annual average temperature
- 6.51°F increase in the average hottest day of the year
- 10-13 percent increase in extreme precipitation[9].

Existing Hazard Mitigation and Adaptation Efforts

In addition to the plans discussed in Section 1.1, Baltimore has a set of programs and actions that improve the City's capability to address hazards mitigation and climate adaptation, many of which are listed below.

Commission on Sustainability

The Baltimore Commission on Sustainability, a 21-member body appointed by the Mayor, oversees the implementation of the Baltimore Sustainability Plan, monitoring and reporting progress annually. The Commission is made up of members representing environmental groups, community organizations, labor unions, public health and environmental justice interests, and private industry.

Floodplain Management

Baltimore City floodplain management is a program of corrective and preventative measures for reducing flood damage, including but not limited to emergency preparedness plans, flood control works, and floodplain management regulations. Floodplain regulations are meant to protect life, health and property; minimize rescue and relief efforts; minimize business interruptions; minimize damage to public facilities; minimize the occurrence of future flood blight areas; minimize public expenditures for costly flood control projects; and prevent increases in the regional flooding. The Baltimore City floodplain code supersedes both State and Federal floodplain regulations.

Flood Maps

The Federal Emergency Management Agency (FEMA) produces Flood Insurance Rate Maps (FIRMs), which identify areas that are at risk of flooding. FIRMs incorporate statistical information such as data for river flow, storm tides, hydrologic/hydraulic analyses, and rainfall and topographic surveys. Based on these analyses, certain floodplain areas are identified on the FIRM as Special Flood Hazard Areas (SFHAs). In Baltimore City, the regulated SFHA includes areas subject to inundation by the 1-percent- and 0.2-percent-annual-chance floods, also known as the 100-year and 500-year floods.

The City of Baltimore Floodplain Management Office provides information about Baltimore City's FIRMs, such as assistance with determining if a property is in the SFHA, what the estimated Base Flood Elevation (BFE) is for a property, and what flood depths may be at that site. Baltimore City Floodplain Managers will also provide information about historic flooding, coastal SFHAs (V zones), the floodway, and natural floodplain functions in a specific area.

Community Rating System

The Community Rating System (CRS) is a voluntary incentive program that recognizes and encourages community floodplain management activities that exceed National Flood Insurance Program (NFIP) requirements. As an incentive, flood insurance premium rates are discounted to reflect reduced risk. Certifying Baltimore as a CRS community was a goal established by the DP3 to help protect Baltimore from flooding and save its residents money on insurance premiums. Both the CRS and NFIP programs are directed and administered at the federal level by FEMA (the Federal Emergency Management Agency).

Capital Improvement Program

To guide the City in making necessary physical improvements, the City Charter requires the Planning Commission to annually recommend a 6-year Capital Improvement Program (CIP) to the Board of Estimates. Each year, the Planning Department works with the various City agencies to prepare and present a new 6-year program and shares guidelines for the project request process that includes information on the requirements of the DP3, floodplain management process, and stormwater management.

Baltimore City Health Department

The Baltimore City Health Department Office of Public Health Preparedness and Response (OPHPR) is committed to preparing Baltimore City for public health emergencies such as large-scale disease outbreaks, bioterror events and other emergencies with an impact on the health of the community. As part of this work, they:

- Talk to residents and community leaders about ways we can prepare ourselves for health emergencies.
- Plan together with government agencies and local healthcare for response.
- Monitor information from hospital emergency department visits, the weather, and other data to identify risks to health or possible health emergencies.
- Partner with City, State, private partners and community groups to identify resources to meet the needs of the public during emergencies that include extreme heat (Code Red) and extreme cold (Code Blue).

Mayor's Office of Emergency Management

Mitigation and adaptation efforts related to emergency response and recovery are also being addressed through plans and initiatives in the Mayor's Office of Emergency Management. These plans include the City's Emergency Operations Plan (the primary response and recovery plan) and the City's Continuity of Operations Plan (COOP).

TreeBaltimore

TreeBaltimore serves as the umbrella organization for all City agencies, private organizations, and individuals in their effort to increase the tree canopy of Baltimore. TreeBaltimore strives to increase the urban tree canopy in part to temper climate-related heat increases. The current canopy cover is 28% and TreeBaltimore's goal is to achieve 40% tree canopy cover by 2037.

Plan Content

This document lays out the 2018 DP3 development process and strategies and actions that will help the City achieve its hazard mitigation and climate adaptation goals.

Chapter 2: Hazard Mitigation and Climate Adaptation

This chapter defines hazard mitigation and climate adaptation and highlights why Baltimore City decided to combine these two plan development processes.

Chapter 3: Hazard Assessment

This chapter identifies and defines natural hazards that threaten the City of Baltimore. It includes the severity, probability and location of each historical hazard and reports on the damages and consequences caused by each. This chapter also integrates predicted changes due to climate change, in order to address the need to adapt.

Chapter 4: Risk and Vulnerability Assessment

This chapter builds upon the hazard identification process to further inform the risk assessment by assessing vulnerability. This chapter evaluates the potential losses associated with a given hazard and estimates the degree to which property damage, economic loss, physical injury, or death are likely to occur. It highlights why Baltimore is at risk and where that risk is greatest.

Chapter 5: Strategies and Actions

This chapter explores ways that Baltimore can best manage risks, protect people and property, and pro-actively plan for the current and future impacts of climate change. It provides key strategies and actions for four sectors: infrastructure, buildings, natural systems and public services.

Chapter 6: Implementation, Monitoring and Evaluation

This chapter identifies how implementation of the DP3 strategies and actions will begin. It identifies lead agencies, stakeholders, timeline, financing options and policy mechanisms for each action.

Chapter 7: Moving Forward

This chapter identifies high-level recommendations designed to foster continued equitable engagement and strengthen community resilience. It also summarizes concurrent efforts underway in the Office of Sustainability.

Glossary

A glossary consisting of key and unique terms used and referenced throughout the document can be found at the end of the text.

Chapter 2

Hazard Mitigation and Climate Adaptation

Summary of Changes

- Minor updates were made to address any changes that took place over the last 5 years

Regulatory Checklist

No CFR requirements

Introduction

The Disaster Mitigation Act of 2000 (DMA 2000) requires local governments to develop and submit a hazard mitigation plan in order to receive grant assistance specifically for mitigation projects. Baltimore's Disaster Preparedness and Planning Project (DP3) is Baltimore City's alternative to the standard required All Hazards Mitigation Plan (AHMP). The DP3 combines hazard mitigation and climate adaptation planning to strategically address both existing and predicted hazards from intensifying climate change impacts. Strategies that address both current and future hazards are intended to increase the overall resilience of Baltimore City and improve the City's preparation for, response to, and recovery from acute shocks and chronic stresses. This chapter of the plan defines key concepts and terminology used throughout the document.

Defining Key Concepts

What is Hazard Mitigation?

According to FEMA, **HAZARD MITIGATION** is any sustained action taken to reduce or eliminate long-term risks to people and their property from hazards. The purpose of hazard mitigation planning is to identify both short and long-range policies and actions that can be implemented to reduce the magnitude of current risks and future losses. The City's hazard mitigation strategies and actions should also enable Baltimore City to increase its overall resilience to the hazards it faces. In Baltimore City, **RESILIENCE** is defined as the ability to anticipate, accommodate, and positively adapt to or thrive amidst changing climate conditions or hazard events and enhance quality of life, reliable systems, economic vitality, and conservation of resources for present and future generations.

The planning process is just as important as the plan itself. Risk-based decision-making guides communities to become more sustainable and disaster-resistant by focusing efforts on hazards and disaster-prone areas, and by identifying appropriate mitigation actions. The process also ensures that priorities are identified along with anticipated costs. Communities have limited resources to address all concerns. The DP3 recommendations recognize and balance the expenditure of limited resources in the consideration of priorities and recommendations. As such, the 2018 DP3 acts as the foundation and clearinghouse for Baltimore's long-term strategy to reduce disaster losses, damage, and expenses. It recommends practical solutions that can be implemented by the City in partnership with businesses, non-profit organizations, community groups, volunteers, and other levels of local government. Additionally, the 2018 DP3 project will follow all tasks and procedures required for local mitigation plans by FEMA.

What are Climate Change and Climate Adaptation?

CLIMATE CHANGE refers to any significant change in the measures of climate lasting for an extended period of time. Both human and natural activities are influencing changes in Earth's atmosphere, oceans and local weather patterns. Changes include significant shifts in temperature, precipitation, wind patterns, and ecologies, which may occur over several decades or longer. For example, over the past century, Maryland's average temperature has risen by 1.8°F and is projected to continue rising. These rising temperatures have been accompanied by changes in local weather and climate, including more high-impact weather events, longer and more frequent heat waves, and a rise in relative sea level, just to name a few. A changing climate is now affecting many of the natural hazards that influence affect daily life, causing these events to become more extreme over time.

Simultaneously, new hazards have been arising, which will introduce additional planning challenges for public safety and policy makers alike.

Nevertheless, many of the impacts associated with climate change may still be prevented by reducing greenhouse gas (GHG) emissions. Baltimore's Climate Action Plan (CAP) (discussed in Chapter 1) is the City's most recent effort to establish policies and programs that focus on this task. The CAP highlights the GHG emission reduction measures that also have adaptation impacts and identifies priority strategies for this and other future adaptation planning efforts. While GHG mitigation initiatives continue to be essential to stabilizing the climate in the long term, it will indeed take time for our planet to respond to GHG reductions. Consequently, GHG concentrations already present in our atmosphere commit us to a range of climate change impacts that we can expect to face in the near future.

Baltimore cannot entirely prevent the changes in climate that have already been set in motion. Without taking additional measures, a reduction in GHG emissions will not be a sufficient response. Instead, it is increasingly accepted that we must learn to live with, or adapt to, a modified climate. **CLIMATE ADAPTATION** is a process that intends to reduce long-term risks from hazards associated with climate variability and climate change. More specifically, adaptation refers to changes that are made to better respond to new climate conditions, thereby reducing harm and taking advantage of present opportunities. Climate-related impacts are already affecting Baltimore residents. Heat waves, relative sea level rise, and flooding due to more extreme precipitation events can impact the City's environmental, social, and economic systems. Building adaptation measures into this plan allows Baltimore to reduce risk to people and property while increasing the resiliency of our communities and businesses.

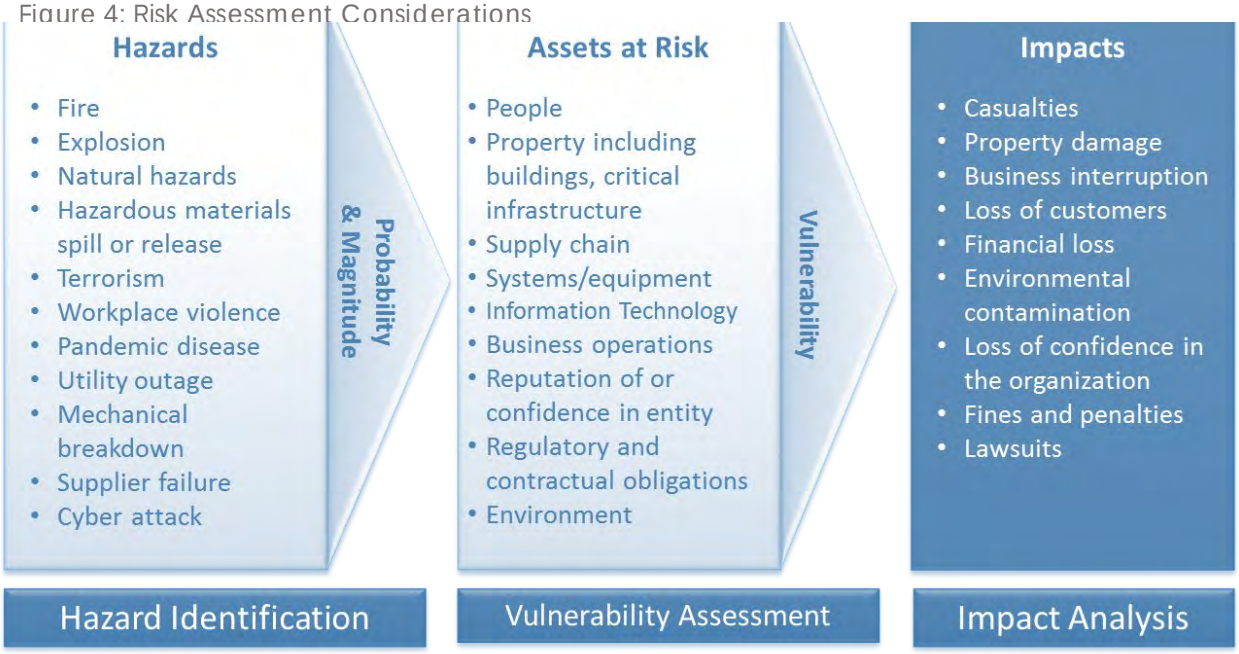
How are Hazard Mitigation and Climate Adaptation Connected?

Climate change is going to happen for the foreseeable future, and the impacts of development last for decades. It takes time to see the results of successful proactive planning. Thus, the City may continue to experience risks associated with elevated GHG emissions for decades to come. While these changes cannot be prevented, Baltimore can prepare by incorporating the anticipated risks associated with climate change into hazard mitigation planning efforts. Integrating hazard mitigation planning, which focuses on past events, with climate adaptation planning, which focuses on what will likely happen in the future, offers a positive, win-win solution for Baltimore City. Both processes require a risk assessment that includes a detailed inventory of natural hazards and a vulnerability analysis. These efforts inform actions to mitigate hazards and to adapt to predicted climate impacts. This provides clear guidance and a unified strategy that supports Baltimore's sustainability and resilience goals.

It takes a significant amount of time to reach long-term goals. Therefore, we must act now and prepare for the future by proactively mitigating natural hazards and adapting to climate change. Proactively planning for a hazard is much more effective than responding to impacts following a disaster. Additionally, a proactive method can provide significant cost savings. For instance, every dollar FEMA spends on natural hazard mitigation will produce, on average, $6 in future benefits.[10] More importantly, proactively planning for hazard mitigation and climate adaption protects the health and well-being of Baltimore's residents and supports a sustainable, growing City.

What is a Risk Assessment?

Figure 4: Risk Assessment Considerations



The purpose of an AHMP is to identify policies and actions that can be implemented over the long term to reduce risk and future losses. In order to do so, a major component of the AHMP is a risk assessment. This process is a necessary first step for DP3: identifying the nature, location, intensity and probability of a threat, and then determining Baltimore's vulnerabilities and exposure to that threat while considering the capacities and resources available for the City to address or manage it. Baltimore's risk assessment comprises the bulk of the DP3 report, with the individual steps of this analysis divided between the coming chapters.

The first step in a **RISK ASSESSMENT** is the identification of all natural hazards that have impacted, or may impact, the City. The **HAZARD IDENTIFICATION** process helps highlight the historical nature and extent of natural hazards that have impacted the City of Baltimore, considering the unique characteristics and potential consequences of each. This process also incorporates the magnitude associated with each hazard and the probability of the hazard occurring in the future. Chapter 3 of this report, Hazard Assessment, discusses the historical and contemporary impacts and extent of individual hazards, using this recorded data alongside scientific projections to estimate the probability of future occurrences.

A **VULNERABILITY ASSESSMENT** complements the hazard identification process. Chapter 4, Risk and Vulnerability Assessment, further develops the risk assessment by examining Baltimore's current exposure (measure(s) of defense), sensitivity (degree to which the City could be affected), and adaptive capacity (ability for the City to recover). After addressing general, city-wide concerns for Baltimore, the Risk and Vulnerability chapter evaluates key areas of exposure, sensitivity, and adaptive capacity for each hazard. Additionally, by looking ahead, the vulnerability assessment explores what, specifically, may be vulnerable (i.e., what assets—including community assets (vulnerable populations, economic assets, etc.) and critical facilities—could be at risk) to the future impacts of climate change.

The vulnerability assessment includes an inventory of assets that identifies, where possible, what specific properties and resources may face greater impact by considering precisely how severe that impact may be during future events.

The initial elements examined in the vulnerability assessment lay the foundation for the **IMPACT ASSESSMENT**. This assessment identifies the degree to which, and in what manner, hazards will impact Baltimore's people, places, and economy. The impact assessment determines, for instance, how many people will be affected, and how so. In other words, the impact assessment identifies what stands to be damaged due to a hazard event, and the costs associated with such a loss.

Hazard identification and vulnerability assessments are the first stages of the risk assessment. Once the possible impacts are identified, investing in appropriate hazard mitigation and climate adaptation methods can reduce the overall risk. To this end, the information discovered in each stage of the risk assessment (hazard identification, vulnerability assessment, and impact assessment) is utilized in the decision-making process and contributes to the development of the strategies and actions identified in Chapter 5. The recommendations in this 2018 DP3 update build on the risk assessment results, with the goal of helping the City and its residents holistically understand risks, mitigate and prepare for hazards, and adapt to projected changes in climate.

Chapter 3

Hazard Assessment

Summary of Changes

- New Hazard Identification Risk Assessment (HIRA), including:
    - New local risk perspective (Technical Advisory Committee and community survey results)
- All hazard data tables and associated text have been updated to include descriptions, for all natural hazards that affect Baltimore, of the following:
    - Type;
    - Location; and
    - Extent
- Updated hazard profiles on previous occurrences of hazard events and on the probability of future hazard events

Regulatory Checklist

B1. Does the Plan include a description of the type, location, and extent of all natural hazards that can affect each jurisdiction? 44 CFR 201.6(c)(2)(i) and 44 CFR 201.6(c)(2)(iii)

B2. Does the Plan include information on previous occurrences of hazard events and on the probability of future hazard events for each jurisdiction? 44 CFR 201.6(c)(2)(i)

Introduction

Natural hazards that have impacted or have the potential to impact the City of Baltimore were identified in the 2013 DP3 and reviewed during the 2018 plan update. The hazard identification and assessment of hazards includes the compilation of data from past hazard occurrences, analysis of current hazards, and prediction of hazards and associated severity due to climate change. Integrated into the hazard identification and assessment process are damages and consequences that result from each hazard, such as destroyed homes, damaged trees, and compromised utility systems. Determining the extent (severity) and probability (likelihood of occurrence) of each hazard enables the City to determine the risk associated with each hazard.

This chapter of the plan includes the *2018 Hazard Identification and Risk Assessment* (HIRA), including risk criteria, ranking results, and HIRA conclusions. The local hazard risk perspective was emphasized during the preparation of the DP3 update. Local risk perspective surveys were developed for both the Advisory Committee and the general public. Results of both surveys have been integrated into the 2018 HIRA and throughout the DP3 update. In addition, hazards identified within this chapter have been profiled and include information on location, extent, and previous occurrences, using maps where appropriate.

Hazards identified in the previous DP3 were retained and assessed in the 2018 HIRA as part of the DP3 update. It is important to note, while natural hazards were assessed in the DP3 update, additional hazards—including threats—were assessed in the 2017 *City of Baltimore Threat Hazard Identification Risk Assessment* (THIRA) *Report*. These threats and hazards included, but were not limited to, the following: Pandemic, Explosive Devices, Cyber Attack, and Active Shooter.

Are hazards and threats different? Yes, a hazard differs from a threat in that a threat is directed at an entity, asset, system, network, or geographic areas, while a hazard is not directed.

Source: DHS Risk Lexicon, 2010 Edition

Hazard Assessment

Hazard Identification

Hazard identification is the process that identifies and defines the natural hazards that threaten the City of Baltimore. The hazard identification process looks at past hazard events—including an analysis of current hazards in addition to those predicted due to climate change—and integrates damages and/or consequences that result from each hazard, such as destroyed homes, damaged trees, and compromised utility systems. Hazard identification includes the extent of impacts or consequences (severity) and the probability (likelihood of occurrence) of each hazard, as well as the locations they are likely to affect.

Further consideration was given to the apparent increase in the frequency of high-impact, "no-notice" weather events to affect Baltimore and the State of Maryland since 1990. Relative to time periods prior to 1990, Baltimore has experienced more frequent high snow-accumulation winter storms and severe weather outbreaks, as well as a rising number of higher-than-average temperature readings.

In consideration of available information and data, this plan will address the following natural hazards by analyzing their impacts on Baltimore City and recommending mitigation and adaptation strategies:

Flooding

Flooding and Dam Failure

Coastal Hazards

Tropical Storms and Hurricanes; Sea Level Rise; and Storm Surge/Coastal Inundation; Tsunami

Precipitation Variability

Precipitation; Thunderstorms, with Lightning and Hail; Winter Storms and Nor'easters; Drought

Wind

Associated with Storms; Derechos; Tornados

Extreme Heat

Heat and Air Quality

Land

Earthquakes; Landslides; Karst/Sinkholes

Hazards identified by the City of Baltimore include the five hazards that must be addressed, at a minimum, in all local hazard mitigation plans, according to the *State of Maryland Local Hazard Mitigation Planning Guidance, May 2015*. Natural hazards that impact the State of Maryland were identified using Federal Disaster Declarations. The five hazards that consistently resulted in widespread impacts across the State included:

- Coastal Hazards
- Flood
- Winter Storm
- Tornado
- High Winds

Coastal hazards were defined as follows, to include probable hazards such as sea level rise and increasing flood risk due to climate change:

> Coastal hazards take many forms, ranging from storm systems like tropical storms, hurricanes, and Nor'easters that can cause storm surge inundation, heavy precipitation that may lead to flash flooding, and exacerbation of shoreline erosion to long-term hazards such as sea level rise. Therefore, coastal hazards are to include, if applicable, coastal storms, storm surge, hurricane, tropical storm, Nor'easter, sea level rise and shoreline erosion.
>
> Source: 2016 State of Maryland Hazard Mitigation Plan

Hazard Risk

To update the *Hazard Identification Risk Assessment* (HIRA) for the 2018 DP3 update, a local hazard risk perspective was sought from both the plan update Advisory Committee and the citizens of Baltimore City. The Advisory Committee survey was initiated in June 2018, and results were presented on July 18, 2018. Survey participants were asked to rate their level of concern for Baltimore City's hazards. The majority of the Advisory Committee participated, with results reviewed and confirmed at the July meeting.

Table 5: Local Risk Perspective Survey

Hazards	Local Risk Perspective Survey Results
Flooding	
Flood	Very Concerned
Dam Failure	Somewhat Concerned
Coastal Hazards	
Tropical Storms & Hurricanes	Very Concerned
Storm Surge/Coastal Inundation	Concerned
Sea Level Change	Very Concerned
Tsunami	Not Concerned
Precipitation Variability	
Thunderstorms (Lightning & Hail)	Concerned
Winter Storms & Nor'easter	Concerned
Drought	Somewhat Concerned
Wind	
Thunderstorm Winds & Derecho	Concerned
Tornados	Somewhat Concerned
Extreme Heat	
Heat & Air Quality	Very Concerned
Land	
Earthquakes	Not Concerned
Land slump/Subsidence	Not Concerned
Sinkholes	Concerned

In addition to the local risk perspective survey completed by the Advisory Committee, an on-line survey specific to personal risk perceptions of various hazards was distributed to the citizens of Baltimore City. The web-based survey was given via Survey Monkey using email distributions maintained by Baltimore City agencies and community organizations, and through social media. A printed version of the web survey was distributed to senior centers, health clinics, and Resiliency Hub leaders for dissemination. The survey was open and distributed between July 17 and August 15, 2018. The number of surveys completed by respondents as of August 15, 2018, was 1,028. Respondents reported the most concern for extreme precipitation, heat, wind, and flooding, all of which are consistent with findings presented in Table 4.

2018 Hazard Identification Risk Assessment (HIRA)

A blend of quantitative factors extracted from the National Center for Environmental Information, local damage assessment data, and the 2018 local risk perspective survey were used for Baltimore's 2018 HIRA.

The following rating parameters were used to develop a hazard risk ranking for the 15 identified hazards:

Probability

Probability refers to the likelihood of the hazard occurring; it is defined in terms of general descriptors, (for example, unlikely, somewhat likely, likely, highly likely), historical frequencies, and/or statistical probabilities, and may be shown on hazard probability maps.

Deaths

Hazard-related deaths correlate to the severity of impact to the community from any specific hazards.

Injuries

Hazard-related injuries correlate to the severity of impact to the community from any specific hazards.

Damages

Hazard-related damages include both property and crop damages and correlate to the severity of impact to the community from any specific hazards.

Local Hazard Risk Perspective

A local hazard risk perspective provides a basis for determining those hazards that are of concern to people who work or live in the planning area. Levels of concern are defined in terms of general descriptors, (for example, not concerned, somewhat concerned, concerned, very concerned).

Table 4 provides the specific rating criteria used in this analysis. All rating criteria are equally weighted. HIRA results are presented in Table 5. A more detailed description of the data sources used for this assessment can be found in Appendix 3-1.

Table 6: Hazard Rating Criteria

Probability Rating		Local Risk Perspective		Damages	
Rating	Criteria	Rating	Criteria	Rating	Criteria
1	0-0.49 events/year	1	Not Concerned	1	None
2	0.50-1 events/year	2	Somewhat Concerned	2	Minor
3	1.1-2.5 events/year	3	Concerned	3	Significant
4	2.6 or more events/year	4	Highly Concerned	4	Major

Deaths		Injuries	
Rating	Criteria	Rating	Criteria
1	None	1	None

4	1 or more	4	1 or more

Table 7: Overall Hazard Risk Ranking

Hazards	Probability	Deaths	Injuries	Damages	Local Risk Perspective	Hazard Risk Ranking
Flooding						
Flood	3	4	4	4	4	19
Dam Failure	1	1	1	1	2	5
Coastal Hazards						
Tropical Storms & Hurricanes	1	1	1	4	4	11
Storm Surge/Coastal Inundation	2	1	1	2	3	9
Sea Level Change	4	1	1	4	4	14
Tsunami	1	1	1	1	1	5
Precipitation Variability						
Thunderstorms (Lightning & Hail)	1	4	4	1	3	13
Winter Storms & Nor'easters	4	4	4	4	3	19
Drought	1	1	1	4	2	9
Wind						
Thunderstorm Winds & Derechos	4	4	4	4	3	19
Tornados	1	1	4	3	2	11
Extreme Heat						
Heat & Air Quality	4	4	4	1	4	17
Land						
Earthquakes	1	1	1	4	1	8
Landslump/Subsidence	1	1	1	1	1	5
Sinkholes	3	1	1	4	3	12

Hazard Risk Ranking Categories		
Low Risk	Medium Risk	High Risk
0-6	7-13	14-20

Note: Hazards that do not include past occurrence data were assessed for future probability. Hazards assessed as having a low probability of occurrence within the planning area, indicated as a "1" in Table 6, were then assessed as "1" for all other rating parameters. Those hazards included dam failure and tsunami. Hazards assessed as probable, indicated as a "2" or higher in the table, were then assessed for all other rating parameters, based on their likelihood of occurrence and associated impacts. The methodology for completing the Overall Hazard Risk Ranking shown in Table 6 and other detailed hazard event data can be found in Appendix 3-1.

Flooding

Flooding occurs when rivers, creeks, streams, ditches, or other hydrological features receive too much water. Three categories of flooding are common in the State of Maryland: flash, riverine, and coastal. In Baltimore, major flooding events are the result of riverine flooding along the stream tributaries of

the Patapsco River—including the Gwynns Falls and the Jones Falls, as well as their own tributaries, or from tidal flooding in the Northwest Harbor and Middle Branch of the Patapsco River.[11] Riverine flooding, usually from persistent rain or snowmelt, forces excess water beyond the water body and into the adjacent floodplain.[12] According to the 2014 FEMA Flood Insurance Study (FIS) report for the City of Baltimore, principal flood problems include tidal and riverine flooding. The City of Baltimore is subject to tidal flooding caused by Nor'easters and hurricanes. Nor'easters can occur at any time of the year but are more prevalent in late fall through early spring, whereas hurricanes usually occur in late summer and early fall. Riverine flooding in the City can be caused by a range of problems, including urbanization, which creates more runoff from impervious surfaces and higher, sharper flood peaks; stream channel encroachments, which include structures within the floodplain and undersized railroad and roadway bridges; and inadequate storm sewer drainage. These flooding problems are enhanced by high tides along the City's waterfront and by climate change.

Along the City's waterfront, high tides amplify flooding events. The flood hazard was ranked as a high risk with the 2018 HIRA, shown in Table 6. Both the Advisory Committee and public survey results support this high-risk ranking.

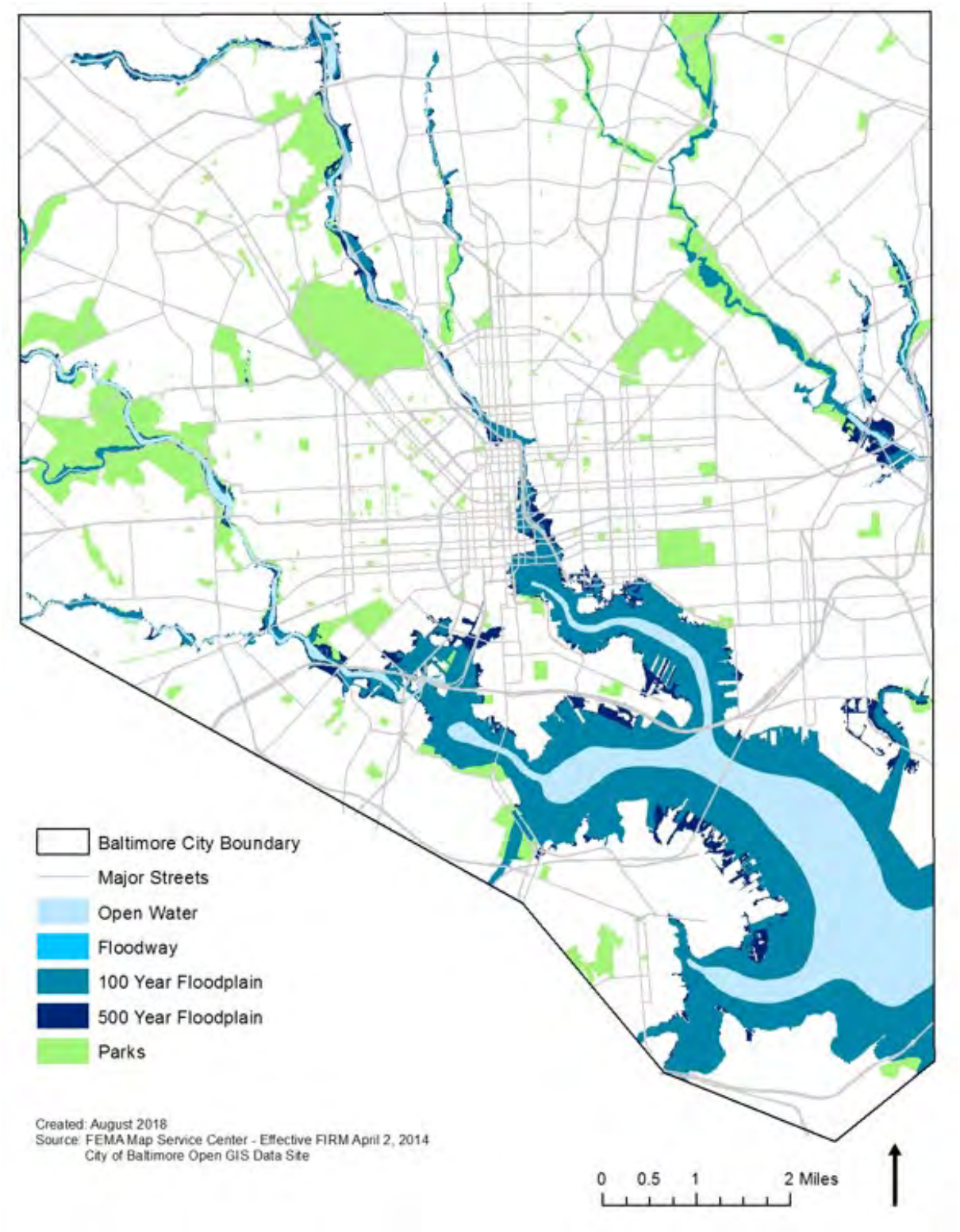
Figure 5 and Figure 6 delineate the Baltimore City floodways, along with the FEMA-designated 100- and 500-year floodplain areas. The 100-year floods are those having a 1-percent chance of being equaled or exceeded in scale in any given year; the 500-year flood designation relates to a flood with a 0.2-percent chance of being equaled or exceeded. The floodplains subject to inundation by the 1-percent-annual-chance flood, also called the base flood, are identified on FEMA's flood maps as Special Flood Hazard Areas (SFHAs).

The Flood Insurance Rate Map (FIRM) for Baltimore City has some panels that became effective on February 2, 2012, and others that were updated on April 2, 2014. It is important to note that FEMA, in cooperation with the State of Maryland and Baltimore, is in the process of updating the Baltimore City FIRM once again. This effort will result in more accurate mapping products reflective of current conditions. FEMA FIRMs, at this time, do not take into consideration future conditions due to climate change. However, the DP3 update is a FEMA-approved multi-hazard mitigation plan that considers both current and future conditions. Mitigation and adaptive planning strategies presented in the 2018 DP3 update reflect this approach and recognition of changing conditions.

Flood Insurance Rate Map– An official map of a community, on which FEMA has delineated both the SFHAs and the risk premium zones applicable to the community.

Most of Baltimore's recorded floods have been the result of either flash flooding during sudden, short-lived rainstorms, or localized flooding due to poor drainage and stormwater management. The FIS report for the City of Baltimore indicates that major historic flood events occurred in 1817, 1837, 1863, 1868, 1933, 1955, 1972, 1975, and 2003. These floods led to the loss of human life and caused significant damage to dwellings, industries, and infrastructure. In August 1817, flooding along the Jones Falls swept away homes, bridges, and livestock. Floodwaters during this event were reportedly

Figure 5: Baltimore City Floodplain



between 12 and 20 feet above normal levels.[13] Similarly, the Jones Falls rose 20 feet during the flood of July 1868, when the river claimed more than 50 lives and caused millions of dollars in damages, primarily in downtown Baltimore. In July 1923, recorded flood damage was even more immense; and the flood of 1966 took 39 lives.[14]

Table 8: Flood Events (Flash Flood, Flood and Heavy Rain) 1996-2017

County/City	Total Events	Annualized Events
Baltimore City	72	3.27

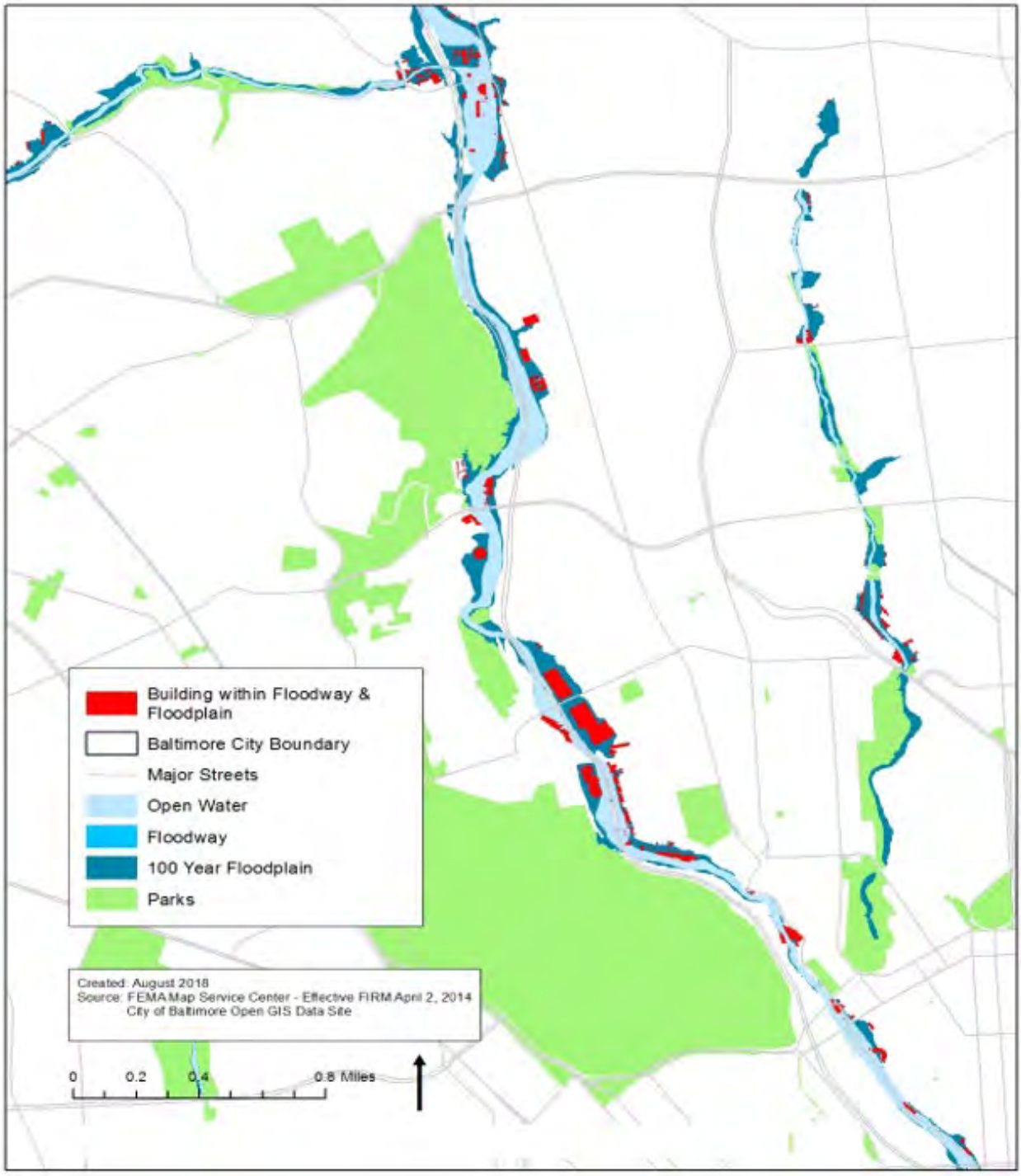
Source: National Centers for Environmental Information (NCEI)

As shown in Table 8, Baltimore County and/or portions of the City are subjected to more than three flood events per year on average. These flood events include urban and flash flooding.

In Baltimore, tidal flooding usually occurs as a result of storm events, such as Nor'easters or hurricanes (see Precipitation Variability Hazard Profile; see Coastal Hazards Profile). As an additional concern, flood maps indicate that some areas are also affected by high-velocity tidal flooding. High-velocity flows, where floodwaters can move faster than 5 feet per second, can exacerbate damage. During the storm of 1933, downtown Baltimore was inundated by tides, which rose 8.33 feet at Fort McHenry. Flooding during Tropical Storm Agnes, in June 1972, stands as one of Maryland's biggest natural disasters. In some areas, flood peaks were twice as high as the 100-year level. Statewide, Agnes caused $43 million in damages to public infrastructure and $66 million in damage to private property. Baltimore City alone suffered $33.9 million in losses. More recently, in fall 2003, Hurricane Isabel hit Baltimore. At the time, the storm was referred to as the "perfect" 100-year tidal flood—meaning that floodwaters reached depths predicted for 100-year floods, as reflected on the City's FIRM. The extent of Isabel's flooding also corresponded to the boundaries of the adopted 100-year flood zone. The City was regulating development based on these maps. Fortunately, thanks to Baltimore City's freeboard requirements, buildings with first floors at or above the 1-foot freeboard elevation did not sustain major flooding damage, and only 16 flood insurance claims were filed. It is worth noting that even though those maps reflect Isabel's impact as a 100-year storm, the new tidal floodplain analysis shows that Isabel was a 500-year flooding event.

Floods in Baltimore have forced evacuation, displaced hundreds of residents, overwhelmed emergency communication lines, and negatively impacted businesses. Major storm events and floods become even more menacing when critical emergency facilities are impacted, as was the case in November 2006 and July 2008, when different hospitals were impacted by floodwaters; or in 2012, when Sandy flooded research facilities at Johns Hopkins (though it had little impact on patient care facilities). This vulnerability must be taken into account as the City looks to the future. In Baltimore, 5.19 square miles of property (6.4 percent of the City's total land area) currently rests within the flood zone, while 3 percent of Baltimore's overall land—primarily in the Inner Harbor and the Fells Point Historic District—is within the coastal floodplain. By the end of the century, approximately 180 square miles of dry land along Maryland's coastline is expected to be inundated. Coupled with more frequent and extreme precipitation events (see Precipitation Variability Hazard Profile), these conditions could present a regular hazard.

Figure 6: Buildings within the Jones Falls Floodplain



Dam Failure

The risk associated with dam failure is considered an aspect of flooding in this plan. Dams are constructed to manage water storage, control flooding, and divert runoff into reservoirs upstream. Dams are sources of concentrated vulnerability. and their failure can lead to serious regional disasters. Dam failure is the collapse or breach of the dam structure, for which there is often either very little or no advance warning. While most dams in the Baltimore region have relatively small water volumes, and failures would therefore have little or no repercussions, dams with larger storage volumes can have disastrous consequences should they fail.

Any one or a combination of the following can cause dam failures:

- Prolonged periods of rainfall and flooding (cause of most dam failures in the U.S.).
- Inadequate spillway capacity, resulting in excess overtopping flows.
- Internal erosion caused by embankment or foundation leakage or piping.
- Improper maintenance, including failure to remove trees, repair internal seepage problems, replace lost material from the cross section of the dam and abutments, or maintain gates, valves, and other operational components.
- Improper design, including the use of improper construction materials and construction practices.
- Negligent operation, including the failure to remove or open gates or valves during high flow periods.
- Failure of upstream dams in the same drainage basin.
- Landslides into reservoirs, which cause surges that result in overtopping.
- High winds, which can cause significant wave action and result in substantial erosion.
- Earthquakes, which typically cause longitudinal cracks at the tops of the embankments, thereby leading to structural failure (see the Land Hazards Profile).

In Maryland, most dams consist of an earthen embankment to retain water and a combination of spillways designed to convey water safely around or through the facility. The Baltimore City Department of Public Works owns and maintains the seven Public Works dams around the City. All of the City's dams are earthen (one is earthen with rockfill), and all but one is considered off-stream dams. The National Inventory of Dams, a database maintained by the U.S. Army Corps of Engineers, classifies one of the seven dams as being low hazard, one as presenting a significant hazard, and five as high hazard. Dams with a low hazard potential are those where failure or improper operation would result in no probable loss of human life and low economic or environmental losses. Dams with a significant hazard potential are those where failure or improper operation would result in no probable loss of human life, but could cause economic loss, environmental damage, disruption of lifeline facilities, or other impacts. Dams with a high hazard potential are those where failure or improper operation will likely cause loss of human life. Table 8 details the names, associated waterways, and hazard potential classification for all of the dams found within, or used and maintained by, Baltimore City. All Baltimore City dams classified as having a high hazard potential have corresponding Emergency Action Plans (EAPs).

Table 9: Baltimore County Dams by Waterway and Hazard Potential

Dam Name	Waterway	Hazard Potential Classification	Emergency Action Plan
Druid Hill Lake	Offstream-Jones Falls	H	X
Guilford Reservoir	Offstream-Stony Run	H	X
Hillen Road Water Supply Lake	Offstream-Herring Run	H	X
Lake Ashburton	Gwynns Run	H	X
Lake Montebello	Offstream-Herring Run	S	
Lake Roland Dam	Jones Falls	H	X
Liberty Dam	North Branch, Patapsco River	H	X
Loch Raven Dam	Gunpowder River	H	X
Montebello Waste Water Lake	Offstream-TR-Herring Run	L	
Old Loch Raven Dam	Gunpowder River	L	
Pecks Branch Dam (Ashburton)	Offstream-Gwynns Run	H	X
Prettyboy Dam	Gunpowder Falls	H	X
Pikesville Reservoir	Offstream–Gwynns Falls	H	X
Mays Chapel Reservoir	Offstream–Jones Falls	H	X
Towson Reservoir	Offstream–Jones Falls	H	X

National Inventory of Dams, http://crunch.tec.army.mil/nid/webpages/nid.cfm and Hal Van Aller, P.E. of MDE Dam Safety Division

Coastal Hazards

Tropical Storms and Hurricanes

Tropical storms and hurricanes are very intense, low-pressure wind systems that form over tropical or sub-tropical waters. Both tropical storms and hurricanes are considered tropical cyclones; the distinction is based on wind speeds and, typically, on the amount of destruction produced (i.e., the "impact"). Tropical storms are given a name when the maximum sustained wind speeds within the storm's eyewall reach or exceed 39 mph. If a tropical storm continues to grow in strength, and peak wind speeds reach 74 mph, it is then declared a hurricane.

The Saffir-Simpson Hurricane Intensity Scale categorizes intensities of hurricanes based on the hurricane's sustained wind speed. Higher wind speeds increase storm surge. A storm surge, one of the most damaging impacts of a coastal storm event, is an abnormal local rise in sea level, caused by deepening low pressure in the core of the storm that creates an extreme difference in barometric pressure between the tropical system and the atmospheric environment outside the system. As a result, a dome of water rises under the eye of the storm and is eventually pushed onto the coastline as the storm makes landfall. The height of a surge is measured as the deviation (in feet) above average sea level. In extreme circumstances, storm surge has exceeded a height of 25 feet in other areas around the world. The Sea, Lake and Overland Surges from Hurricanes (SLOSH) model is the computer model utilized by the National Oceanic and Atmospheric Administration (NOAA) for coastal

inundation risk assessment and the operational prediction of storm surge. Storm surge is especially damaging due to the combination of a high volume of water covering a large geographic area that is moving towards land at a high velocity. According to NOAA, 9 out of every 10 deaths associated with coastal storms are caused by storm surge—demonstrating why this water phenomenon is often the greatest threat to life and property from a tropical system. Storm surge may also accompany significant coastal storms that are known along the east coast as "Nor'easters." (For a discussion of hazards associated with Nor'easters, see the Winter Storms and Climate Influences section below).

Coastal storm systems can persist for extended periods of time, and cross great distances. As hurricanes are sometimes hundreds of miles across, their effects can be felt in areas that may be quite distant from the storm's center. Hurricane Agnes in 1972, for example, did not pass directly over Baltimore, but it is considered to be one of the most damaging hurricanes in Baltimore's history. At impact, Agnes was a Category 1 hurricane. Baltimore experienced widespread flash flooding and considerable riverine flooding. The State of Maryland reported 21 storm-related deaths and a total public-sector cost in excess of $110 million. In 2003, the Category 2 Tropical Cyclone Isabel hit the region. In Baltimore City, Isabel's cost to the public sector totaled $4,883,364. Fifteen commercial properties and more than 570 homes were declared uninhabitable due to Isabel's major flood damage, while approximately 100 structural collapses occurred throughout the county. As an additional hazard, tropical storms and hurricanes are capable of spawning tornados. For example, in 1979, Tropical Storm David spawned 8 tornados in Maryland. Similarly, Hurricane Irene produced tornados near the Eastern Shore of Maryland.

As hurricanes and tropical storms near land, they may generate torrential rains, high winds, storm surge inundation, coastal flooding, and inland flooding. Hurricanes can also produce difficult-to-predict tornadoes within embedded rain bands (for a description of tornado hazards, see the Wind Hazard Profile). Depending on where a tropical system makes first landfall, coastal storms can lead to dangerous storm surges and inundation of low-lying land. In Baltimore, hurricanes and tropical storms have produced wind damage, riverine flooding along tributaries, and inundation of shorelines and harbors by way of intense storm surges.

Due to a combination of geographic and climatic factors, major hurricanes of Categories 3 and above generally begin to weaken upon reaching the Mid-Atlantic. Prior to making landfall, a storm may have much faster wind speeds—and may be classified as one or more categories higher—than what is recorded once the storm makes landfall. Camille's wind speeds, for example, in 1969, dropped from 165 mph to just 25 mph when passing over Baltimore. Recent hurricanes and tropical storm impacts to Baltimore have included minor flooding from heavy rainfall and winds. The eight storm events that affected Baltimore from 2013 to 2017 are listed in Table 10.

Table 10: Baltimore City Recent Hurricanes and Tropical Storms

Date	Storm Event Name	Storm Event Narrative
June 7, 2013	Tropical Storm Andrea	Caused minor flooding in the Baltimore-Washington Area. Total rainfall just over 2 inches resulting from post tropical storm system.
Oct. 9-12, 2013	Tropical Storm Karen	Heavy rainfall across the State of Maryland.
June 20, 2015	Tropical Storm Bill	Heavy rainfall, thunderstorms, and gusty winds to the State of Maryland.
Sept. 19-22, 2016	Tropical Storm Julia	Cold front and rain across the State of Maryland.
Oct. 8-9, 2016	Hurricane Matthew	Hurricane Matthew did not make landfall, but the large storm brought heavy rainfall and gusty winds to the State of Maryland.
June 23-24, 2017	Remnants of Tropical Storm Cindy	The storm brought heavy rainfall to the entire State of Maryland.
Sept. 2, 2017	Hurricane Harvey	The storm brought heavy rain, thunderstorms, and gusty winds across the State of Maryland.
Oct. 21, 2017	Tropical Storm Phillipe	The storm brought heavy rain and winds to the State of Maryland.

Source: National Weather Service

A notable historic hurricane, Hurricane Isabel, brought Baltimore its worst flooding from storm surge in 70 years. The storm tide ran 8 feet above normal in 2003.

Figure 7: Snapshot of Hurricane Isabel Impacts (2003)

Hurricane Isabel put bikes and cars out of commission when its storm surge flooded Baltimore's Fells Point and Inner Harbor in 2003. *Source: Maximillian Franz/The Daily Record*

Excerpt from Chesapeake Quarterly-October 2102

The Perfect Surge: Blowing Baltimore Away, by Michael W. Fincham

According to Ming Li, an oceanographer from University of Maryland Center for Environmental Science, if sea level rise projections prove true then every surge, slosh, and high-tide long wave would be magnified—but in a non-linear way. It's not a case of simple addition, says Ming Li, the oceanographer who's building models to answer questions like this. Consider the effect on storm surge. According to Li's calculations, if sea level rises 2.1 feet, you add an additional 20 percent to get the actual increase—2.5 feet—in the size of the storm surge. The 8.3-foot storm tide from Hurricane Isabel grows to a 10.8 foot, a one-story tide that could swamp Fells Point (again), flood the Inner Harbor, and invade parts of the downtown business district.

But the surge from the next Isabel could be larger still. What if the surge from the next Isabel is moving in sync with the long wave and the big slosh and perhaps the rare, low-pressure Proudman effect? As the Bay narrows, the surge grows taller, friction grows smaller, the surge moves faster. And one big bulls-eye would be Baltimore.

Storm surge from hurricanes, high tides, and sea level rise all contribute to coastal hazard risk. Any one of these hazards is problematic; however, together these hazards pose a considerable risk of more severe impacts in the future.

Table 11 indicates that the annualized rate of occurrence using data spanning from 1999 to 2017 is 0.68 percent.

Table 11: Coastal Hazards (Storm Surge/ Tide and Coastal Flood) 1999-2017

County/City	Total Events	Annualized Events
Baltimore City	13	0.68

Source: National Centers for Environmental Information (NCEI)

Sea Level Change

For a number of reasons—including climate change and an increase in global temperature—the world's sea levels have been rising over the past 100 years. In Baltimore, NOAA sea level gauges at Fort McHenry, as well as other official reports, have shown that relative sea level in the Harbor area has increased by 12 inches since 1900. The most current sea level data from the Maryland State Climate Change Commission and from the Intergovernmental Panel on Climate Change indicate that sea levels in the Baltimore region could experience an additional rise of 1.5 to 3 feet in the next 50 years. Approximately 1.33 percent of Baltimore City's land is within the projected sea level rise zone.[15]

Projections for global increases in sea level range from less than 1 foot for lower emissions scenarios to as much as 1.6 feet for higher emissions scenarios by the middle of the century. By 2100, these projections swell to between 1.7 and 4.6 feet. In Maryland, relative sea-level rise projections range from 0.9 to 2.1 feet by 2050 and 2.1 to 5.7 feet by 2100.[16] In fact, recent findings reveal that sea level rise is accelerating faster than previously projected due to rapid polar ice sheet melting. In particular, sea level rise has also been greater than anticipated along Mid-Atlantic coastlines, where the waters rise as the flow of the Gulf Stream slows.[17]

Although relative seal level rise is a gradual process, Baltimore City may still experience acute impacts in the near term. Some examples include increased frequency of low-level inundation, storm-exacerbated floodwater rise that coincide with high tides or astronomical-influenced tides, increasing rates of coastal erosion in non-bulk-headed areas, and increased saltwater intrusion into underground utilities and infrastructure. Furthermore, scientists recommend planning for the higher range of projection values, to take into account-increased risks associated with flooding during storms.

When the temporal factor of sea level rise is coupled with the relative increase in land subsidence, the potential for tropical systems to cause extreme tidal flooding will increase. Baltimore's waterfront is densely developed and will continue to have development pressure for the foreseeable future. Coastal storm surges may be amplified by sea level rise, creating a greater threat. This will impact current and future shoreline development. The impacts of rising sea level on Baltimore City will continue to present significant short- and long-term challenges to its waterfront communities.

Figure 8: Projected Storm Surge Flooding in Baltimore's Inner Harbor

Storm surge potential with Sea Level Rise for Category 1 (blue), Category 2 (green), Category 3 (yellow), and Category 4 (red) hurricanes in the Baltimore Inner Harbor. *Source: USACE Storm Surge Modeling*

Tsunamis

While the focus of hazard identification and mitigation planning in this document has centered on atmospheric- and surface-related natural hazards, recent oceanic events have introduced new concerns regarding the potential vulnerability of coastal areas such as Baltimore to unusual hazards such as

tsunamis. This section summarizes the existing analysis regarding tsunami risk, presented in the 2011 Maryland State HMP, and discusses recent scientific research on potential risks and causes of East Coast tsunami events.

As stated in the 2011 Maryland State Hazard Mitigation Plan (HMP), "A tsunami is a series of sea waves caused by the displacement of a large volume or body of water. Tsunamis may result from local or distant large-scale seafloor displacement, including seismic activity, volcanic activity or landslides that generate uplift or drop in the ocean floor."[18] In Maryland's 2016 HMP, the tsunami hazard was not included due to the low probability of this hazard impacting Maryland. The State of Maryland followed the Emergency Management Accreditation Program (EMAP) process while updating the HMP. Under the EMAP process, all hazards identified in the HMP must be thoroughly analyzed in totality; this does not account for the hazard risk rating process within the FEMA hazard mitigation planning requirements, which prioritizes hazards to determine both risk and vulnerability. Completing this planning and prioritization process results in the development of mitigation strategies that meet a benefit-cost analysis. Baltimore has identified the tsunami hazard; however, the risk ranking for this hazard in Baltimore is "low."

> "Waves travel in all directions from the originating tsunami sources, building in height as the wave approaches the shore. The topography and geometry of the coastline, wave direction or path, and offshore topography influence the run-up (or terminal height) of the wave and therefore potential for damage." – NOAA West Coast/Alaska Tsunami Warning (June 13, 2013)

While tsunamis resulting from two of the three primary causes are generally considered extremely low-probability events, the 2011 Maryland HMP discussed a particular scenario that could present a significant long-term tsunami hazard to Baltimore, as well as including this hazard in the "no-notice" category with derechos and other severe weather events.

A rare event was reported in local media and later examined closely by NOAA meteorologists and other scientists. NOAA later classified the event as a "meteo-tsunami" in a July 2013 report, stating:

> Tsunami-like waves were observed along the US east coast during the afternoon of Thursday, June 13, 2013. Over 30 tide gages recorded the fluctuations with impacts noted along the New Jersey shore and in Massachusetts. In Barnegat Light, NJ, at least two people were swept off a breakwater and required medical treatment. The NOAA meteorologist from the JPWTS reported in the official account that "the event occurred in close conjunction with a strong weather system moving from west to east off the New Jersey coast which is labeled by the NWS as a low-end derecho."[19]

While a tsunami is traditionally caused by geological forces such as undersea landslides, earthquakes, volcanoes or other seismic influences, this occurrence could be considered an example of a "geo-atmospheric" event that, upon closer investigation, could present a new hazard planning concern for vulnerable high-population areas such as Baltimore City and surrounding areas. This potential new hazard is being considered by the Disaster Preparedness and Planning Project Committee to study the following concerns:

- A "meteo-tsunami" or similar wave-event could occur in the Chesapeake Bay at a critical time when large numbers of people are assembled near the water;

- Policy-makers and infrastructure planners may need to make considerations for additional resiliency to no-notice coastal flooding in new construction as part of ongoing coastal hazard mitigation strategies; and
- Geological research suggests that many areas of the continental shelf in proximity to the mouth of the Chesapeake may contain at-risk regions, which can produce undersea landslides.

The 2011 Maryland HMP lists and overview of historical tsunami events in the Atlantic Ocean basin that affected the U.S. east coast, including the Mid-Atlantic region:

- Earthquakes in the Azores-Gibraltar convergence zone (e.g., Lisbon earthquake in 1755);
- Earthquakes along the Hispaniola-Puerto Rico-Lesser Antilles (Caribbean) subduction zone, in and around the Puerto Rico Trench or near the Leeward Islands;
- Large mass failure event, including the potential flank collapse of the Cumbre Vieja;
- Volcano in the Canary Islands; and
- Landslide tsunamis caused by Submarine Mass Failures (SMF) triggered along the East Coast continental slope by moderate seismic activity. Significant geological and historical evidence (e.g., the 1929 Grand Bank landslide tsunami and the Currituck Slide off North Carolina and Virginia) suggests that SMF tsunamis pose the most significant tsunami hazard to the upper east coast, triggered on the continental slope by moderate seismic activity (magnitude 6.0 to 7.5).

Given the existing vulnerabilities of Baltimore City's coastal infrastructure and vulnerable populations, the tsunami hazard was included to provide an overview and context.

Precipitation Variability

The amount of precipitation that falls over an area will vary significantly as global temperatures increase. Precipitation events are likely to increase in magnitude in Baltimore City, leading to increased flash flooding. Among the many harmful effects of climate change, increased stormwater runoff and demand for stormwater management are anticipated to be some of the greatest challenges facing cities.[20] Climate projections for the State of Maryland predict that the average annual precipitation will increase 5-12 percent by the end of the century.[21] In Baltimore, studies suggest that precipitation could increase by as much as 227mm each year by the middle of the century.[22] At the same time, the northeast region is expected to experience more frequent heavy precipitation events where more than 2 inches of rain falls within a 48-hour time period. The intensity of heavy precipitation events is projected to increase by 12-15 percent.[23] Precipitation hazards, specifically for winter storms, were ranked as high-risk with the 2018 HIRA, shown in Table 6. Public survey results indicate that extreme precipitation is very concerning.

Most of Maryland's precipitation falls in the summer months, but winter precipitation is expected to rise, and the form of this precipitation is likely to be altered. While temperatures increase, more rain will fall in Maryland's winter months, with a projected 50-percent decrease in snow volume by the end of the century.[24] As precipitation frequency and intensity increase, Baltimore will be more vulnerable to flash flooding events. Heavy precipitation may, at times, be conveyed through what scientists refer to as "atmospheric rivers." These channels carry immense quantities of water across the planet and contribute to the intensity of heavy precipitation events. Atmospheric rivers may cause both

rainstorms and snowstorms. For instance, an atmospheric river was responsible for the "Snowmageddon" event that hit Baltimore in 2010.[25] Even more alarming, atmospheric rivers are likely to become stronger due to a warming planet and higher saturation levels of water vapor in the atmosphere. This increase could lead to an increase in both the severity and the frequency of rain and snowfall, and it could contribute to significant flooding and other damage.

Thunderstorms

When atmospheric conditions combine to provide moisture, lift, and warm unstable air that elevates rapidly, a thunderstorm is formed. Thunderstorms can occur at any time of day and in all months of the year, but they are most common during summer afternoons or evenings and in combination with frontal boundaries. Maryland experiences approximately 20-40 thunderstorm days per year, and they occur frequently in Baltimore. Thunderstorms are considered a significant hazard due to their ability to spawn tornadoes, hailstorms, strong winds, flash floods, and damaging lightning. Significant lightning and hail events in Baltimore, as reported in Table 12, have resulted in at least two deaths. On June 9, 2018, multiple people were struck by lightning, according to a Baltimore Patch news article by Elizabeth Janney, updated on June 11, 2018. Two children and one adult were struck by lightning near the tennis courts at Patterson Park, near the 200 block of South Linwood Avenue. The article included information from NOAA's National Severe Storms laboratory indicating that the odds of being struck by lightning in one's lifetime are 1 in 13,000. Damages have resulted from hail events in Baltimore, particularly from hail sized as one inch or more (Table 13).

Table 12: Thunderstorm (Lightening and Hail) 1957-2017

County/City	Total Events	Total Injuries	Total Deaths
Baltimore City	22	4	2

Source: National Centers for Environmental Information (NCEI), Baltimore Patch, 2018 Associated Press

Severe thunderstorms have varied characteristics and can inflict considerable damage. The National Weather Service classifies a thunderstorm as severe if it produces hail that measures at least 1 inch in diameter, winds of 58 mph or greater, or a tornado. Thunderstorms affect a smaller area than winter storms or hurricanes, but for a number of reasons can be dangerous and destructive. Storms can form in less than 30 minutes, giving very little warning, and can cause considerable damage. Baltimore has also recorded damages from hail events, in particular from hail 1 inch or more in diameter.

Table 13: Significant Hail Events 1957-2017

Date	Time	Size (Inches)
8/1/1963	16:00:00	1
6/18/1970	16:10:00	4.5
5/25/1979	18:10:00	1.75
4/24/1991	11:30:00	1
4/24/1991	11:52:00	1
6/2/1998	17:29:00	1.75
7/30/1999	18:50:00	1.75
5/13/2000	14:40:00	1
7/14/2000	16:15:00	1.75
5/2/2002	14:10:00	1
5/13/2002	13:35:00	1
7/10/2007	11:45:00	1
8/14/2012	20:07:00	1
5/8/2013	14:54:00	1
6/18/2014	23:47:00	1.25

Source: National Centers for Environmental Information (NCEI)

Winter Storms and Climate Influences

Winter storms produce more than just snow. Winter weather can take many forms, including freezing rain, sleet, extreme cold, and high winds. These conditions may occur singly or in any combination. Freezing rain is rain that falls onto a surface where the temperature is below freezing, causing the rain to form a coating of ice. Sleet occurs when raindrops freeze into ice pellets in the cold air before reaching the ground. Like snow, freezing rain and sleet can create hazardous conditions for motorists. Even small accumulations of ice can make walking or driving extremely dangerous. Moreover, significant accumulations of ice can fell trees and utility lines, resulting in loss of power and communication.

Regarding winter weather projections, the noticeable uptick in major winter storm events in Baltimore since 1996 has been compared to the relatively snowy periods in the 1950s and 1960s. This suggests that although climate change has influenced average temperatures, it is also possible that the Baltimore region could experience increased precipitation in the form of snowfall due to increased moisture content driven by rising evaporation from warmer bodies of water. An April 2013 journal article from the Bulletin of the American Meteorological Society, titled Monitoring and Understanding Trends in Extreme Storms, noted that "observed increases in extreme precipitation are 'consistent with the observed increases in atmospheric water vapor, which have been associated with human-induced increases in greenhouse gases." The article also points to findings relevant to concerns for Baltimore City's unique weather in recent years that "while the role of water vapor as a primary cause for the increase in extreme precipitation events is compelling, the possibility of changes in the characteristics of meteorological systems cannot be ruled out. There may also be regional influences from the temporal redistribution of the number of El Niño events versus La Niña events and from land use changes." Tables 14 and 15 list severe winter storm events in Baltimore. The public- sector cost of a blizzard in 1996, for instance, totaled $20 million in Maryland. Winter storm warnings are issued when

snowfall is expected to accumulate more than 4 inches within 12 hours, or when a quarter of an inch or more of freezing rain will accumulate. Severe winter storms can significantly slow traffic, decrease commercial activity, lead to power outages, disrupt communications, and even force vulnerable buildings to collapse.

Table 14: Significant Winter Storms in Baltimore

Date	Snow & Ice (Inches)
March 15-18, 1892	16.0 inches
February 12-14, 1899	21.3 inches
February 16-18, 1900	12.0 inches
January 27-29, 1922	26.5 inches
March 29-30, 1942	22.0 inches
February 15-16, 1958	15.5 inches
December 11-12, 1960	14.1 inches
March 5-7, 1962	13.0 inches
January 30-31, 1966	12.1 inches
February 18-19, 1979	20.0 inches
February 11-12, 1983	22.8 inches
January 22, 1987	12.3 inches
January 7-9, 1996	26.6 inches
January 25, 2000	14.9 inches
February 16-18, 2003	26.8 inches
December 18, 2009	18 Inches
February 5-6, 2010	25-29 Inches
February 9-10, 2010	19.5 inches
February 12-14, 2014	15 inches
January 22 – 24, 2016	27 inches

National Weather Service, www.nws.noaa.gov/er/lwx/winter/storm%2Dpr.htm & National Centers for Environmental Information (NCEI)

While winter storms are expected in Baltimore and the City budgets and prepares for snow removal activities each year, winter storms occasionally reach a magnitude that overwhelms local response efforts. This may place stress on the transportation system, as roads are unable to be efficiently salted or plowed, or on the electrical infrastructure. As a result of a 1994 ice and sleet storm, for example, the City of Baltimore experienced power and phone line outages, as well as rolling blackouts, due to increased use of electricity and natural gas. Some residents were left without power or heat for nearly 2 weeks.

Table 15: Significant Winter Storms and Freezes

Date of Storm	Storm Type	Severity of Impact	Damages Reported	Recovery Time	Public Sector Cost	Historical Elements or Facilities Impacted
2/11/1983	Snow Storm	22.8 inches				
2/10/1994	Ice and Sleet	3 inches of freezing rain/ice -28-degree wind chills 40+MPH wind		People without power and heat for nearly 2 weeks		
1/8/1996	Blizzard of '96	26.6 inches			$20 million in Maryland	
1/25/2000	Severe Winter Storm	14.9 inches	Rolling blackouts due to increased use of electricity and natural gas; tree loss due to heavy ice; power and phone line outages; Car accidents			
2/15-18/2003	Severe snowfall	28.2 inches			$3,000,000	Roof collapse of B&O Railroad Museum
2/11-12/2006	Snow Storm	13.1 inches	62,000+ People Lost Power			
12/18/2009	Snow Storm	18 inches			$2,191,670 (Baltimore)	
2/5/2010	Severe winter storm	25.0 inches	34,000 BGE Customers without power (region		$34,783,976 (Baltimore)	Harbor Hospital, Oldtown Station, BPD Southern District, Stratford water pump station lost power
2/9/2010	Severe winter storm	19.5 inches				
1/26/2011	Snow Storm	9.8 inches				3800 E. Biddle (garage), 6400 Pulaski Hwy (plow shop), 239N. Calverton (substation)
2/12-14/2014	Winter Storm	15 inches	Car accidents; JFX gridlocked; vehicles abandoned on			

Date of Storm	Storm Type	Severity of Impact	Damages Reported	Recovery Time	Public Sector Cost	Historical Elements or Facilities Impacted
			roadways; 122,000 BGE customers without power			
1/22-24/2016	Winter Storm	25 inches				

Source: National Centers for Environmental Information (NCEI)

Over the past decade, Baltimore City has experienced several strong winter storms that disrupted regular activities and caused a number of automobile accidents and power outages. Climate averages for Baltimore denote 21.1 inches of snowfall in any given year. Years that bring several winter storms, frequent episodes of disruptive precipitation, or extreme cold can tax the energy supply, raising the cost of heating homes, businesses and public facilities. In 2010, two severe winter storms took place just days apart. Following the 25 inches of snow that had fallen on February 5, a second snowstorm on February 9 brought an additional 19.5 inches of snow, negatively impacting critical emergency facilities. The public-sector cost for these two storms totaled nearly $35 million for the City of Baltimore alone. More recently, Winter Storm Jonas brought 25 inches to Baltimore in January 2016.

FEMA-4261-DR

Severe Winter Storm and Snowstorm
Winter Storm Jonas-January 2016

Snowfall measurements by jurisdiction, according to the National Weather Service recording stations reported 25" in Baltimore City. Impacts included power outages, road closures, and numerous motor vehicle accidents.

While major snow and ice storms may appear to be on the rise in the short term, according to the Intergovernmental Panel on Climate Change 2014 Fifth Assessment Report (AR4), one factor which may be driving this observation is a decrease in global snow and ice cover. The IPCC noted in the AR4 that "observations show a global-scale decline of snow and ice over many years, especially since 1980 and increasing during the past decade, despite growth in some places and little change in others."[26] While "most mountain glaciers are getting smaller, and snow cover is retreating earlier in the spring, sea ice in the Arctic is shrinking in all seasons, most dramatically in summer."[27] The report notes that important coastal regions of the ice sheets are thinning in places like Greenland and West Antarctica. This thinning contributed to a sea level rise of at least 1.2mm globally in the 10-year period from 1993 to 2003.

For Baltimore, the contrasting reduction in snow cover and sea ice has been identified as an influential factor in altering weather patterns over the Northern Hemisphere. This climate contrast has produced extreme cold and snow in some regions—such as central and northern Europe in 2012 and 2013—while leaving other regions, including the U.S. mid-Atlantic, with highly variable snowfall and winter temperatures from year to year. As average annual temperatures increase overall, winter temperatures

will likewise become warmer. While winter temperatures have increased only slightly in Baltimore in recent decades, temperatures are projected to increase 4-7°F by 2025. Carrying this projection forward, winter temperatures could be an estimated 7.4-10.6°F warmer by the end of the century.[28] For this reason, and due to high fluctuations in winter weather impacts, many eastern U.S. cities, including Baltimore, are actively preparing for winter extremes.

Winter storms may also significantly disrupt the ability of Baltimore residents to complete their daily routines. Populations who are less mobile, or who have chronic illnesses or age-related limitations, are most vulnerable. For these residents, snow and ice pose additional health hazards, including heart attacks from the physical exertion of clearing a sidewalk of snow, inability to access vital medical services, or being trapped indoors.

Nor'easters

Some of the most significant winter storms that affect Maryland are known as "Nor'easters" because they are accompanied by strong northeast winds. These storms often form in the Gulf of Mexico, intensify, and then move up the East Coast. High-pressure systems over the Maritime Provinces of Canada deliver the cold air to Nor'easters that result in winter precipitation. The cold air flowing from the north forms what actually looks like a wedge, bounded on the west by the mountains of Washington and Allegany Counties and by warmer winds coming off the Atlantic Ocean on the east. Meteorologists call this the "cold air dam" or "the damming effect." Moist air coming from the south flows up over this dam, producing heavy winter precipitation.

Often, the heaviest snow with a Nor'easter occurs in a 50- to 100-mile-wide band, usually setting up over the central or eastern areas of Maryland. Precipitation along this band typically changes from snow in the west, to a transition area of freezing rain and sleet, then finally to rain in the east. Areas receiving mostly snowfall can experience totals of greater than a foot of precipitation. In the most intense Nor'easters, thunder and lightning may also be observed. The distribution, intensity and type of precipitation associated with Nor'easters are highly dependent on the track of the center of the storm system. A system that tracks nearest the coast is more likely to produce rain along the coast and snowfall further inland. A system that tracks a bit further out to sea is more likely to produce mostly snowfall even along the coast.

Table 16: Winter Storms and Nor'easter (Winter Weather, Winter Storm, Ice Storm, Blizzard, Heavy Snow, Frost/Freeze and Cold/Wind Chill) 1996-2017

County/City	Total Events	Total Injuries	Total Deaths
Baltimore City	162	20	3

Source: National Centers for Environmental Information (NCEI)

Winter storms can also be life threatening as shown in Table 16.

Drought

Droughts are extended periods of dry weather, caused by a natural reduction in the amount of precipitation over an extended period. Droughts may be classified as meteorological, hydrologic, agricultural, or socioeconomic events Table 17 presents definitions for these types of droughts:

Table 17: Drought Classification Definitions

Type	Definition
Meteorological	The degree of dryness or departure of actual precipitation from an expected average or normal amount based on monthly, seasonal, or annual time scales.
Hydrologic	The effects of precipitation shortfalls on stream flows and reservoir, lake, and groundwater levels.
Agricultural	Soil moisture deficiencies relative to water demands of plant life, usually crops
Socioeconomic	The effect of demands for water exceeding the supply as a result of a weather-related supply shortfall.

Meteorological and hydrologic droughts are natural hazards that present major threats to the City and regional water supply. Such droughts may ultimately evolve into socioeconomic droughts in which the City's ability to deliver water to residents or businesses becomes limited. Additionally, Baltimore provides public water to areas outside of the City's boundaries; therefore, a drought may greatly diminish the water supplies that are available not only to the City of Baltimore, but also to the surrounding counties.

Droughts may vary greatly in their extent, duration, severity, and impact. Drought conditions may be heightened due to human activities, high temperatures, high winds, and low humidity. To mitigate the intensity of a drought's effects, the City may be forced to impose water-rationing requirements on households. This form of restriction has only been applied once in recent years; however, limits on car washing or other commercial/institutional uses have been more common. Such restrictions can have a negative economic impact on water-dependent businesses. During a prolonged drought event, land values can decrease, unemployment can increase, and certain industries or individuals may be impacted more than others. The agriculture industry, for instance, generally experiences the first and harshest effects of droughts (for a more detailed discussion about agriculture, see Extreme Heat Hazard Profile).

A list of significant Maryland droughts is presented in Table 18. For each dry period, the table lists the region that was affected and the economic cost for three of the events. A drought recurrence interval is the average amount of time a streamflow would be lower than usual during a drought event. The U.S. Geological Survey (USGS) can determine annual departures from average streamflow and assign recurrence intervals to each drought. For Baltimore, the USGS identified five regional droughts that had a significant extent and duration: (1) 1930 to 1932; (2) 1953 to 1956; (3) 1958 to 1971; (4) 1980 to 1983; and (5) 1984 to 1988. The drought from 1930 to 1932 was likely the most severe agricultural drought ever recorded in Maryland. Rainfall during that period was approximately 40 percent less than average, and 1930 was the driest year recorded since 1869. Total cost of crop losses during 1930 were estimated at $40 million in the region.[29]

Since 1930, droughts have occurred about once every 10 years, with mixed severity and duration. Recurrence intervals during the 1953-1956 drought had generally been 10 to 25 years—except for areas north and east of Baltimore, where recurrence intervals were less than 10 years. From 1958 through 1971, a 13-year regional drought with recurrence intervals greater than 25 years caused severe

streamflow deficiencies throughout Maryland. Greatly exceeding regional losses during the 1930 drought, the 1986-1988 drought accounted for an estimated loss of $302 million.

Table 18: Historical Droughts in Maryland

Dates	Area Affected	Economic Cost
1930-1932	Regional	$40,000,000 in crop losses (1930)
1953-1956	Regional	
1958-1971	Regional	
1980-1983	Multi-State	
1984-1988	East MD	$302,000,000 in estimated agricultural losses (1986-1988)
1998	Regional	$20.040 M crop damage
1999	Regional	
2002	Central MD	
2007	Regional	

Source: U.S. Geological Survey & National Centers for Environmental Information (NCEI)

While long-term or water-supply droughts—where rainfall deficits of more than 14 inches persist for 2 years or more—currently occur less than 4 percent of the time in Maryland, that percentage is expected to increase to approximately 5 percent by the end of the century. Furthermore, the duration of annual dry spells in Maryland is projected to increase from the current average of 15 days to as many as 17 days.[30]

Wind

Wind is the motion of air past a given point, caused by differences in pressure from one place to another. Wind poses a threat to Maryland in many forms, including winds that are produced by severe thunderstorms and tropical weather systems. The effects of wind can include blowing debris, interruptions in elevated power and communications utilities, and intensified effects of winter weather. Harm to people and animals, as well as damage to property and infrastructure, may result.

In the mainland United States, the mean annual wind speed is reported to be 8–12 mph, with frequent speeds of 50 mph and occasional wind speeds greater than 70 mph. In coastal areas from Texas to Maine, tropical cyclone winds may exceed 100- mph. In the mid-Atlantic, high wind speeds are generally produced by severe thunderstorms and tropical storms/hurricanes. The most severe windstorms may produce tornadoes.[31]

Windstorms also have the capacity to cause considerable personal and property damage. Data records indicate 156 high wind events took place between 1956 and 2017. Table 19 shows that these events resulted in a combined 29 injuries and 1 death. Additionally, total recorded property damage exceeded $8 million, with an average of nearly $135,000 in damage for each event, as shown in Table 20.

Table 19: Thunderstorm Wind, High Wind and Strong Wind 1956-2017

County/City	Total Events	Total Injuries	Total Deaths
Baltimore City	156	29	1

Source: National Centers for Environmental Information (NCEI)

Destruction of trees and other vegetation may produce secondary damage to structures and power lines, or block roadways and storm drainage systems. For instance, downed trees may topple power lines or cause property damage. Finally, minor structural damage to shingles, gutters, etc. may also result from wind events.

Table 20: Wind (Thunderstorm Wind, High Wind, Strong Wind) Crop and Property Damages 1957-2017

Property Damage (Total)	Property Damage (Annualized)	Crop Damage (Total)	Crop Damage (Annualized)	Total Damage	Total Damage (Annualized)
$8,261,050	$135,427	$2,000	$32	$8,263,050	$135,459

Source: National Centers for Environmental Information (NCEI)

Tornado

A tornado is a violent atmospheric disturbance characterized by one or more twisting and funnel-shaped columns, extending from a thunderstorm cloud toward the ground. Tornadoes can touch the ground with winds over 300 mph. While relatively short-lived, tornadoes are intensely focused and are one of nature's most violent storms. Tornadoes are measured according to their wind speed on the Fujita Scale (EF-Scale). Revised in January 2007, the Enhanced Fujita Scale, illustrated in Table 21, ranges from an EF0 to an EF5. The strongest tornadoes ever observed have produced winds over 200 mph. Different wind speeds may cause similar-looking damage from place to place and from building to building.

Table 21: Enhanced Fujita Tornado Intensity Scale

Category	Wind Speed	Examples of Possible Damage
EF0	Gale Tornado (65–85 mph)	Light damage. Some damage to chimneys; break branches off trees; push over shallow-rooted trees; damage to sign boards.
EF1	Moderate Tornado (86–110 mph)	Moderate damage. The lower limit is the beginning of hurricane wind speed; peel surface off roofs; mobile homes pushed off foundations or overturned; moving autos pushed off roads.
EF2	Significant Tornado (111–135 mph)	Considerable damage. Roofs torn off frame houses; mobile homes demolished; boxcars pushed over; large trees snapped or uprooted; light-object missiles generated.
EF3	Severe Tornado (136–165 mph)	Severe damage. Roofs and some walls torn off well-constructed houses; trains overturned; most trees in forest uprooted; cars lifted off ground and thrown.
EF4	Devastating Tornado (166–200 mph)	Devastating damage. Well-constructed houses leveled; structure with weak foundation blown some distance; cars thrown, and large missiles generated.
EF5	Incredible Tornado (over 200 mph)	Incredible damage. Strong frame houses lifted off foundations and carried considerable distance to disintegrate; automobile-sized missiles fly through the air in excess of 100 yards; trees debarked; incredible phenomena will occur.

Source: The Enhanced Fujita Scale (National Weather Service). http://www.crh.noaa.gov/arx/efscale.php

Tornado season is generally noted to last from March through August—although tornadoes may occur at any time of the year—and more than 80 percent of tornado strikes happen between noon and midnight. Tornadoes are known to destroy almost everything in their path. Depending on the intensity and size of the tornado, damage may be as minor as a few broken tree limbs and downed power lines, or as devastating as the destruction of houses, businesses, and community vitality. Nationwide, tornadoes account for an average of 70 fatalities and 1,500 injuries each year. From events reported between 1950 and 2010, tornados in Baltimore produced a total of $203,617 in reported property damage, or $3,338 annually (Table 22).

To date, the highest intensity tornado experienced in the Baltimore region has been an EF2. One such event on June 16, 1973, injured four people in the Towson area. In October 1990, another EF2 tornado injured 59 Reisterstown residents. Less than 20 minutes later, this tornado was followed by a less powerful, F1 tornado. A more in-depth collection of significant tornado events in the Baltimore Region is listed in Table 23.

Table 22: Tornado Property Damage in Baltimore

Property Damage (Total)	Property Damage (Annualized)
$203,617	$3,338

Source: Table 373, Maryland Emergency Management Agency.

Table 23: Significant Tornado Events from 1957-2017

Event number	Date	Time	F/EF Scale	Injuries	Fatalities	$ Loss (Millions)
624	8/12/1957	13:30:00	0	0	0	0
249	6/11/1958	15:00:00	0	0	0	0
618	7/19/1996	14:30:00	0	0	0	0
1200	11/17/2010	0:35:00	3	0	0	0.25

Source: National Centers for Environmental Information (NCEI)

Derecho

Derechos are large thunderstorm clusters that produce widespread, long-lasting winds, which can be extremely damaging. The impact of a derecho is similar to that of a hurricane making landfall, and it can be many miles wide and several hundred miles long. An event may be classified as a derecho if the swath of storms is more than 240 miles long and wind speeds of over 58 mph are maintained for at least 6 hours throughout the entire span of the storm front.

Derechos occur most often in the Midwest and Great Lakes regions during the summer months. In the mid-Atlantic region, derechos are less common, occurring every 2 to 4 years in Maryland. Consequently, residents have typically been less familiar with this type of storm. Recently marked in the memories of many Baltimore residents was the devastation following a June 29, 2012, mid-Atlantic and Midwest derecho. According to the National Weather Service, this storm, which was exceptionally severe for the Baltimore/Washington region, brought gusts of wind between 65 and 75 mph. As a result, numerous overhead electrical units suffered damage, two individuals were electrocuted by downed power lines, and more than 1 million customers across the region were left without power. In some areas, efforts to restore power persisted for more than a week. Additionally, these strong winds disrupted communication with vital emergency response facilities, interrupting 911 services in Northern Virginia. Maryland declared a state of emergency as the National Weather Service Forecast Office of Baltimore/Washington received over 300 early reports of severe damage and continued gathering reports in the weeks that followed. In Baltimore City, public-sector costs of the June 29 storm exceeded $2.5 million. A listing of additional derechos in Maryland is shown in Table 24.

2012 Derecho Impact on the City of Baltimore

Damage from the Mid-Atlantic Derecho was extensive. Many of the City's trees were uprooted or snapped causing widespread power outages. The storm ripped off sections of roofs and many cars were crushed by debris. In some areas, it took nearly 10 days to restore power.

Source: Tree Baltimore and Kim Harris

Table 24: Noteworthy Derechos Impacting Maryland

Date	Description
June 6, 1977	Southern-Mid-Atlantic Derecho
July 4-5, 1980	"The 'More Trees Down' Derecho"
November 20, 1989	"The Mid-Atlantic Low Dew Point Derecho November 1989"
April 9-10, 1991	"The West Virginia Derecho of 1991"
August 4, 2004	n/a
May 21, 2004	n/a
July 10-11, 2011	"The Cross-Country Derecho of July 2011"
June 29-30, 2012	"The Ohio Valley / Mid-Atlantic Derecho of June 2012"

No new events were reported from 2012 to present.
Source: http://www.spc.noaa.gov/misc/AbtDerechos/derechofacts.htm

A number of other hazards may also be associated with derechos—including heat waves, tornados, and flash floods. As derechos occur in the summer months, they may indirectly lead to fatalities if power outages correspond with extreme heat waves. Indeed, this is a significant concern as derechos often appear on the fringe of heat waves due to favorable storm conditions created by extreme shifts in temperature. In the derecho of 2012, for example, Baltimore experienced a record-setting heat wave, where temperatures measured at BWI Airport reached or exceed 90°F for 12 consecutive days.[32] This heat wave began on June 27—2 days prior to the derecho event—and high temperatures endured for more than a week while hundreds of thousands of residents were deprived of power and/or air conditioning.

It should also be noted that the same conditions inducing the formation of a derecho are also favorable for tornados. Furthermore, the immense downpour of precipitation associated with derechos and thunderstorms may lead to instances of flash floods.

Extreme Heat

An extreme heat condition is identified when prolonged temperatures are 10° or more above the average high temperature for a region. In Baltimore's past, between the 1950s and the 1970s, an average of 60 percent of summer days met the maximum temperature extremes. In the 2000s, approximately 75-90 percent of summer days reached the maximum temperature extremes. Studies predict that Baltimore may experience between 85 and 95 percent before the middle of the century, or between 90 and 95 percent by 2100.

These extreme heat predictions may be further evaluated by considering what temperature extremes are being met. Between 1981 and 2010, Baltimore experienced an average of 1.1 days a year with temperatures above 100°F. In 1930, Baltimore endured its longest stretch of 100-degree days, spanning a 4-day period between July 19 and 22. A 3-day stretch was experienced in 2011, between July 21 and 23.[33] Conservative projections for Baltimore City estimate that the average number of days with temperatures above 100°F could increase to as many 1.6 days a year by 2050, or 2 days a year by the end of the century. Similarly, in the Northeast region, low emissions scenario projections estimate a regional increase to as many as 9 days a year by the middle of the century.[34]

According to NOAA, Baltimore experienced an average of 31 days a year when temperatures met or exceeded 90°F in the years between 1981 and 2010. In 2012, the June 29 derecho occurred on the fringe of a major heat wave in Baltimore. For more than a week straight, temperatures soared above

90°F. In Baltimore, the number of days when temperatures reach or exceed 90°F are projected to increase to between 35 and 38 days by 2050, and between 38 and 41 days a year by the end of the century. Similarly, according to the National Climate Assessment, regional climate model simulations suggest that Maryland could experience more than twice as many days per year over 95°F by mid-century— with an estimated 15 additional days above 95°F each year.[35] This is expected to severely impact vulnerable populations, infrastructure, agriculture and ecosystems. In the future, Baltimore expects that periods of extreme heat are likely to increase in frequency, duration, and intensity.

The summer season in Baltimore City is known to have frequent high temperatures accompanied by high humidity. On some summer days, urban air can reach temperatures up to 10°F warmer than that of surrounding suburban or rural areas—a phenomenon known as the "urban heat island effect." Densely developed metropolitan areas tend to replace natural land cover with asphalt, sidewalks, buildings, and other hard infrastructure. As opposed to natural elements of an ecosystem, which can absorb the sun's heat and cool the surrounding air through evapotranspiration, these hard materials retain and radiate heat. The resulting warm urban temperatures can give rise to adverse public and environmental health problems and can increase energy usage for summertime cooling.[36] The urban heat island effect is anticipated to intensify as extreme heat events increase as a result of climate change.

In Figure 9 and Figure 10, maps of land surface type and temperature for Baltimore, Maryland reveal the tight relationship between development and the urban heat island effect. Land temperatures in the densely developed city center are as much as 10°F higher than the surrounding forested landscape.

Figure 9: Baltimore Land Surface Temp

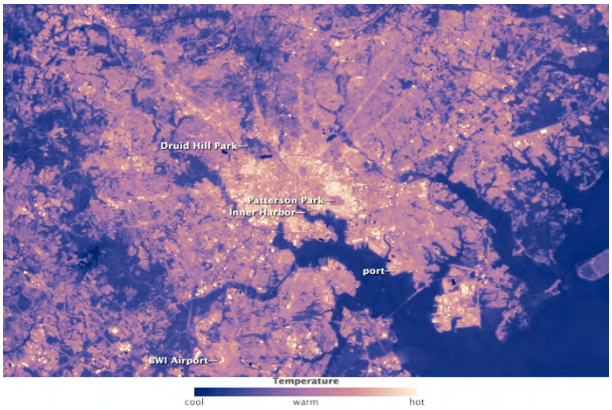
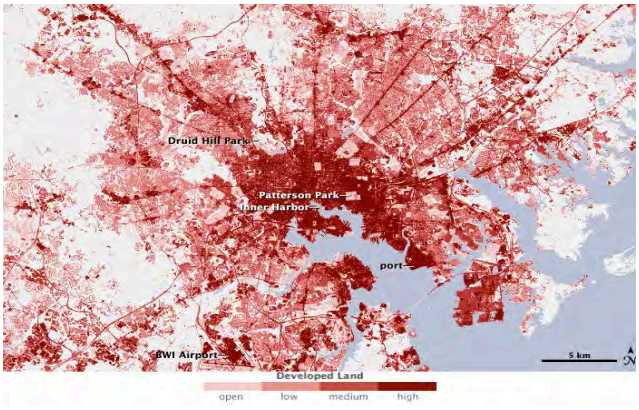


Figure 10: Baltimore Developed Area



Source: www.earthobservatory.nasa.gov/images/urban-heat-island-baltimore-md

Over the past 50 years, average temperatures in the United States have increased more than 2°F. By 2100, Maryland's average winter temperatures are projected to increase by 2-6°F and average summer temperatures are projected to increase by 3-9°F.[37] Greenhouse gas (GHG) emissions will impact future scenarios; as GHG emissions continue to rise, so will average temperatures. Increases in average temperatures will lead to longer consecutive periods of 90°-100°F temperatures.

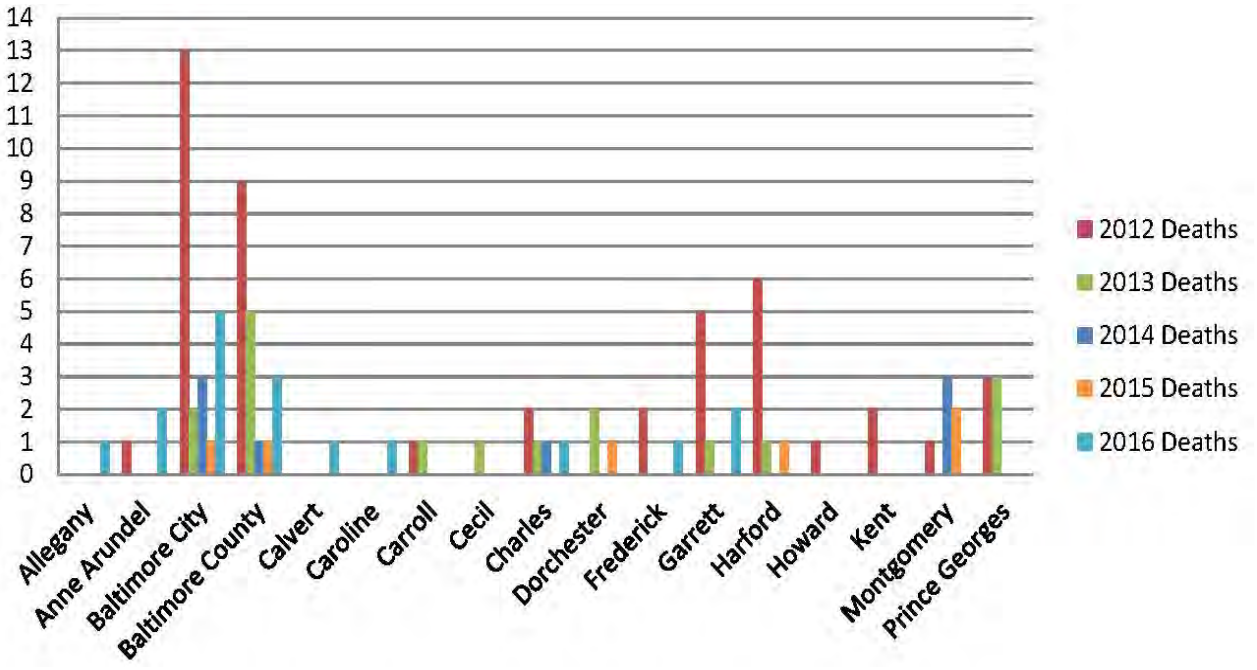
Table 25: Extreme Heat Impacts (Excessive Heat and Heat) 1996-2017

County/City	Total Events	Total Injuries	Total Deaths
Baltimore City	61	280	68

Source: National Centers for Environmental Information (NCEI)

Table 25 provides information from the National Centers for Environmental Information (NCEI) on extreme heat event impacts. A significant increase in the number of extreme heat days could place people at even greater risk of suffering from heat-related health conditions, including heat stress, heat exhaustion, or heat stroke, as evidenced by Table 25. A significant increase in the number of extreme heat days could place people at a greater risk of suffering from heat-related health conditions, including heat stress, heat exhaustion, or heat stroke. These medical problems are a particular threat to the elderly population, young children, and people with respiratory difficulties. For instance, in the heat wave following the June 29, 2012 derecho, eight heat-related fatalities were reported in Baltimore City.[38] Baltimore City has the highest risk of extreme heat of any Maryland jurisdiction. As such, extreme heat and air quality was rated as a high-risk hazard within the 2018 HIRA completed as part of the DP3 plan update process.

Figure 11: 2012-2016 Maryland Heat Deaths by Jurisdiction

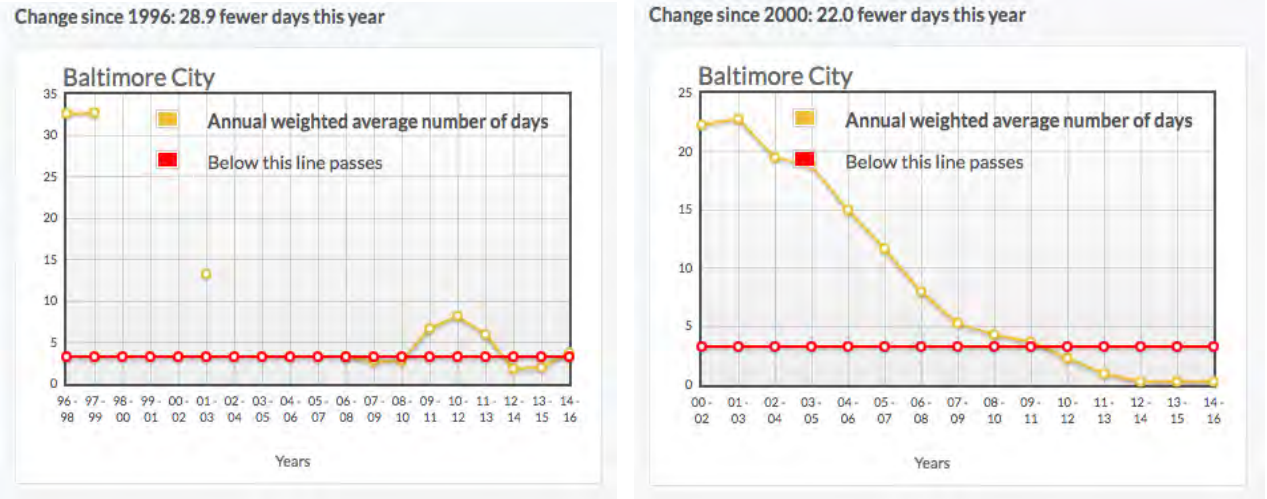


Source: State of Maryland DHMH – 2016 Heat-Related Illness Surveillance Report (November 23,2016)

Air Quality and Respiratory Illnesses

aHealth risks associated with heat—particularly risks that worsen symptoms triggered by respiratory diseases—are further provoked by diminished air quality. Trees and other vegetation cool the surrounding air and are shown to help to improve air quality. According to the American Lung Association, Baltimore City received an Ozone Grade of "F" and a Particle Pollution 24-hour grade of "B" in the State of the Air 2018 report. Furthermore, the report explains that many cities across the Nation experienced more days when ground-level ozone reached unhealthy levels in 2014-16, owing to record-setting heat.

Figure 12: High Ozone Days (left) and Particle Pollution (right)



Source: American Lung Association- http://www.lung.org/our-initiatives/healthy-air/sota/cityrankings/states/maryland/baltimore-city.html

Note: The State of the Air 2018 report looks at levels of ozone and particle pollution found in official monitoring sites across the United States in 2014, 2015, and 2016. The report uses the most current quality-assured nationwide data available for these analyses.

Acting as filters, trees gather particles from the air; scientists have long considered the capacity of trees to affect air pollution. Researchers with the U.S. Forest Service, studying a number of cities including Baltimore, were recently able to quantify one health benefit of the urban tree canopy. Their study found that trees in Baltimore remove approximately 14 tons of pollution each year.[39] Tying these findings to public health, this service is equated with one less premature death, nearly 140 fewer asthma attacks, and avoiding an estimated 240 cases of labored breathing. Other highly populated cities with denser tree canopies have shown even greater influence. In New York City, for example, the study estimated that the tree canopy could be credited with preventing as many as eight deaths.[40]

Summertime heat increases energy usage, which, in turn, produces emissions that boost the concentration of harmful pollutants in the air. Furthermore, higher temperatures accelerate the chemical reaction that produces ground-level ozone, or smog. By the middle of the century, Baltimore is expected to endure a 28-percent increase in the average number of days exceeding 8-hour ozone standards.[41] Coupled with the possibility of higher pollen generation from plants due to a changing climate, air quality conditions may become a more considerable threat. Air pollution triggers asthma attacks, exacerbates allergies, and can lead to long-term health problems such as heart disease or stroke. Currently, asthma is the number one chronic disease among this Nation's youth, afflicting 1 out of every 10 schoolchildren. Higher cases of these heat- and air-quality-induced conditions can place a stress on medical facilities.

In addition to respiratory illnesses, vector-borne diseases and impacts to water sources and agriculture/aquaculture are associated with extreme heat. These impacts are discussed in Chapter 4.

Land

Earthquakes

An earthquake, also called a seismic event, is a trembling of the ground caused by the sudden movement of large sections—called tectonic plates—of the Earth's outermost crust. The edges of tectonic plates are marked by faults. Most earthquakes occur along fault lines when two or more plates slide past each other or collide against one another. As a result, the shifting masses send out shock waves that may be powerful enough to:

- Alter the surface of the Earth, thrusting up cliffs and opening great cracks in the ground; and
- Cause great damage, collapse of buildings and other man-made structures, broken power and gas lines (and consequent fires), landslides, avalanches, tsunamis, and volcanic eruptions.

Earthquakes are measured in terms of their magnitude and their intensity. The effect of an earthquake on the Earth's surface is called the intensity. The intensity scale consists of a series of certain key responses, such as people awakening, movement of furniture, damage to chimneys, and (in the worst case) total destruction. Although numerous intensity scales have been developed over the last several hundred years to evaluate the effects of earthquakes, the U.S. currently utilizes the Modified Mercalli Intensity (MMI) scale (Table 26). Developed in 1931 by a pair of American seismologists, the MMI scale distinguishes between 12 increasing levels of intensity—ranging from imperceptible shaking to catastrophic destruction—designated by Roman numerals (Table 27). Because the MMI scale measures intensity based on the observed effects of an earthquake's impact, it is often a better indication of severity to the nonscientist than is the measure of magnitude.

Earthquakes are low-probability, high-consequence events. Although earthquakes may occur infrequently, they can have devastating impacts. Ground shaking can lead to the collapse of buildings and bridges and disrupt gas lines, electricity, and phone service. Deaths, injuries, and extensive property damage are possible. Some secondary hazards caused by earthquakes include fire, hazardous material release, landslides, flash flooding, avalanches, tsunamis, and dam failure. Moderate and even very large earthquakes are inevitable, although very infrequent, even in areas of normally low seismic activity.

Table 26: The Modified Mercalli Intensity Scale of 1931 (Abridged)

Intensity	Experience
I	Not felt, except by very few people under especially favorable conditions.
II	Felt by a few people, especially those on upper floors of buildings. Suspended objects may swing.
III	Felt quite noticeably indoors. Many do not recognize it as an earthquake. Standing motor cars may rock slightly.
IV	Felt by many who are indoors; felt by a few outdoors. At night, some awakened. Dishes, windows and doors rattle.
V	Felt by nearly everyone; many awakened. Some dishes and windows broken; some cracked plaster; unstable objects overturned.

Intensity	Experience
VI	Felt by everyone; many frightened and run outdoors. Some heavy furniture moved; some fallen plaster or damaged chimneys.
VII	Most people alarmed and run outside. Damage negligible in well-constructed buildings; considerable damage in poorly constructed buildings.
VIII	Damage slight in special designed structures; considerable in ordinary buildings; great in poorly built structures. Heavy furniture overturned. Chimneys, monuments, etc. may topple.
IX	Damage considerable in specially designed structures. Buildings shift from foundations and collapse. Ground cracked. Underground pipes broken.
X	Some well-built wooden structures destroyed. Most masonry structures destroyed. Ground badly cracked. Landslides on steep slopes.
XI	Few, if any, masonry structures remain standing. Railroad rails bent; bridges destroyed. Broad fissure in ground.
XII	Virtually total destruction. Waves seen on ground; objects thrown into the air.

Source: Earthquake Fact Sheet, MGS, www.mgs.md.gov/esic/brochures/earthquake.html,

Table 27: Relationships Between Earthquake Magnitude, Intensity, Worldwide Occurrence and Area Affected

General Description	Richter Magnitude	MMI	Expected Annual Incidence	Distance Felt (miles)
Microearthquake	below 2.0	--	600,000	--
Perceptible	2.0-2.9	I--II	300,000	--
Felt generally	3.0-3.9	II-III	49,000	15
Minor	4.0-4.9	IV-V	6,000	30
Moderate	5.0-5.9	VI-VII	1,000	70
Large (Strong)	6.0-6.9	VII-VIII	120	125
Major (Severe)	7.0-7.9	IX-X	18	250
Great	8.0-8.9	XI-XII	1.1	450

Source: MGS, Earthquake Fact Sheet, www.mgs.md.gov/esic/brochures/earthquake.html

Table 28 displays earthquake events within 200 miles of Baltimore City between 1950 and 2017. While no earthquake epicenters have been located within the City of Baltimore, strong earthquakes are capable of being felt for hundreds of miles. In 1897, the Giles County Virginia Earthquake measured 2.0 MMI in Baltimore. The strongest earthquake felt in the Baltimore region, however, was another Virginia earthquake that measured an intensity of 5.8, originating in Louisa County on August 23, 2011. This event caused considerable damage in Baltimore; a number of buildings were damaged, including the historic and celebrated Baltimore Basilica, which reported $3-5 million in damages.

Table 28: Earthquake Events Within 200 Miles of Baltimore City

Date	Location	Magnitude	Date	Location	Magnitude
11/11/2017	0.8 km (0.5 mi) ESE of Roxbury, Maryland	1.5	10/28/1993	Ellicott City, Maryland (39.25, -76.77)	1.8
10/30/2017	Glenelg, Maryland	1.52	10/28/1993	Ellicott City, Maryland (39.25, -76.77)	2.1

Date	Location	Magnitude	Date	Location	Magnitude
8/23/2011	Louisa County, Virginia (37.94N, 7793W)	5.8	7/12/1993	Columbia, Maryland (39.19, -76.87)	2.1
7/16/2010	Potomac Region (39.17, -77.25)	3.4	7/9/1993	Columbia, Maryland (39.19, -76.87)	1.9
9/29/2009	Bel Air, Maryland (39.607, -76.342)	1.6	4/8/1993	Columbia, Maryland (39.19, -76.87)	1.0 to 1.5
7/1/2009	SW New Jersey (39.64, -75.48)	2.8	4/4/1993	Columbia, Maryland (39.19, -76.87)	1.5
2/23/2005	SE Baltimore (39.26, -76.58)	2	3/26/1993	Ellicott City, Maryland (39.28, -76.82)	<1.5
12/9/2003	Virginia (37.599N, 77.932W)	4.5	3/22/1993	Columbia, Maryland (39.19, -76.86)	about 0.0
8/26/2003	New Jersey (40.61N, 75.11W)	3.8	3/21/1993	Aberdeen, Maryland (39.47, -76.30)	1.5
3/22/2002	Columbia, Maryland (38.19, -76.84)	1.0 to 2.0	3/19/1993	Columbia, Maryland (39.19, -76.87)	<1.0
12/18/2001	Columbia, Maryland (38.19, -76.84)	1.5 to 2.0	3/19/1993	Columbia, Maryland (39.19, -76.87)	1
9/25/1998	Pennsylvania (41.49N, 80.38W)	4.5	3/17/1993	Columbia, Maryland (39.19, - 76.87)	<= 1.0
12/22/1996	Columbia, Maryland (39.19, -76.87)	2.0, 2.3	3/16/1993	Columbia, Maryland (39.19, -76.87)	1.8
12/16/1996	Ellicott City, Maryland (39.25, -76.77)	about 1.0	3/16/1993	Columbia, Maryland (39.19, -76.87)	1.8
12/14/1996	Columbia, Maryland (39.19, -76.87)	<1.5	3/15/1993	Columbia, Maryland (39.19, -76.87)	2.7
12/6/1996	Columbia, Maryland (39.19, -76.87)	<1.5	3/12/1993	Columbia, Maryland (39.19, -76.87)	2
10/17/1996	Rising Sun, Maryland (39.7, -76.60)	2.2, 2.3	3/10/1993	Columbia, Maryland (39.19, -76.87)	2.5
8/2/1996	Perryville, Maryland (39.57, -76.08)	22	9/28/1991	Granite, Maryland (39.35, -76.83	2.4
10/28/1994	Glen Burnie, Maryland (39.1, -76.60)	2.7	4/4/1990	Granite, Maryland (39.35, -76.78)	1.7
1/16/1994	Pennsylvania	4	1/13/1990	Randallstown, Maryland (39.36, -76.78)	2.6
1/16/1994	Pennsylvania	4.6	5/23/1986	Accoceek (38.69, -77.04)	2.5
11/27/1993	Columbia, Maryland (39.19, -76.87)	about 1.5	4/23/1984	Lancaster County, Pennsylvania	4.4

Date	Location	Magnitude	Date	Location	Magnitude
11/27/1993	Columbia, Maryland (39.19, -76.87)	<1.5	4/26/1978	Hancock (39.7, -78.24)	3.1
11/17/1993	Columbia, Maryland (39.19, -76.87)	1.7	9/7/1962	Hancock (39.7, -78.20)	3.3

Compared to other parts of the United States, the Baltimore region has a relatively low probability of experiencing strong earthquakes. The Baltimore region has an expected peak acceleration of 8%g. At this level, any potential damage is expected to be very light.

Landslides and land slumping may contribute to, or heighten, the probability of earthquake events in Baltimore. Landslides often occur along steep slopes, karst terrain (see below), or otherwise unstable land. Slopes greater than 15 percent often become unstable due to one or more conditions, including loose soil or rock, lack of vegetation, insufficient moisture, or instability, during or after an earthquake. The Maryland Geological Survey (MGS) does not consider Baltimore to have a significant risk of landslide due to the lack of mountainous areas. While there are indeed some steep slopes, particularly near streams, these slopes are usually vegetated and stable, and are therefore unlikely to instigate minor earthquakes.

The MGS does caution, however, that land slumping could become a significant hazard in the event of a major earthquake. Downtown Baltimore has been developed on a considerable amount of artificial fill that extends into harbor waters. Deposited in the water as a means to dispose of debris after the Great Fire of 1904, the fill provided reclaimed land for the growing city. Were a severe earthquake to occur in or near Baltimore, scientists at MGS predict that many structures built on the filled land would likely suffer significant damage.

Land Subsidence

Land subsidence is the gradual settling or sinking of the Earth's surface. Subsidence may be gradual or sudden and can range in extent from broad, regional reductions in elevation to localized areas of collapses. It is often caused, principally, by aquifer system compaction, drainage of organic soils, underground mining, hydro-compaction, natural compaction, sinkholes, and thawing permafrost. Subsidence is a global problem; in the United States, more than 17,000 square miles in 45 States—an area roughly the size of New Hampshire and Vermont combined—have been directly affected by subsidence.

Regional subsidence is believed to be the result of post-glacial rebound following the last glacial maximum. The mass of the ice sheet had displaced land, pushing the land surrounding the ice sheet's coverage upward (Chesapeake Bay region in Maryland). Ever since the ice sheets retreated, the elevated area has been subsiding. At the regional level, Maryland has been subsiding at a rate of approximately 1.5mm/yr.[42] Recent climate assessments have reported Baltimore's rate of land subsidence to have been roughly half a foot in the last century.[43] When coupled with rising waters, local land subsidence can exacerbate relative sea level rise.

Urban Karst/Sinkholes

The term "karst" refers to land that is characterized by various subterranean features—including sinkholes, caves/caverns, underground streams, and other features that are formed by the dissolution of calcium and magnesium oxides in certain rocks. Karsts may produce surface and subsurface conditions that give rise to a number of problems. According to a report published by the Western Maryland Resource Conservation and Development Council, Karst regions are prone to unpredictable or easily contaminated groundwater supplies.[44] Additionally; karst lands are susceptible to subsidence and other changes in land, such as sinkholes, which present a physical hazard. Karst formations develop in specific ways that are influenced by unique local conditions. These geological conditions are not naturally present in Baltimore, so the City is not significantly impacted by karst formations. In fact, to date, there have been no Federal Declared Disasters or events recorded by NOAA's National Climatic Data Center for karst-related hazards anywhere in Maryland.[45]

In addition to natural processes, however, sinkholes can be induced through human actions. Human-induced sinkholes can be triggered by simple alterations to the local hydrology. Inadequate drainage along highways and increased runoff from pavement can also be sources of sinkhole development. In Baltimore, infrastructure-related sinkholes have been the primary concern.

Maryland is affected by a broad regional subsidence phenomenon and more localized land collapsing due to sinkhole formation. Sinkholes have the potential to cause damage to infrastructure and buildings and may result in injuries or even fatalities. When coupled with heavy rainfall, risks associated with sinkholes may increase. In August 2012, following heavy rains, a sinkhole opened on Baltimore's East Monument Street above a 120-year-old drainage culvert (Table 29). When another storm released an estimated 1 to 3 inches of rain on top of the repair effort, emergency workers were forced to once again evacuate the site.

Table 29: Major Baltimore Sinkholes in the Past Decade

Location	Date
Race and West Street	2008
2238 East Monument Street	2009
2100 S. Clinton Street	2009
600 Cathedral Street	2011
I-83 & 29th Street	2012
2300 block of East Monument Street	2012
W 37th and Keswick	2013
721 Gorsuch Avenue	2013
1000 Block of Riverside	2014
Eutaw Street	2015
100 Center Street	2016
500 Mulberry Street	2016
2400 East Monument Street	2016
700 Cathedral Street	2016

Source: Baltimore City Department of Public Works & The Baltimore Sun

Sinkholes appear to be happening more frequently. An article from December 2012 noted that sinkholes had been occurring in large numbers across the country, suggesting that frequent and large sinkholes may be quickly becoming the "new normal." The article noted that, in Baltimore specifically, more than four sinkholes had recently developed in 3 weeks that December. In fact, the article states that "as [Baltimore] crews worked on one sinkhole, another opened up about 125 ft. west of the original sinkhole widening rapidly within 15 minutes." The article noted also that two Fells Point homes were sinking at that same time. While it would appear that sinkholes are becoming more of a threat in Baltimore, it remains difficult to identify key sensitivities.

Chapter 4

Risk and Vulnerability Assessment

Summary of Changes

- Plan Integration of data, mapping products, and results from related planning initiatives, namely:
    - 2018 Coastal Adaptation Planning and Implementation Report highlighting the importance of using an equity lens for all hazard mitigation planning and community resilience plans;
    - 2014 FEMA Flood Risk Report-Baltimore City, MD Coastal Study;
    - National Flood Insurance Program Community Rating System, Floodplain Management Planning;
    - Community Asset Inventory;
    - Historic and Cultural Resources Inventory;
    - Maryland Commission on Climate Change Fact Sheets and Report;
    - 2012 FEMA E-74 Reducing the Risk of Nonstructural Earthquake Damage–a Practical Guide;
    - 2015 State of Maryland Local Hazard Mitigation Plan Guidance; and,
    - Various News Articles.
- Added repetitive local roadway flooding and areas of flooding.
- Emphasized essential facilities vulnerability and prioritization for community resilience.

Regulatory Checklist

B3. Is there a description of each identified hazard's impact on the community as well as an overall summary of the community's vulnerability for each jurisdiction? 44 CFR 201.6(c)(2)(ii)

B4. Does the plan address NFIP insured structures within each jurisdiction that have been repetitively damaged by floods? 44 CFR 201.6(c)(2)(ii)

C2. Does the plan address each jurisdiction's participation in the NFIP and continued compliance with NFIP requirements, as appropriate? 44 CFR 201.6(c)(3)(ii)

Introduction

Vulnerability, specifically, refers to the *susceptibility* of people, properties, and resources to the impacts associated with hazard events. For example, a range of community assets—including residential or public structures and infrastructure—may be deemed vulnerable to various hazard risks. The level of vulnerability depends on factors including location, construction, property contents, and the economic value of the function(s) being provided by an individual, facility, or system. Vulnerability may be intensified by a lack of resources or information. Additionally, certain geographic areas or social dynamics may contribute to the circumstances that make one population more sensitive to hazards than others. When vulnerability is greater for particular social groups or individuals, addressing it can become a matter of environmental justice. The vulnerability assessment investigates the exposure (lack of defense), sensitivity (degree to which a system is affected), and Adaptive Capacity (ability to recover) of an individual or asset in regard to each hazard.

Observing conditions in Baltimore as a whole, the vulnerability assessment identifies the City's key community assets and critical facilities to understand where special consideration may be required. Later in the chapter, vulnerability is assessed for each of the specific hazards identified in Chapter 3. This assessment identifies which community assets and critical facilities are vulnerable to each hazard. These focused inventories will, when possible, provide descriptions of why certain structures, critical facilities, or vulnerable populations are most susceptible. Updates to the vulnerability assessment were made during the 2018 DP3 update, based upon the best available data. The flood hazard was ranked as a high risk within the Hazard Identification Risk Assessment (HIRA); however, there are certain limitations for updating flood vulnerability. FEMA's Flood Insurance Study (FIS) and associated Flood Insurance Rate Map (FIRM) are currently under development, but FEMA's non-regulatory Coastal Risk Map product, which includes both data and mapping, was used for updating this chapter. In addition, vulnerable populations were identified and assessed within the 2018 Coastal Adaptation Planning and Implementation Report (CAPIR), specifically for inclusion in the DP3 update. Various data tables, maps, and text have been updated throughout this chapter.

The vulnerability analysis identifies assets and systems that are most likely to be impacted during a hazard event, based on their exposure, sensitivity, and adaptive capacity. The formal impact assessment offers a better understanding of the types and costs of injury or damage that a hazard event may cause in Baltimore. As a result, the impact assessment builds upon the earlier stages of the risk assessment through an evaluation of the asset inventory, highlighting particular assets that are likely to be affected and summarizing estimated potential losses sustained as the result of a particular hazard.

The vulnerability and impact assessment findings discussed below, when combined with the information in the HIRA (Chapter 3) will lay the foundation for effective adaptation and mitigation strategies.

Chapter 4 provides the following information:

- Self-Assessments Tools and Plan Integration;
- Description of Hazus-MH assessment tool and data limitations;
- General inventory of assets, including critical and essential facilities;
- Specific vulnerability assessments by hazard, including:

- Identification of the range of vulnerabilities to community assets;
- Identification of the range of vulnerabilities to critical and essential facilities;
- Estimated economic impacts;
- Initial selections of key vulnerabilities; and
- An explanation of adaptive capacity.

Vulnerability Assessment Tools Used

Self-Assessment Tools and Plan Integration

To supplement the technical and quantitative methods used to analyze potential natural hazards in Baltimore, the 2018 DP3 plan update process included input from community stakeholders, as well as expertise from members of the Advisory Committee. Both contributed a self-assessment of the local perspective on risk and vulnerability. This process guided development of the 2018 DP3 plan by identifying issues and priorities.

Various meetings held during the plan update process included presenting the results of the HIRA and vulnerability assessment. The 2018 HIRA included a local risk perspective gained through surveys of people who live and/or work in Baltimore, to assess their level of concern about different hazards. Survey respondents included members of the Advisory Committee and citizens. The results of both the HIRA and vulnerability assessment data informed the assessment of existing mitigation strategies and the development of new ones. This is evidenced by the emphasis placed on mitigation strategies specific to high-risk hazards and strategies that addressed multiple hazards. A new hazard-specific column was added to the updated mitigation strategies prioritization table, as a result of the self-assessment and overall plan update process.

Advisory Committee Meeting held on August 1, 2018
Source: SP&D Michele King

In addition, various planning documents were reviewed and subsequently integrated into the 2018 DP3. The Coastal Adaptation Planning and Implementation Report was prepared by the City using financial assistance provided by the Coastal Zone Management Act of 1972, as amended, administered by the Office of Coastal Management, National Oceanic and Atmospheric Administration (NOAA). The Baltimore Office of Sustainability, the lead agency for the 2018 DP3 update, gathered a diverse team of other Baltimore Department of Planning staff working on equity, mapping, and the Resiliency Hubs, as well as a consultant who specialized in building and enhancing the resiliency of communities before, during, and after disasters. Community members and City agency staff involved in the Resiliency Hubs and emergency preparedness provided input on the structure of the Hubs and on current gaps in community resiliency planning. The report contains the following elements that directly informs the DP3 plan update:

- A description of the equity lens that will be used for the City of Baltimore's all hazard mitigation plan (DP3) update.
- A framework for community resilience plans, using factors related to local hazards and individual and community vulnerability to these hazards to identify areas of the City and individual neighborhoods most in need of a Resiliency Hub and a community resiliency plan.

The 2018 Coastal Adaptation Planning and Implementation Report (CAPIR) suggested content for the DP3 update, which has been included within this plan chapter. In addition to the 2018 CAPIR, the 2014 FEMA Flood Risk Report for the Baltimore City, MD Coastal Study has been integrated into the vulnerability assessment update. The Flood Risk Report (FRR) provides non-regulatory information to help local or tribal officials, floodplain managers, planners, emergency managers, and others better understand their flood risk, take steps to mitigate those risks, and communicate those risks to their citizens and local businesses. Because flood risk often extends beyond community limits, the FRR provides flood risk data for the entire flood risk project area, as well as for the individual community. This also emphasizes the fact that flood risk reduction activities may impact areas beyond jurisdictional boundaries.

Finally, members of the Advisory Committee, along with other City staff, provided new information for the vulnerability assessment. Frequently flooded roadways and areas of repetitive flooding were identified, and new mitigation strategies were added to the plan update as a result.

Hazus

The City of Baltimore has utilized the Hazards U.S.–Multi-Hazard, or "Hazus-MH," software offered by FEMA. Hazus-MH is a nationally standardized methodology that provides a framework for estimating potential losses from natural hazard events—specifically, earthquakes, floods, and hurricanes. Hazus-MH uses Geographic Information Systems (GIS) technology to map and estimate the potential physical, economic, and social impacts of these natural disasters. Providing an essential function of pre-disaster planning, the mapping processes can illustrate the coverage of identified high-risk areas, allowing users to visualize the spatial relationships between these specific hazards and Baltimore's many populations, assets, and resources.

Hazus-MH is used for both mitigation and recovery efforts, as well as for preparedness and emergency response activities. Government agencies, GIS specialists, and emergency planners use Hazus- MH, reviewing estimated losses to determine the most beneficial mitigation approaches for minimizing impacts. As a part of the 2018 DP3's risk assessment, products of Hazus-MH analyses helped to identify critical vulnerabilities and significant impacts, and to inform long-term strategies and actions for preventing damage, effectively aiding in recovery and reconstruction efforts. Additionally, the maps generated by Hazus-MH software are being used to supplement the information discussed in this report, as well as to increase general hazard awareness across the City.

Assessing General Hazard Vulnerability

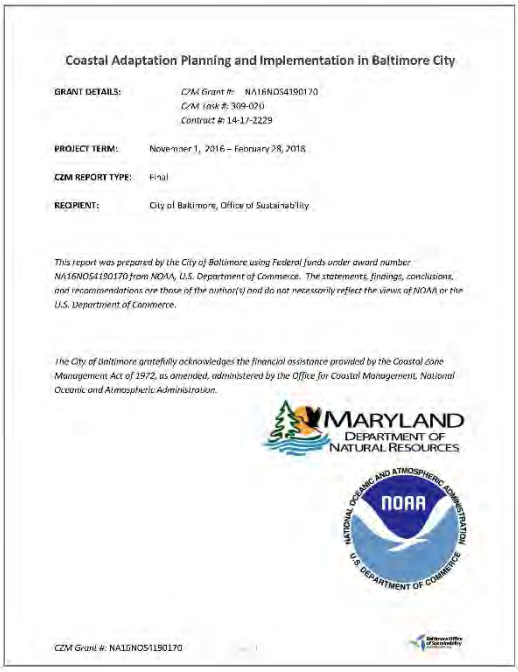
Assessment Methods

Baltimore City has a rich history and boasts many diverse, vibrant communities. Community assets are the people, places, and activities that shape everyday life. A Community Asset Inventory (CAI) considers both physical structures and social environments. The CAI considers highly vulnerable populations, historic and cultural resources, economic elements, natural resources and recreation areas, and other important services.

While the CAI review included a number of facilities that contribute to the City's emergency response to hazards, the impacts to many other community assets—while they do not directly affect the City's capacity for emergency response—will be devastating if people are not aware of their vulnerability and do not take appropriate steps to mitigate and prepare. Updates to the CAI will lead to the next steps in continuing and implementing the 2018 DP3, including outreach to the responsible parties identified in the CAI, communicating the risks of hazards, offering assistance in additional vulnerability assessments, and offering help to the parties responsible for these assets. The outcome of this effort is to foster partnerships and identify common-interest mitigation measures.

Societal Impact Analysis

As stated, the CAI reviews an asset in terms of its hazard risk and vulnerability. The assessment below considers the various conditions that may make one person, place, or activity more vulnerable than others. In all instances of hazard events, the vulnerability of the human population is based on the availability, reception, and understanding of early warnings of hazard events (i.e., Hurricane Watches and Warnings issued by the NWS, and Tornado Warnings issued by the NWS) as well as access to substantial shelter and a means and desire to evacuate if so ordered. In some cases, despite having access to technology (computer, radio, television, outdoor sirens, etc.) that allows them to receive a warning, individuals have language differences that are a barrier to understanding. Certain populations including children, elderly residents, and non-English-speaking residents, may face great challenges when overcoming the impacts of a hazard event. The 2018 Coastal Adaptation Planning and Implementation Report (CAPIR) focused on using GIS-based information and analysis to support the effort to prioritize communities for resilience plans as part of the 2018 DP3 update. Part of the CAPIR work effort was to identify and map layers related to vulnerable populations, such as:


Coastal Adaptation Planning and Implementation in Baltimore City

GRANT DETAILS: CZM Grant #: NA16NOS4190170
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MARYLAND DEPARTMENT OF NATURAL RESOURCES

NOAA NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION U.S. DEPARTMENT OF COMMERCE

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- Age, specifically areas with larger populations (by percent) of young and elderly residents;
- Immigrants and/or non-English speaking populations;
- Vehicle access;
- Poverty;
- Evictions;

- Foreclosures;
- Percentage of renters; and,
- Food and healthcare access.

In addition, the 2018 CAPIR stated that the information on a Community Resilience Framework should be included in the DP3 update. To that end, high-level guidance was developed on how best to:

- Connect to institutional preparedness planning with community-based resilience plans;
- More fully incorporate an equity lens in disaster preparedness, assessing the emergency capabilities of communities; and
- Identify key vulnerable populations.

The work completed for the 2018 CAPIR for inclusion in the DP3 is more extensive and detailed than that previously available. Detailed data, mapping, and discussion will be presented later in this chapter.[46]

Economic Impact Analysis

This risk and vulnerability analysis also included a review of information regarding some of Baltimore's major employers. These facilities and businesses play a significant role in Baltimore's economy. Furthermore, due to the number of residents who may be employed by, or benefit from, these businesses, their integrity must be considered to to reduce and prevent the severity and scope of any possible impact as a result of a natural hazard.

Environmental Impact Analysis

Baltimore City has a number of natural features, open spaces, and parks and recreational facilities, which should also be considered in the hazard mitigation and climate adaptation process. Natural features provide valuable ecosystem services and may be vulnerable to the impacts of hazards. Similarly, parks and recreational areas offer unique value to the City and its communities and may be susceptible to hazard events. On the other hand, natural systems often play a role in mitigating impacts from climate change and hazard events and can be seen as a resource.

Historic and Cultural Impact Analysis

Historic and cultural resources are also considered, as they make a significant contribution to the City and often generate strong emotional ties within the community. Baltimore has a rich historic fabric, and the City prides itself on being a national leader in historic preservation. In fact, Baltimore has 36 local historic districts, 70 national historic preservation districts, and 200 landmarks. Designated historic structures represent approximately one- third of Baltimore's built environment. Baltimore has one of the highest percentages of designated historic structures of any major city in the United States.

Historic structures may be at an even greater risk than new ones, as these buildings were constructed prior to the adoption of appropriate building standards (e.g., floodplain development code, electrical code). FEMA has produced guidance on this topic, "Integrating Historic Property and Cultural Resource Considerations into Hazard Mitigation Planning." It is important to recognize that these assets may require special considerations or specific technical and financial assistance. The City of Baltimore is currently studying a hazard mitigation strategy for its many historic structures.

Finally, other assets and facilities deserve attention, as they can have an immediate or lasting impact on people and everyday services. In the event of a no-warning hazard, densely populated facilities, for instance, would be of more concern due to the number of people that might potentially be within. This list includes hotels, malls, theaters and auditoriums, and churches, among other things. Some of Baltimore's larger scale facilities include the convention center, stadiums and arenas, and major tourist destinations like the National Aquarium in Baltimore and the Science Center. High-density residential and commercial developments could likewise result in high injury or fatality rates if damaged. Other assets also provide vital services that ensure the continuity of everyday activities. These facilities include grocery stores, banks, government buildings, gas stations, and agricultural areas, to name a few.

Some assets may be more vulnerable than others, depending on their age, location, or other characteristics. Additionally, facilities are impacted differently depending on the type of hazard experienced. A more detailed impact on Baltimore assets accompanies the assessment of each hazard type presented in this chapter.

Critical Facilities and Essential Facilities Impact Analysis

According to FEMA, a "critical facility" is a structure or other improvement that, because of its function, size, service area, or uniqueness, has the potential to contribute to serious bodily harm, extensive property damage, or the disruption of vital socio-economic activities if it is either destroyed or damaged, or if functionality is impaired. Critical facilities include a subset called essential facilities, such as hospitals, critical care facilities, outpatient clinics, and any other facility that would be able to provide immediate emergency relief and care following a hazard event. Additional essential facilities include emergency response stations and evacuation centers, as well as fire stations, police stations, and emergency operation and 9-1-1 communication centers. According to the 2015 State of Maryland Local Hazard Mitigation Plan Guidance, essential facilities must be included in all local mitigation planning.[47] Each of these facilities plays a vital role in disaster response and recovery and must therefore remain fully operational and accessible before, during, and after a hazard event. Table 30 includes both critical and essential facilities.

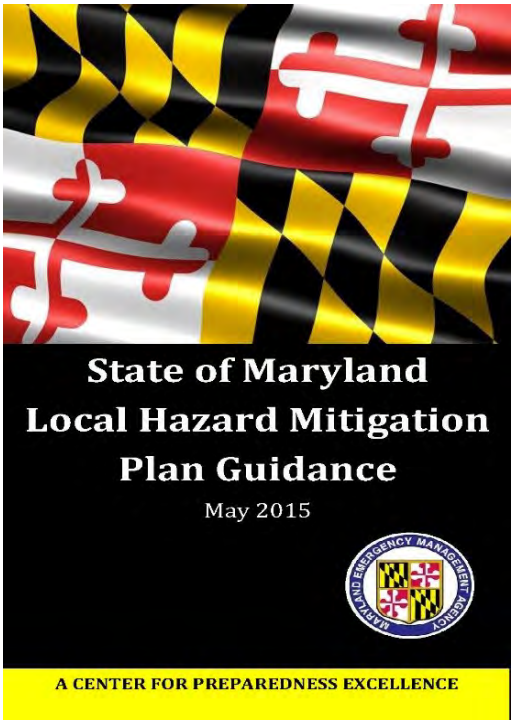


Table 30: Critical Facilities and Essential Facilities in Baltimore City

Essential Facility	Number
Emergency Operation Centers (EOC)	2
Fire Stations	41
Hospitals	15
Police Stations	10
Schools (Public and Private)	233
Colleges	15
Critical Facility	**Number**
Government Facilities	374
Banks	54
Grocery Stores	48
Hardware Stores	37
Gas Stations	238
Water Pumps	15
Electrical Cooperatives	-
Wastewater Treatment Facilities	3
Sewage Treatment Facilities	12
Drinking Water Treatment Facilities	11
Critical Roadways	61
Hazardous Waste Facilities	-
Total	1,169

Source: Baltimore City Enterprise Geographic Information Services and Hazus

* Note: Essential Facilities were reviewed and updated during the plan update process.

Table 30 depicts the locations of the five types of essential facilities:

- Emergency Operation and 9-1-1 Communication Centers;
- Fire and EMS Stations;
- Medical Facilities;
- Police Stations; and
- Schools.

These facilities are essential to the health and welfare of people and perform especially important services following a disaster.

Figure 13: Locations of Essential Emergency Facilities

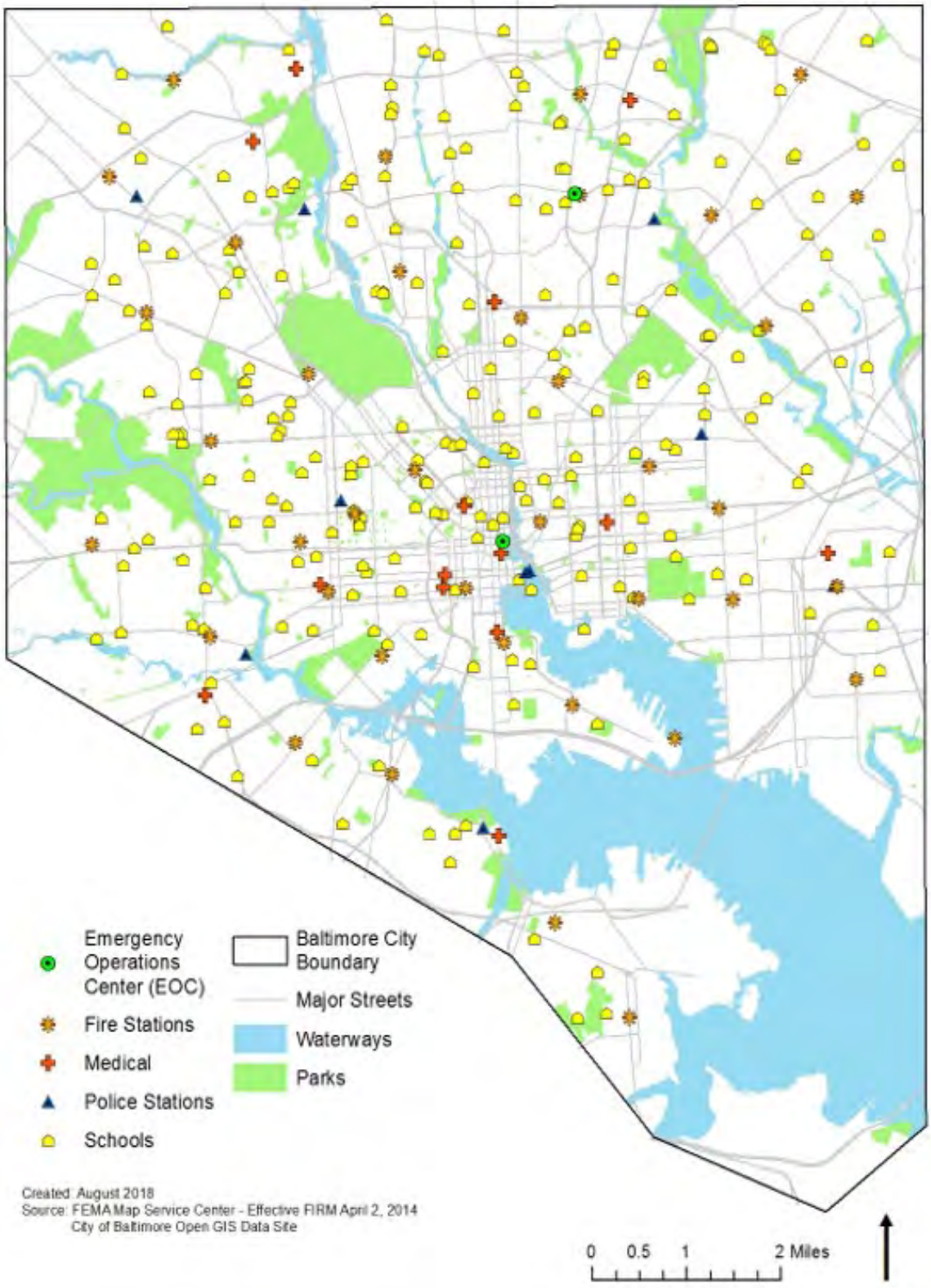


Table 31: List of Essential Emergency Facilities

Facility Type	Facility Name	Neighborhood	Facility Type	Facility Name	Neighborhood
Emergency Operation Center	EOC1	Penn-Fallsway	Emergency Operation Center	EOC2	New Northwood
Fire Station	E-45 T-27 M-14	Mount Washington	Fire Station	E-23 T-2 M-1 BC-6 R-1 AF-1	Downtown
Fire Station	E-46	Woodmere	Fire Station	Headquarters	Downtown
Fire Station	E-40 T-12 BC-5	Dorchester	Fire Station	Communications	Downtown
Fire Station	E-29 M-17	Central Park Heights	Fire Station	E-13 T-16 M-4	Madison Park
Fire Station	E-44 T-25	Roland Park	Fire Station	E-5 T-3 M-10	Upper Fells Point
Fire Station	E-21 M-11	Hampden	Fire Station	E-51	Ellwood Park/ Monument
Fire Station	E-31 M-3	Better Waverly	Fire Station	E-41 BC-1	Canton
Fire Station	E-43 M-18, BC-4	Glen Oaks	Fire Station	E-50 M-2	Broening Manor
Fire Station	E-4 T-29	New Northwood	Fire Station	E-55 T-23	Washington Village
Fire Station	E-56	Westfield	Fire Station	E-2	Federal Hill
Fire Station	E-42 M-6, M-13	Lauraville	Fire Station	T-6	Federal Hill
Fire Station	E-33 M-16 T-5	East Baltimore Midway	Fire Station	E-26 M-5	Riverside
Fire Station	E-27 T-26	Parkside	Fire Station	FB-1 FRB-1	Locust Point Industrial Area
Fire Station	E-20 T-18 M-8	Walbrook	Fire Station	E-58	Westport
Fire Station	E-30 T-8 M-12	Carroll-South Hilton	Fire Station	E-35 T-21 M-9 BC-6 Hazmat-1	Brooklyn
Fire Station	E-47	Morrell Park	Fire Station	E-57	Curtis Bay
Fire Station	E-14	Booth-Boyd	Fire Station	E-124 T-20	Hopkins Bayview
Fire Station	E-36	Midtown-Edmondson	Fire Station	E-54 T-30	Cedmont
Fire Station	E-52	Parkview/ Woodbrook	Fire Station	E-53	Hunting Ridge
Fire Station	E-8 T-10 M-15 BC-3	Harlem Park	Fire Station	T-15	Broadway East
Fire Station	E-6 T-1 M-7 BC-2 AF-2 Sh. Cmd	Oldtown			
Hospital	John Hopkins Hospital	Dunbar-Broadway	Hospital	John Hopkins Bayview Medical Center	Hopkins Bayview

Facility Type	Facility Name	Neighborhood	Facility Type	Facility Name	Neighborhood
Hospital	Maryland General Hospital	Mount Vernon	Hospital	Mercy Medical Cen.	Downtown
Hospital	Bon Secours Hospital	Penrose/Fayette Street Outreach	Hospital	University of Maryland Medical Center	University Of Maryland
Hospital	Sinai Hospital	Levindale	Hospital	VA Medical Center	University Of Maryland
Hospital	Harbor Hospital Center	Middle Branch/ Reedbird Parks	Hospital	Kernan Hospital	Dickeyville
Hospital	St. Agnes Hospital	Violetville	Non-Acute Hospital	Mt. Washington Pediatric Hospital	Mount Washington
Hospital	Union Memorial Hospital	Charles Village	Non-Acute Hospital	University Specialty Hospital	Otterbein
Hospital	Good Samaritan Hospital	Loch Raven			
Police Station	Headquarters	Downtown	Police Station	Eastern	Berea
Police Station	Central	Downtown	Police Station	Southern	Middle Branch/ Reedbird Parks
Police Station	Northern	Woodberry	Police Station	Southeastern	Hopkins Bayview
Police Station	Northeastern	Morgan State University	Police Station	Southwestern	Gwynns Falls
Police Station	Northwestern	Woodmere	Police Station	Western	Sandtown-Winchester

Source: Baltimore City Enterprise Geographic Information Services

* Schools were not included, due to the large number of facilities.

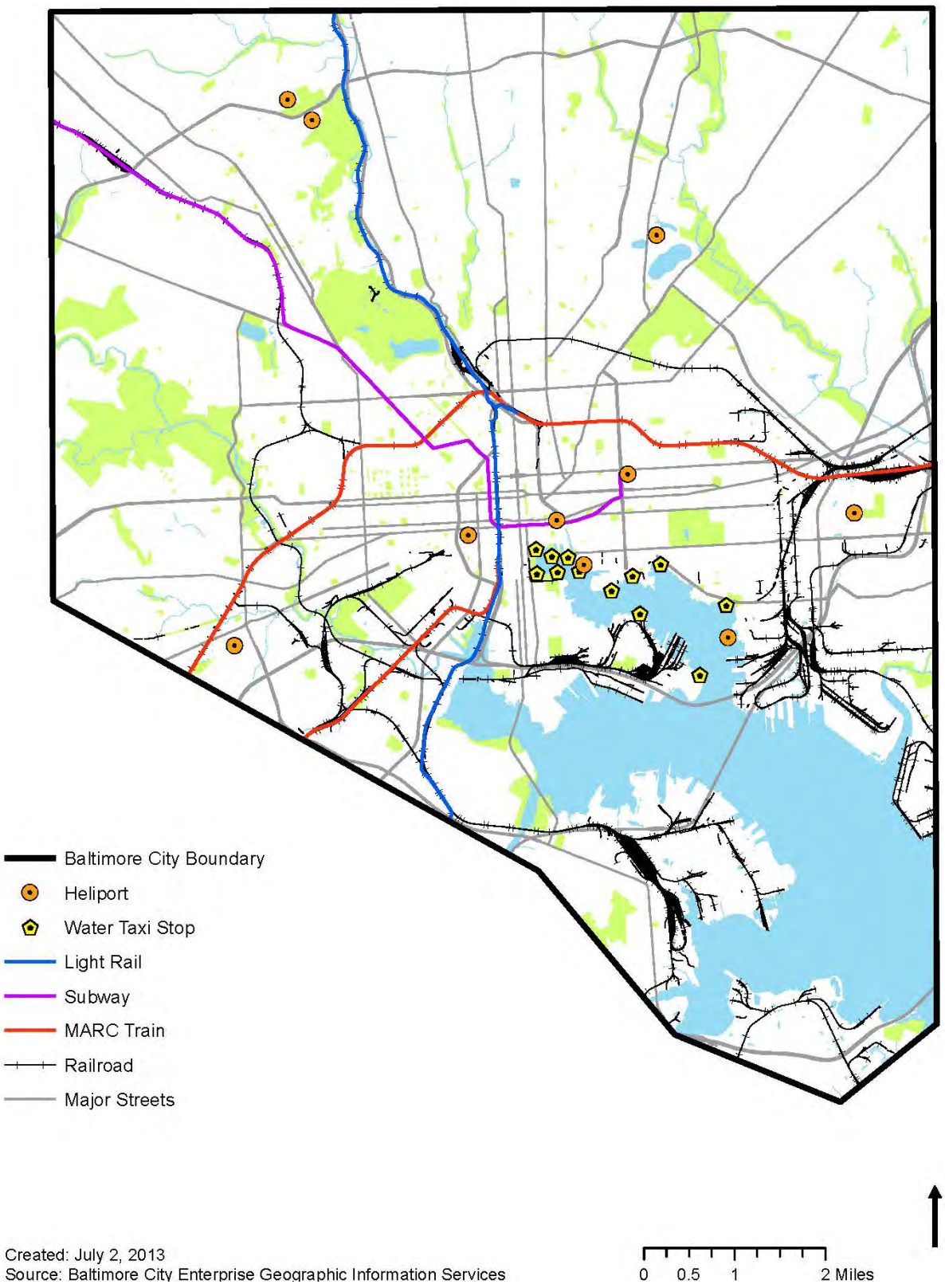
By evaluating key facilities, roadways, transportation corridors, and resources within the community, the vulnerability analysis of critical facilities determines the degree to which each facility is exposed to various hazards. As Table 30 indicates, there are approximately 1,169 critical facilities, with 316 of those classified as essential. The level of vulnerability and the total potential economic loss associated with each of facility will vary by hazard event and additional factors, including location, construction, property contents, and the economic value of the function(s) being provided by the facility. The parties responsible for critical facilities need to understand and respond to hazard vulnerabilities to lessen or avoid interruptions to essential services.

Transportation systems, which enable movement for emergency response as well as evacuation, may be significantly impacted by hazard events. Figure 15 illustrates the major streets and transportation systems within Baltimore. In a hazard event, Baltimore must maintain its lifeline utility and infrastructure systems. These systems provide access and assets to respond. Communication systems need redundancy, particularly with emergency response entities, and critical City services should be evaluated for further mitigation/preparedness measures, particularly water delivery, wastewater treatment and power generation. Additionally, efforts should be made to ensure that critical evacuation routes are evaluated for various impacts so these services continue to be available to Baltimore's residents and businesses.

Finally, there are high potential loss and hazardous material facilities, which would pose a danger should they be destroyed or damaged. Such facilities include hazardous waste facilities, dam structures, and any facilities housing industrial/hazardous materials. There are no vulnerability maps for dam facilities or hazardous material facilities, as this information is considered sensitive. Our risk analysis will be shared with those facilities and other appropriate parties to ensure proper measures are being taken.

Some critical facilities may be more vulnerable than others, depending on their age, location, and other characteristics. Additionally, facilities are impacted differently depending on the type of hazard experienced. A detailed impact assessment of critical facilities is included in the review of each hazard type described on the following pages.

Figure 14: Baltimore City Transportation Systems



Detailed Vulnerability Assessment by Hazard

Flooding

Background

At the heart of City, the water of the Inner Harbor and the many tributaries that flow into it are a central feature of Baltimore's historic landscape. Considering how closely Baltimore has developed alongside the water, it is understandable that the City has endured a history of significant flooding events. As Table 32 conveys, the annualized flood occurrences total for Baltimore City is 3.27, including flash floods and flooding from heavy rain. Recognizing this historical information and anticipating future increases, flooding is considered a high-risk hazard for the City of Baltimore.

Table 32: Flood Events (Flash Flood, Flood, and Heavy Rain) 1996-2017

County/City	Total Events	Annualized Events
Baltimore City	72	3.27

Source: National Centers for Environmental Information (NCEI)

In Baltimore, 5.19 square miles of property, or 6.4 percent of the City's total area, is currently designated as a high-risk flood zone; while 3 percent of Baltimore's overall land, primarily in the Inner Harbor area or the Fells Point Historic District, is within the coastal floodplain.[48] By the end of the century, approximately 180 square miles of currently dry land along Maryland's coastline is expected to be inundated. Coupled with more frequent and extreme precipitation events (See the Precipitation Variability Hazard Profile in Chapter 3) these conditions could become a common hazard.

Moreover, a number of anticipated climate change impacts may intensify the extent of and damage from flood events. Future sea level rise (for a discussion of sea level rise, refer to the Coastal Hazards Risk and Vulnerability Assessment below) or land subsidence, in addition to storm surge increasing flood depths, would intensify losses even further.

Source: Baltimore Sun (June 15, 2018); Top Photo Source: Jerry Jackson, Baltimore Sun Video; Bottom Photo Source: Crystal Mason Will

Following a flood event on May 27, 2018, the Baltimore Sun Newspaper reported that a portion of Frederick Avenue in Southwest Baltimore, between Beechfield Avenue and North Bend Road, was closed for a week as the Department of Transportation repaved sections of the street and ensured its structural integrity. During the flood, 7 feet of water rushed through the Beechfield neighborhood, stranding 20 motorists, flooding homes, and displacing 6 residents. After the flood, the Office of Emergency Management hosted an open house at Stillmeadow Community Fellowship Church on Frederick Avenue for those with concerns about insurance claims, safety issues, temporary housing needs and more. As reported during the meeting, the

flood resulted in approximately 3 million dollars in preliminary damages.

This vulnerability analysis makes a distinction between tidal-influenced floods (i.e., a storm surge) and non-tidal floods (i.e., a precipitation event). For example, the flooding from Isabel was strictly tidal. The flooding was the result of a storm surge that pushed the waters 7 feet above the predicted tide level. However, it would be possible to have that same storm surge coupled with a precipitation event. In addition to drawing the distinction between tidal and non-tidal flooding, the vulnerability analysis reports the impacts of flood events with different probability intervals (that is, the 100-year or 1-percent-annual-chance storm event vs. the 500-year or 0.2-percent-annual-chance storm event).

The section below presents the results and a discussion of the vulnerability analysis. Some of the vulnerability analysis is based on results from Hazus analyses (refer back to the discussion on Hazus-MH) performed by both the State and the City. In addition, results from the 2014 FEMA Flood Risk Report-Baltimore City, MD Coastal Study were integrated into the vulnerability assessment update. The vulnerability analysis continues with a Community Asset Inventory.

Vulnerability Assessment

The City utilized Hazus modeling software, FEMA Flood Insurance Rate Maps (FIRMs), and NOAA's Critical Facilities Exposure Tool to determine citywide vulnerability to flooding. Results were analyzed by the State of Maryland and Baltimore City flood experts to determine vulnerabilities in the floodplains and floodways.

Exposure

An evaluation of exposure identifies who and what may be vulnerable to flooding hazards. This analysis takes into consideration where flooding occurs through a process that delineates floodplains and floodways and identifies what assets or facilities are within those areas. Maps of flooding exposure, as well as information regarding the level at which various City assets are exposed to flooding, are depicted in the inventories of community assets and critical facilities below. Additionally, the Baltimore City Department of Planning, in partnership with FEMA, is developing new digital FIRMs which, when complete, will provide a more accurate picture of exposure in the updated floodplain and floodway. Expected completion date for these new FIRMS is 2019.

In addition to the financial damages caused by previous 100-year and greater floods, localized flooding has disrupted the lives of Baltimore residents. Figure 16 illustrates the areas that are susceptible to flooding from 100- and 500-year flooding events. Figure 17, Figure 18 and Figure 19 further clarify how the structural fabric of two particular areas—Fells Point and Westport—may be impacted by such events.

Figure 15: Baltimore City Floodplains and Floodway

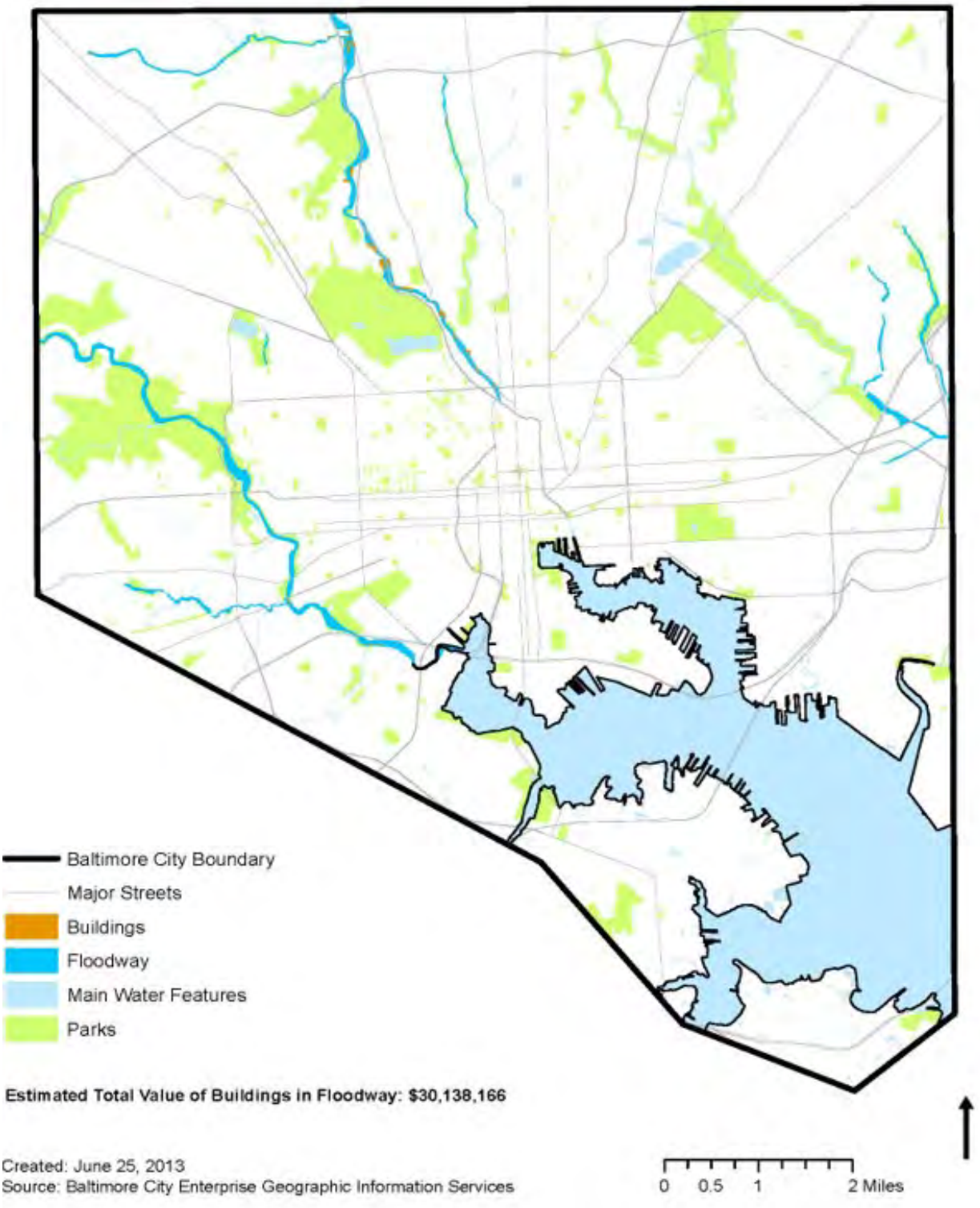


Figure 16: INSET | Fells Point Flood Exposure Areas

Figure 17: INSET | Westport Flood Exposure Areas

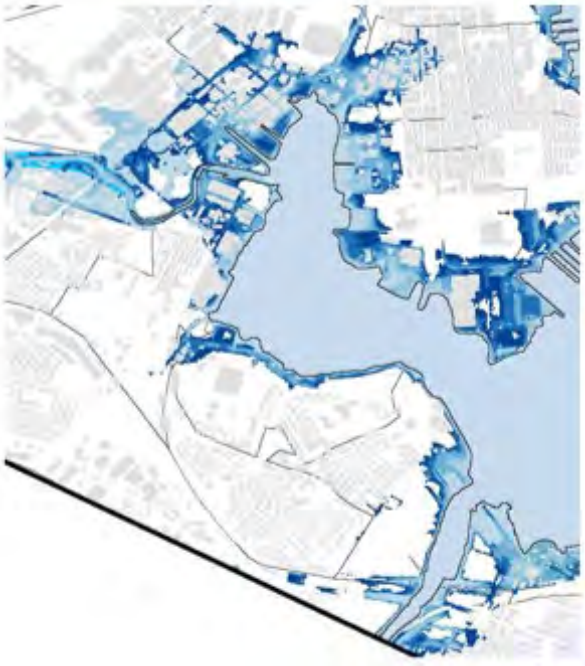
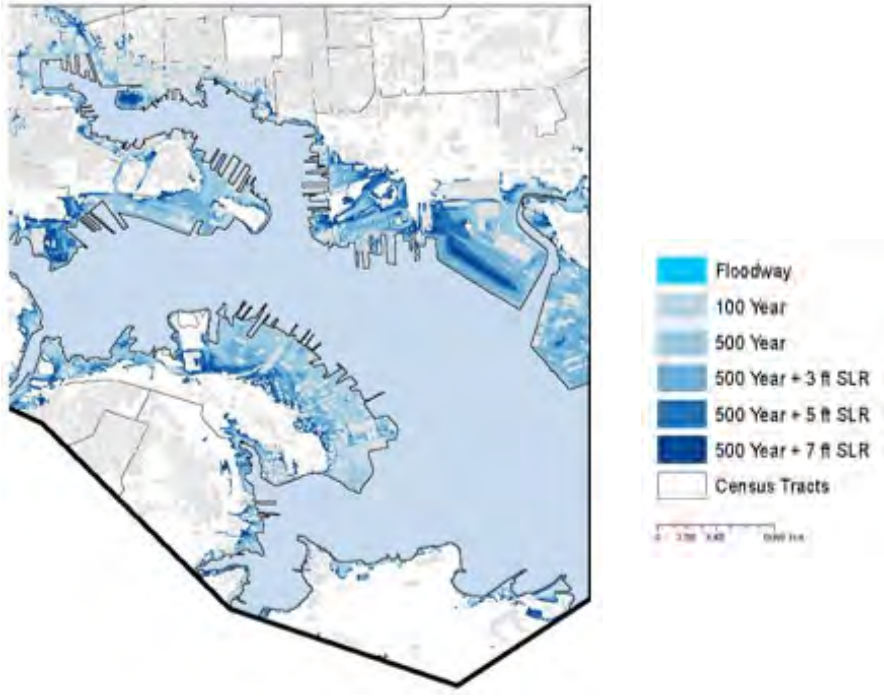


Figure 18: Industrial Flood Exposure Areas



Sensitivity

Considering the number of assets that are exposed to flooding hazards, sensitivity identifies the degree to which these assets are vulnerable and how some may be more so than others. When considering flooding, for instance, a structure may be more vulnerable if the building is not compliant with Base Flood Elevation (BFE) guidelines. Additional characteristics may influence sensitivity further. Facilities that have been classified as essential to the continued health and welfare of the community must remain operational.

Adaptive Capacity

An asset's ability to respond to a hazard defines its adaptive capacity. In areas like Fells Point, many structures have repeatedly endured extreme flooding events. Indeed, many buildings can be adapted, but this potential is dependent upon additional factors, including occupant understanding and behavior, or the City's recognition of future changes to the hazard's frequency and intensity.

Inventory of Community Assets Susceptible to Flooding

Populations and property are extremely vulnerable to flooding. Homes and business may suffer damage and be susceptible to collapse due to heavy flooding. In addition, floods may threaten water supplies and water quality and initiate power outages. Floodwaters can carry chemicals (there are about half a dozen hazardous material sites and one oil refinery within Baltimore's flood zones), sewage (four wastewater facilities within flood zones), and toxins from roads, factories, and farms; therefore, any property affected by a flood may be contaminated with hazardous materials.[49] Debris from vegetation and man-made structures may also become hazardous during the occurrence of a flood. During flood events, objects (floating material such as wood or cars) in rivers and streams carry the force of the water behind them, increasing the potential for damage to other structures, like buildings and bridges. In permitting development, the City needs to take into account the need and capacity of emergency personnel to respond to a facility facing a hazard, particularly flood hazard zones.

Table 33: Sum of Parcels Within the 100 and 500-Year Floodplains

100 Year	Sum of parcels	2,941
	Square Footage	45,835,550 ft
	Year Constructed*	1754-2012
	Estimated Value	$2,659,994,010
500 Year	Sum of parcels	3,027
	Square Footage	43,062,241 ft
	Year Constructed**	1754-2012
	Estimated Value	$1,861,554,433

A flooding vulnerability assessment estimates the number of structures that are within the regulated 100-year floodplain and thus susceptible to 100-year flooding. There are about 2,941 facilities with an estimated value of $2,659,994,010 within the City's 100-year floodplains. (Economic loss estimates do not include calculations for contents and inventory.) Additionally, as many as 2,000 people would be displaced by a 100-year tidal flood. As many as 3,027 properties, with an estimated value of $1,861,554,433, are within the 500-year floodplain (Table 33).

Table 34 provides details regarding city-owned properties within the floodplain and floodways; floodplain counts include the properties within the floodway.

Table 34: City-Owned Facilities Within the 100-500 Year Floodplains

Facility Name	Neighborhood
DPW Museum	Inner Harbor
Brokerage Annex	Downtown
Wahl Bldg (Clinic)	Downtown
Culinary Arts Bldg	Downtown
Abel Wolman Bldg	Downtown
Signet Building	Downtown
Kids Diner	Downtown
Parking Control Agency	Penn-Fallsway
Surveys & Records Office	Penn-Fallsway
Impound Lot Cashier's Booth	Penn-Fallsway
War Memorial Bldg	Downtown
Water Street	Downtown
Adminis-DPW, Director's Staff	Downtown
U.S. Custom House	Downtown
Headquarters	Downtown
Police Headquarters, Annex	Downtown
Mounted Police	Penn-Fallsway
Fort Holabird Comfort Station	Holabird Industrial Park
Fort Holabird Park Service Bldg	Holabird Industrial Park
Thames Park	Fells Point
9 N Front St	Jonestown
1840 House	Jonestown
Administrative Bldg	Jonestown
Archeology Center	Jonestown
Carroll Mansion	Jonestown
Exhibition Center	Jonestown
Peale Museum	Downtown
Shingle Bldg (Overton's Old House)	Harford-Echodale/ Perring Parkway
Camp Small	Coldspring
Inner Harbor Park	Inner Harbor
Leon Day Park Baseball/ Football Fields	Gwynns Falls/Leakin Park
Port Discovery Fountain	Downtown

The completed vulnerability analysis found that the Inner Harbor and Downtown neighborhoods are the most vulnerable to inland flooding, based on the number of City-owned structures potentially impacted (Table 34). The Downtown neighborhood has 14 City-owned structures within the 100- and 500-year floodplains, and the Inner Harbor has two. Other neighborhoods with exposed City-owned facilities include Penn-Fallsway, Holabird Industrial Park, Fells Point, Harford-Echodale/Perring Parkway, Coldspring, and the Gwynns Falls/Leakin Park neighborhoods.

Inventory of Critical and Essential Facilities Susceptible to Flooding

For some services and facilities, even a slight chance of flooding is too great a threat. These facilities should be given special consideration when forming regulatory alternatives and floodplain management plans. Ideally, critical facilities should not be located within a floodplain if at all possible. However, due to a range of factors, many of Baltimore's critical facilities currently are sited within this zone (Table 35). If a critical facility must be in a floodplain, it should be given a higher level of protection so that it can continue to function and provide services during and after a flood. According to NOAA's Critical Facilities Flood Exposure Tool, the Westport Baltimore Gas and Electric facility and the Gould Street Generating Station are vulnerable to flooding.

Table 35: Critical Facilities in Baltimore Hazus Coastal Flood Extents

Critical Facility	100 Year	500 Year
Subway	0	0.42 miles
Railroad	15.24 miles	51.59 miles
Bridges*	3	4
Tunnels	1	1
Major Roads	15.08 miles	22.93 miles
Police Stations	0	0
Fire Stations	0	1
Emergency Operation Centers	0	0
Public Schools	0	1
Private Schools	0	0
Colleges^^	0	1
Hospitals	0	0
Nursing Homes	0	0
Cultural Facilities	3	6
Power Plants*	0	3
Waste Water Treatment Plants	0	2

Source: Hazus; GIS Data Collections
*Numbers based on Hazus inventory/Coastal Flood Extent, not Baltimore City Data.

The locations of essential facilities within FEMA floodplains are displayed on a map in Figure 20.

Figure 19: Baltimore City Essential Facilities and FEMA Floodplains

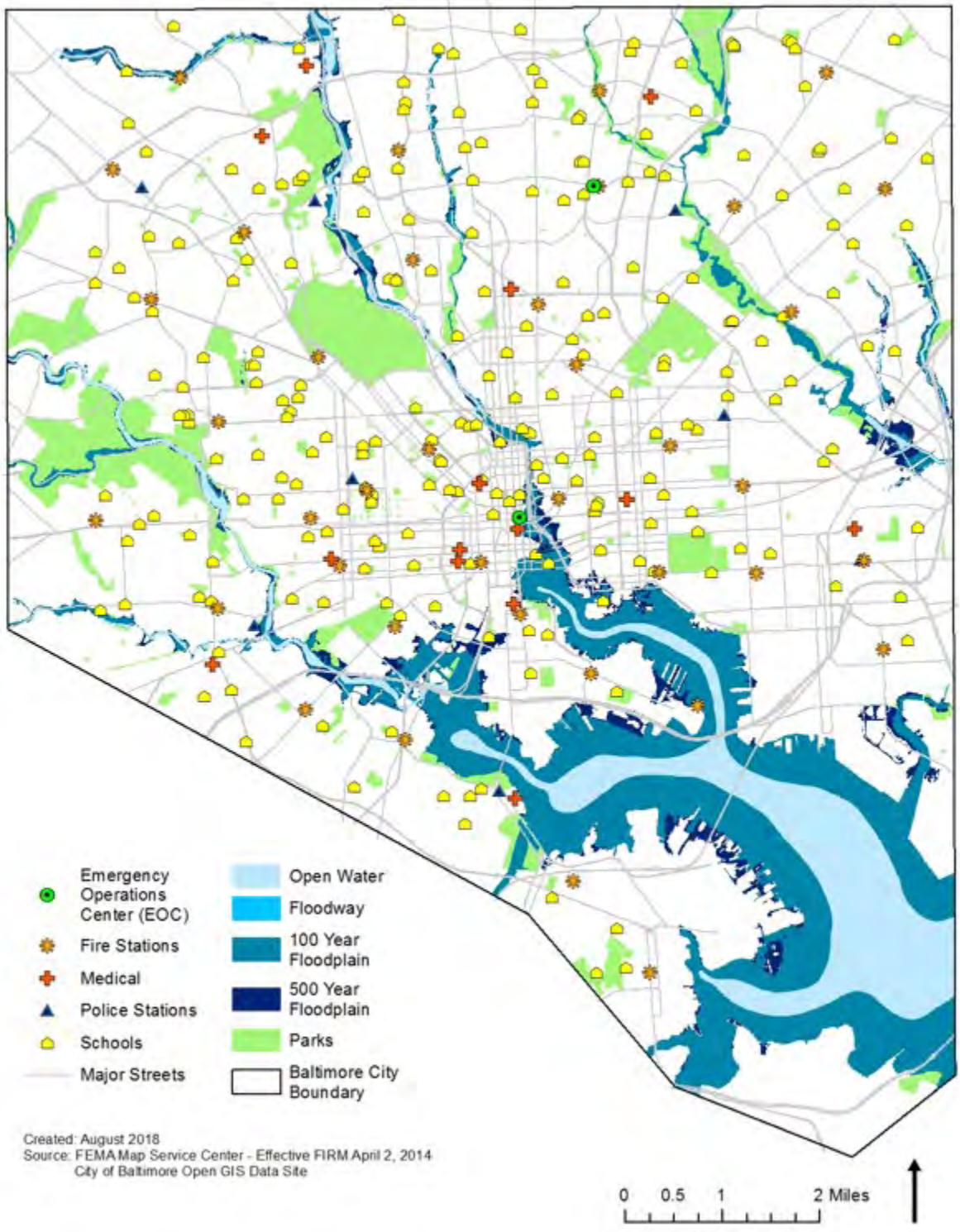


Table 36: Regulated FEMA 100-Year (1% annual-chance) Floodplain Essential Facilities Vulnerability Analysis

Facility Type	Name	Neighborhood
Fire	FB-1 FRB-1	Locust Point Industrial Area
Fire	E-45 T-27 M-14	Mount Washington
Police	Headquarters	Downtown
Police	Central	Downtown
School	University of Baltimore	Mid-Town Belvedere
School	The Crossroads School	Fells Point

Source: FEMA Map Service Center-Effective FIRM, April 2, 2014, and City of Baltimore Open GIS Data Sets

Table 37: Regulated FEMA 500-Year (0.2% annual-chance) Floodplain Essential Facilities Vulnerability Analysis

Facility Type	Name	Neighborhood	Flood Zone
Fire	FB-1 FRB-1	Locust Point Industrial Area	AE
Fire	E-45 T-27 M-14	Mount Washington	AE
Police	Headquarters	Downtown	AE
Police	Central	Downtown	AE
School	University of Baltimore	Mid-Town Belvedere	AE
School	The Crossroads School	Fells Point	AE
School	Cross Country Elementary/Middle	Cross Country	AE

Source: FEMA Map Service Center-Effective FIRM, April 2, 2014, and City of Baltimore Open GIS Data Sets

Note: The Crossroads School and the University of Baltimore structures are within both the 100-year and 500-year floodplains. The Fire Station identified as FB-1 FRB-1 structure is split between the 100-year and 500-year floodplains. Engine Company 45, labeled as E-45 T-27 M-14, is split between the 100-year and 500-year floodplains.

Flood Loss Estimations

In 2017, business at the Port of Baltimore directly generated about 13,650 jobs, while more than 127,000 jobs in Maryland were linked to port activities. The Port was responsible for nearly $3 billion in individual wages and salary and more than $310 million in State and local tax revenues.[50] Without adequate planning and preparation, that vitality may be at risk.

In order to conduct an accurate estimate of the economic losses produced by flooding, it is necessary to know the first-floor elevation for vulnerable structures, as well as the replacement costs, which are calculated using information on construction materials and square footage. Such specific information

for the properties are identified in Table 36 and Table 37, however, is not always readily available. Consequently, it is difficult to develop an accurate estimation of losses. Nevertheless, it is possible to develop specific mitigation measure to address the magnitude of potential losses within the coastal flood zones. The City will share the 2018 DP3 risk assessment with various port-related organizations. By combining the City's risk assessment with their own assumptions and site knowledge about structure size, equipment, function, these entities can respond appropriately.

Estimated flood loss estimations were integrated into the 2018 DP3 update using the 2014 FEMA Flood Risk Report-Baltimore City, MD Coastal Study. Through its Risk Mapping, Assessment, and Planning (Risk MAP) program, FEMA provides communities with updated Flood Insurance Rate Maps (FIRMs) and Flood Insurance Studies (FISs) that focus on the probability of floods and that show where flooding may occur, as well as the calculated 1-percent-annual-chance flood elevation. A 1-percent-annual-chance flood, also known as the base flood or formerly as the 100-year flood, has a 1-percent chance of being equaled or exceeded in any given year. FEMA understands that flood risk is dynamic—that flooding does not stop at a line on a map—and as such, also provides the following flood risk products:

- Flood Risk Report (FRR);
- Flood Risk Map (FRM); and
- Flood Risk Database (FRD).

After a flood risk project is complete, the data can be used in many ways to visualize and communicate flood risk during the flood risk project and other outreach initiatives. The goal of the FRR is to help inform and enable communities to take action to reduce flood risk. Possible users of this report include:

- Local elected officials
- Floodplain managers
- Community planners
- Emergency managers
- Public works officials
- Others with special interests (watershed conservation groups, environmental awareness organizations, etc.)

The risk products may be used to:

- Update local hazard mitigation plans
- Update community comprehensive plans
- Update emergency operations and response plans
- Develop hazard mitigation projects
- Communicate flood risk
- Inform the modification of development standards

The 2014 FEMA FRR for the Baltimore City, MD Coastal Study has been included as part of the 2018 DP3 update, as intended by FEMA. This information informed the mitigation strategies within the plan and will continue to be of use throughout the plan implementation process.

Flood loss estimates provided in the FRR were developed using a FEMA flood loss estimation tool, Hazus. Baltimore City, Maryland's coastal flood risk analysis incorporates results from a Hazus (FEMA version 2.1) analysis, which accounts for newly modeled areas in the coastal flood risk project and newly modeled depths for the 1-percent-annual-chance flood event. Potential losses were compared with updated Hazus general building stock (GBS) exposure data to estimate loss ratios for the 1-percent-annual-chance flood scenario. The following data layers provided within the FRD should be used to further analyze potential losses and areas where they are likely to occur. The tables in Table 38 are drawn from page 29 of the 2014 FEMA FRR for the Baltimore City, MD Coastal Study and show:

- **Flood Risk Project Refined Data** This set of tables in the FRD stores the updated Hazus GBS inventory data and resulting losses for this "Refined" study. The same census block and political area geometries were used, so direct comparisons can be made to FEMA's National 2010 Average Annualized Loss (AAL) study.
- **National 2010 AAL Study Data** This set of features and tables in the FRD stores the default Hazus (version 2.1) GBS inventory (2000 census) data and resulting losses from the National 2010 AAL study.

Table 38: Summary of Potential Flood Losses - Baltimore City (Total Project Area)

Flood Risk Project Refined Losses	Estimated Potential Losses for Flood Event Scenarios											
	Total Inventory		10% (10-yr)		2% (50-yr)		1% (100-yr)		0.2% (500-yr)		Annualized ($/yr)	
	Estimated Value	Percent of Total	Dollar Losses[1]	Loss Ratio[2]	Dollar Losses[1]	Loss Ratio[2]	Dollar Losses[1]	Loss Ratio[2]	Dollar Losses[1]	Loss Ratio[2]	Dollar Losses[1]	Loss Ratio[2]
Residential Building/Contents	$38,889,800,000	29%	N/A	N/A	N/A	N/A	$163,100,000	0%	N/A	N/A	N/A	N/A
Commercial Building/Contents	$61,766,800,000	47%	N/A	N/A	N/A	N/A	$1,030,000,000	2%	N/A	N/A	N/A	N/A
Other Building/Contents	$31,929,300,000	24%	N/A	N/A	N/A	N/A	$326,800,000	1%	N/A	N/A	N/A	N/A
Total Building/Contents[3]	**$132,585,900,000**	**100%**	**N/A**	**N/A**	**N/A**	**N/A**	**$1,519,900,000**	**1%**	**N/A**	**N/A**	**N/A**	**N/A**
Business Disruption[4]	N/A	N/A	N/A	N/A	N/A	N/A	$4,900,000	N/A	N/A	N/A	N/A	N/A
Total[5]	**$132,585,900,000**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**	**$1,524,800,000**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**

National 2010 AAL Study Losses	Estimated Potential Losses for Flood Event Scenarios											
	Total Inventory		10% (10-yr)		2% (50-yr)		1% (100-yr)		0.2% (500-yr)		Annualized ($/yr)	
	Estimated Value	Percent of Total	Dollar Losses[1]	Loss Ratio[2]	Dollar Losses[1]	Loss Ratio[2]	Dollar Losses[1]	Loss Ratio[2]	Dollar Losses[1]	Loss Ratio[2]	Dollar Losses[1]	Loss Ratio[2]
Residential Building/Contents	$13,133,800,000	45%	$0	0%	$0	0%	$0	0%	$0	0%	$0	0%
Commercial Building/Contents	$11,930,300,000	41%	$300,000	0%	$600,000	0%	$800,000	0%	$2,300,000	0%	$50,000	0%
Other Building/Contents	$4,239,400,000	14%	$300,000	0%	$500,000	0%	$600,000	0%	$1,200,000	0%	$40,000	0%
Total Building/Contents[3]	**$29,303,500,000**	**100%**	**$600,000**	**0%**	**$1,100,000**	**0%**	**$1,400,000**	**0%**	**$3,500,000**	**0%**	**$90,000**	**0%**
Business Disruption[4]	N/A	N/A	$90,000	N/A	$200,000	N/A	$200,000	N/A	$400,000	N/A	$10,000	N/A
Total[5]	**$29,303,500,000**	**N/A**	**$690,000**	**N/A**	**$1,300,000**	**N/A**	**$1,600,000**	**N/A**	**$3,900,000**	**N/A**	**$100,000**	**N/A**

Source: Hazus analysis results stored as the Flood Risk Assessment Dataset in the Flood Risk Database.
[1]Losses shown are rounded to nearest $10,000 for values under $100,000 and to the nearest $100,000 for values over $100,000.
[2]Loss ratio = Dollar Losses ÷ Estimated Value. Loss Ratios are rounded to the nearest integer percent.
[3]Total Building/Contents Loss = (Residential Building/Contents Loss) + (Commercial Building/Contents Loss) + (Other Building/Contents Loss).
[4]Business Disruption = Inventory Loss + Relocation Cost + Income Loss + Rental Income Loss + Wage Loss + Direct Output Loss.
[5]Total Loss = (Total Building/Contents) + Business Disruption

Note: The FRD, FRM, and FRR are "non-regulatory" products. They are available and intended for community use but are neither mandatory nor tied to the regulatory development and insurance requirements of the National Flood Insurance Program (NFIP). Communities, if authorized by State and local enabling authorities, may use FEMA Flood Risk Products as regulatory products.

National Flood Insurance Program and Repetitive Loss Properties

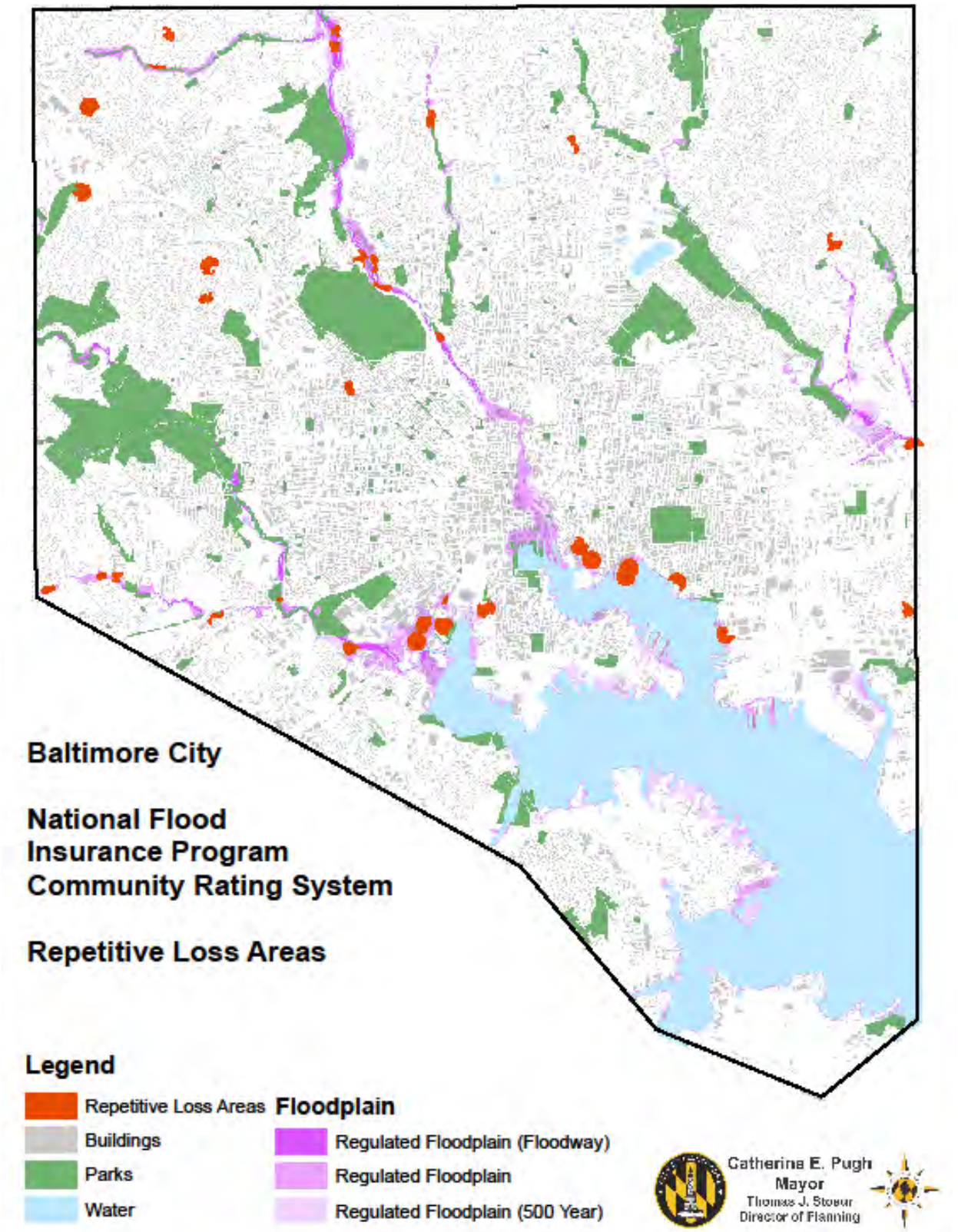
The NFIP's Community Rating System (CRS) classifies jurisdictions that have more than 50 repetitive loss properties as Category C Communities. Repetitive loss properties are properties that have experienced two or more flood insurance claims of at least $1,000 within a 10-year period since 1978. According to the NFIP, as of May 13, 2018, there are 65 repetitive loss properties in the City of Baltimore (see Table 39). These account for close to $15 million dollars in flood insurance claims. Among them, 12 properties are mitigated and 53 are unmitigated; 15 of the 65 are still insured. 18 of the 65 are commercial properties. The City of Baltimore is also a Class 5 CRS community. This provides residents with properties in the Special Flood Hazard Area with a 25-percent flood insurance discount. To keep this status, the City of Baltimore must fulfill its Category C obligations. This includes preparing a repetitive loss area analysis to identify and better understand flooding problems. The goal is to design outreach and mitigation strategies targeted at reducing risk and losses. The repetitive loss

area analysis maps low-lying areas containing repetitive loss properties, as well as nearby and/or adjacent properties with similar flood risk (see Figure 21). The following neighborhoods contain repetitive loss areas: Cheswolde, Glen, North Roland Park, Sabina-Mattfeldt, Kenilworth Park, Woodberry, Hampden, Ashburton Park, Grove Park, Frankford, Pulaski Industrial Area, Wyndhurst, Upper Fells Point, Canton, Broening Manor, Westgate, Beechfield, Carrol-Camden Industrial Area, and St. Agnes Campus. The most affected neighborhoods in terms of the number of repetitive loss properties are Camden Industrial Area, Beechfield, Westgate, the Jones Falls area, and Sabina-Mattfeldt. These neighborhoods are located along the Upper Jones Falls and Maiden's Choice Run (a tributary to Gwynns Falls). According to the 2014 Flood Insurance Study, inadequate storm sewer capacity, undersized bridges, and culverts are principle causes of flooding in these areas. In May 2018, over 100 properties in Beechfield and Westgate, along with nearby communities bordering Frederick Avenue in Southwest Baltimore, were affected by flooding caused in part by backwater flooding from culverts.

Table 39: Repetitive Loss Properties (2018)

Residential	Commercial
Beechfield Avenue	Central Avenue
Berlin Street	Clipper Mill Road (5)
Blackstone Avenue	Clipper Road
Boston Street	Falls Road
Bremen Street	Fell Street
Caroline Street	Lawndale Avenue
Clinton Street	Quad Avenue
Cottonworth Avenue	Smith Avenue (5)
Dulany Street	Wilkins Avenue (2)
Dundalk Avenue	
Falls Road (3)	
Fordham Drive	
Frederick Avenue (7)	
Frederick Road (5)	
Fulton Avenue	
Grantley Road	
Kenilworth Avenue	
Kennison Avenue	
Leadenhall Street	
Maisel Street (2)	
Mallow Hill Road	
Ridgley Street (3)	
Russell Street	
Seifert Avenue	
Sequoia Avenue	
Thames Street	
Union Avenue	
Warner Street (3)	
Western Run Drive	
Wilkins Avenue	

Figure 20: Repetitive Loss Area Analysis (2018)



Finally, during the update of the DP3, the NFIP survey was completed by the City's Floodplain Manager, Victor Ukpolo. The completed survey is included in Appendix 4-1.

The City reviews building permits in accordance with the Baltimore City Floodplain Management Code. This requires base flood elevation determinations to assess where flood protections are needed. The City also provides map information services as part of its CRS participation. These services are provided to anyone inquiring about the flood risk at a property, including flood zone, flood depth, and base flood elevation.

Highlights from the City's floodplain management program include that it:

- Regulates to the 500-year floodplain;
- Adopted a 2-foot freeboard;
- Has a history of acquiring properties in Special Flood Hazard Areas;
- Calculates substantial improvements to include cumulative construction costs over a 6-year period; and
- Prohibits manufactured homes.

Repetitive Flooding Areas and Roadways

In an effort to begin the process of identifying repetitive flood areas, flood, flash flood, and heavy rain data were reviewed, specifically the narratives associated with these datasets. From this review, an area-specific flood listing was compiled (see Table 40). Those neighborhoods shown in bold indicate areas that were cited multiple times within the dataset as being flooded.

Table 40: NCEI 1996-2018 Area-Specific Flood Events

Neighborhoods	
Northeast	Gardenville
North	**Golden Ring**
South	**Hampden**
Brooklyn	Hillen
Camden	**Inner Harbor**
Carroll Park	**Jones Falls**
Clifford	Mt. Royal
Crisp	Mt. Winans
Curtis Bay	Overlea
Fairfield	Roland Park
Fells Point	SW Highlandtown
Fort McHenry	West

Source: NCEI datasets reviewed included flood, flash flood, and heavy rain events

Additional data was gathered to add to area- specific flood issues during the DP3 update process. The planning team developed a listing of repetitive roadway flooding. The Department of Public Works (DPW) reviewed the initial listing and added additional roadways. DPW then provided more detailed location information, followed by causes and/or sources of flooding, which were added to the listing. Finally, the Mayor's Office of Emergency Management identified roadways that are designated evacuation routes, or roadways that are used as an evacuation route out of a neighborhood area.

As shown on Table 41, five of the roadways have been identified as evacuation routes.

Table 41: Repetitive Loss Flooding

Roadways	Evacuation Issue (Yes/No)	Source/Cause of Flooding
35th Street near Alameda	Unknown	Flooding due to inlet spacing/sizing.
3100 blk. Abell Ave., Waverly	No	Piped under residential development historic stream channel. "Manhole on west side of intersection of Abell and 32nd St. overflows with every rain- water bubbles up through manhole. This is likely causing an erosion problem which will result in a sinkhole" - 311 report from 3145 Abell Avenue.
5100 & 5300 block of Springlake Way	No	Stormwater. Area may be affected by a branch of Stony Run that runs through Loyola University, then underground to area of Springlake Way ponds.
Aisquith Street near 25th St.	No	"Reconstruction done at the corner of Aisquith the drain and street unleveled causing flooding of street crosswalk". "Storm manhole overflowing, flooding at North Ave & Aisquith"- 311 reports
Aliceanna St.-Fells Point	Closure	(Tidal) Street floods during heavy rains. Also affected by issue at Regester St.
Caroline & Fleet St.'s near Downtown	Closures	Storm drainage and maintenance issues on Caroline, Lancaster. Check pumps at Living Classrooms. Tidal flooding.
Clipper Mill Rd.	Yes	Floodway of Jones Falls
Coldspring Lane from Falls Rd. to I-83	Closures	Choked inlets; flooding due to Jones Falls floodway.
East Side Interstate 95	Unknown	Flooding from Herring Run and Moores Run
Erdman Avenue-East Side	Closures	Herring Run- Erdman/Pulaski/E. Monument experience flooding and cars stuck in water during heavy rain events.
Exeter Hall Avenue	Unknown	Street flooding
Frederick Avenue between Beechfield Ave. & North Bend	Yes	Maiden's Choice Run: underground pipes not able to handle water pushing South from Maiden's Choice. Water also flows downhill at Ten Hills.
Hillen Rd.	Closure	311 reports cite clogged storm drains at various points on Hillen Rd. Also, at Hillen & Northern Pkwy, water may rise at Mt. Pleasant Golf Course and partially block street, running downhill towards Perring Pkwy. & McClean Blvd.
Jones Falls Expressway @ President & Monument St.	Unknown	This is near the area where pipes run from the Jones Falls into Baltimore Harbor.
Middleton Court		Stormwater. Area may be affected by a branch of Stony Run that runs through Loyola University, then underground to the area of Springlake Way ponds.
Mt. Washington/ Kelly Rd.	Yes	Jones Falls. Repetitive flooding on Smith Ave bridge.
North Caroline St. near East Madison St.		Unknown

Roadways	Evacuation Issue (Yes/No)	Source/Cause of Flooding
Patapsco Ave. in Cherry Hill		Pipe realignment needed- with CIP. Patapsco River flooding.
Regester St. Fells Point	Closure	Possible issue near the sewer grate/manhole cover on Regester Street.
Spelman Rd. in Cherry Hill	Yes	Area previously evacuated- Storm drainage and maintenance issues. Affected by Patapsco River and tributary of Patapsco near Spelman.
St. Dunstan's Garth	No	Stormwater. Area may be affected by a branch of Stony Run that runs through Loyola University, then underground to the area of ponds on Springlake Way?
Thames St. in Fells Point	No	Tidal Flooding. Reports of Water coming up through street on S. Caroline.
Union Avenue	Yes	Floodway of Jones Falls
West Forest Park Dr.	Closure	Associated with Gwynn Falls flooding-Dickeysville
Wicomico St.	No	Gwynns Falls or Middle Branch Patapsco (tidal flooding). Reports of storm drain @ Washington Blvd. not draining. Industrial area near Carroll Park.

Coastal Hazards

Background

In addition to flooding, coastal hazards may have a variety of consequences. The impact of a significant coastal event is greatest for those areas along and immediately near the coast, but it can spread across the region. An evaluation of coastal hazards reported between 1997 and 2017 reveals that Baltimore City experienced more than one coastal event annually, as shown in Table 42. As discussed in the Coastal Hazards Profile of Chapter 3, these events are likely to be more frequent and intense in the future.

Table 42: Coastal Hazard Events (Storm Surge/ Tide and Coastal Flood) 1997-2017

County/City	Total Events	Annualized Events
Baltimore City	13	0.68

Source: National Centers for Environmental Information (NCEI)

Vulnerability Assessment

Baltimore City, with its harbor and proximity to the coast, can be highly vulnerable to coastal hazards. Specifically, electrical and communication utilities, as well as transportation infrastructure, are vulnerable to significant coastal events. Damage to electrical lines or communication towers has the potential to cause power and communication outages. In addition to lost revenues, downed power lines present a threat to personal safety. Further, downed wires and lightning strikes have been known to spark fires (for a description of risks associated with lightning, see the Precipitation Variability Risk and Vulnerability Assessment below).

Exposure

An evaluation of exposure identifies who and what may be vulnerable to coastal hazards. This analysis takes into consideration where significant coastal storms or other coastal hazards tend to occur, and what assets or facilities may be within those most vulnerable areas. The community assets and critical facilities inventories identify specific properties that are exposed to coastal hazards and depict maps of exposed areas (Table 43 to Table 45, Figure 22 and Figure 24).

The City employed Hazus modeling software, combined with expert input, to evaluate citywide vulnerability to coastal flooding. Sea, Lake, and Overland Surge from Hurricanes SLOSH) maps were also utilized to determine exposure. Three categories of storms were evaluated: Category 1 and Category 3 hurricanes, with varying levels of storm surge heights, and tropical storms. Neighborhoods that are not at risk to storm surge were omitted from the coastal flooding analysis.

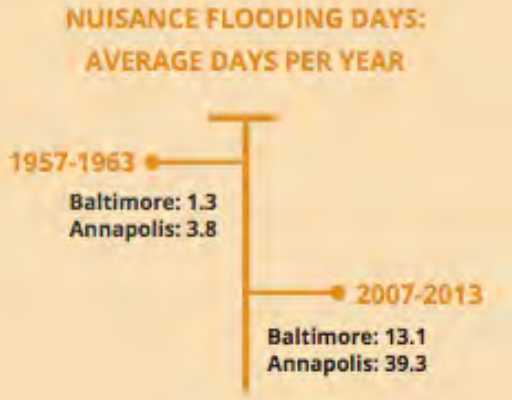
Sensitivity

Sensitivity evaluates the degree to which exposed assets are vulnerable to coastal hazards. Additionally, understanding sensitivity considers how some properties may be more vulnerable to coastal hazards than others. For instance, the sensitivity of a structure to significant coastal hazard events is based, in large part, on a particular building's construction and its location in relation to potential storm surge inundation zones. In general, mobile homes and wood-framed structures are more vulnerable to damage from wind during significant coastal events than steel-framed structures. Such construction types, however, are not typical of Baltimore. Other factors, including the location, condition, and maintenance of trees, also play a significant role in determining vulnerability to damage from coastal hazards. As noted above, various systems, including electrical and utility infrastructure, are highly sensitive to the impacts of coastal hazards.

An asset's ability to respond or adjust to a hazard defines its adaptive capacity. It is possible for the

HOW WILL THIS IMPACT YOU?

Rising sea levels are causing increased nuisance flooding — recurrent flooding at high tide not associated with storms — across the East Coast, especially in Maryland. According to a 2014 report by the National Oceanic and Atmospheric Administration, Annapolis (#1) and Baltimore (#2) rank at the top of a list of 10 U.S. cities where nuisance flooding is getting worse.



Nuisance flooding can overwhelm storm drains, close roads, compromise infrastructure and damage private property.

According to the Maryland Department of Transportation's State Highway Administration (MDOT SHA), Maryland has approximately 7,920 linear miles of roadways. Of those that are state-maintained, 158 miles will be threatened by sea-level rise in 2050, and 356 miles by 2100. MDOT SHA will use this vulnerability data for planning and assessment to determine potential adaptation measures for infrastructure.

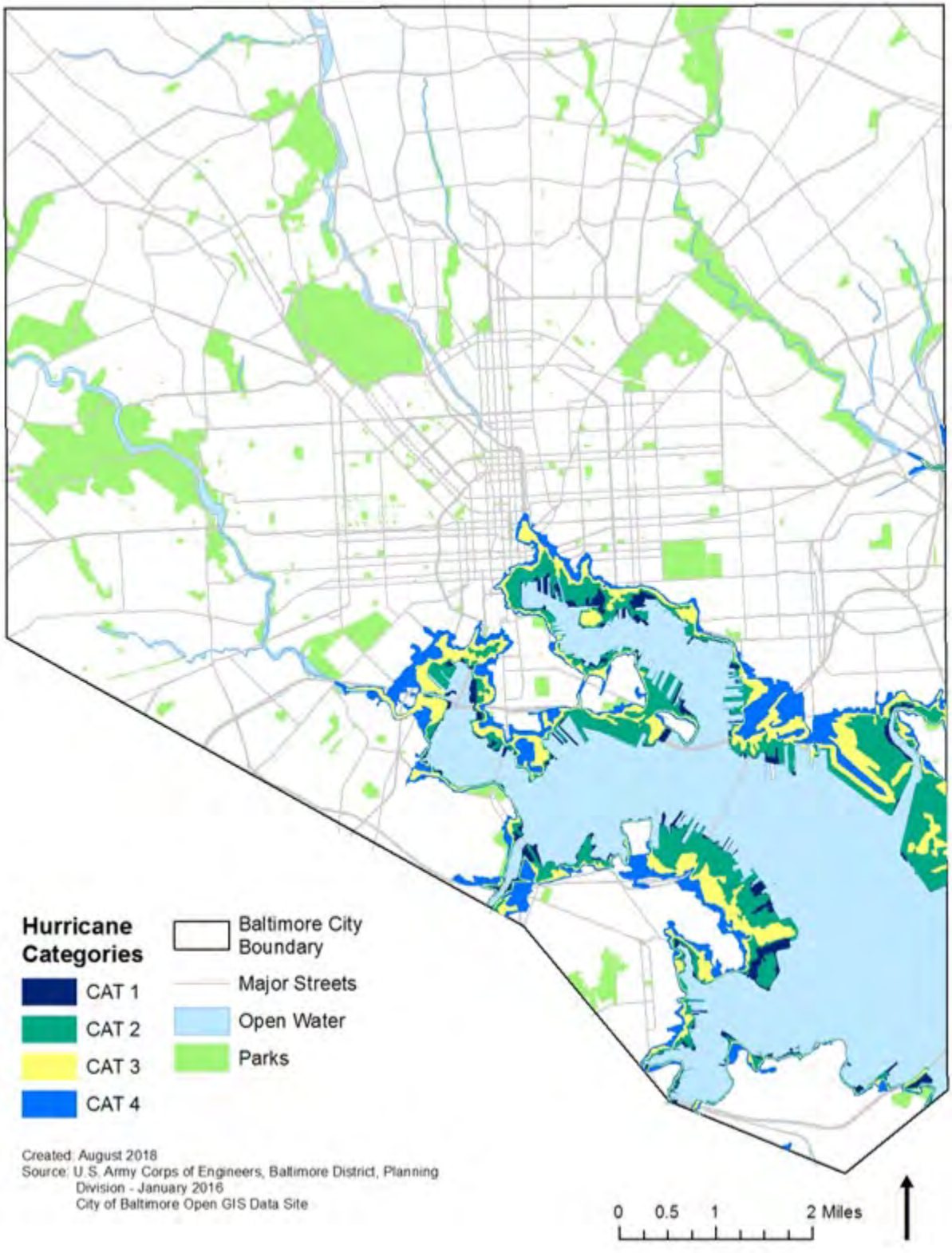
Source: MCCC Fact Sheet 4: Sea-level Rise Maryland Commission on Climate Change website at: www.mde.maryland.gov/mccc

City to adapt to coastal hazards, but this potential is dependent upon additional factors, including a comprehensive understanding of the risks associated with coastal hazards, infrastructural and structural preparedness, and regulations for development within exposed areas.

The vulnerability of Baltimore residents to coastal hazards is primarily based on the availability, reception, and individual understanding of early warnings. Once warned of an impending significant coastal hazard event, seeking shelter in a substantial indoor structure—one that is also wind-resistant and outside of storm surge zones—is recommended as the best protection against bodily harm. Figure 22 depicts a hurricane storm surge map. Storm surge has the potential to inundate a significant portion of the City. Baltimore's harbor and waterways are the life-blood of the City and have been a focus of industrial, commercial, and residential development in recent years.

The City utilized similar techniques when evaluating vulnerability to coastal flooding combined with anticipated Sea Level Rise (SLR). Various SLR scenarios were evaluated. Due to the uncertainty of climate conditions, and thus of relative seal level rise projections, it can be difficult to assign quantitative probabilities to projections of sea level increases. The Maryland Commission on Climate Change's Scientific and Technical Working Group estimates that Maryland shorelines could see up to a 2-foot increase in sea level (over 2000 levels) by 2050 and possibly more than 4 feet by 2100 if global emissions of heat-trapping gases are not dramatically reduced.

Figure 21: Baltimore City Hurricane Storm Surge



Critical and Essential Facilities Susceptible to Coastal Hazards

Table 43 identifies key City-owned assets and facilities within Baltimore's 500-year floodplains, including estimates for an additional 3, 5, or 7 feet in sea level rise.

In all of Maryland, a recent study reports, approximately 800 miles of roadway are vulnerable to impact if sea levels rise more than 2 feet.[51] This same rise would affect 93 bridges, culverts, and highway structures in Maryland. If sea levels rise as much as 5 feet, which is what high-end predictions suggest, an estimated 3,700 miles of road could be underwater.[52] In Baltimore, as Table 43 suggests, 32.35 miles of local roadway would be underwater in a 500-year event with the projected additional 5-foot sea level rise. For this reason, it is essential to consider transportation functionality that accommodates projected sea level rise as part of future strategies.

Table 43: Critical Facilities in Baltimore City, Hazus Coastal Flood Events, and Sea Level Rise

Critical Facility	500 Year	500 Year +3 ft SLR	500 Year +5 ft SLR	500 Year +7 ft SLR
Subway	0.42 miles	0.79 miles	0.79 miles	0.79 miles
Railroad	51.59 miles	76.64 miles	93.59 miles	107.89 miles
Bridges*	4	4	4	8
Tunnels	1	1	1	1
Major Roads	22.93 miles	26.85 miles	32.35 miles	37.14 miles
Police Stations	0	1	1	2
Fire Stations	1	1	1	1
Emergency Operation Centers	0	0	0	0
Public Schools	1	1	1	2
Private Schools	0	0	0	0
Colleges	1	1	1	1
Hospitals	0	0	0	0
Nursing Homes	0	0	0	0
Cultural Facilities	6	16	18	30
Power Plants*	3	4	4	7
Waste Water Treatment Plants	2	2	2	2

Source: Numbers based on Hazus Inventory/Coastal Flood Events, Not Baltimore City Data

Table 43 shows the estimated number of facilities (sorted by type) and their value, that are susceptible to inland flooding. To ensure that these facilities continue to offer their services before, during, and after a hazard event, each will require special attention and a high level of protection. Table 43, Table 44, and Table 45 were included in the 2013 DP3. As part of the 2018 update, new mapping was completed. Table 45 indicates that six essential facilities are within hurricane storm surge inundation areas.

Table 44: Hazus-Flood: Sum of Facilities (Type) in Floodplain

Facilities (Type)	500 Year	500 Year + 3 ft SLR	500 Year + 5 ft SLR	500 Year + 7 ft SLR
	Number of Buildings	Number of Buildings	Number of Buildings	Number of Buildings
Hospitals	16	23	22	24
Schools	4	5	5	7
Fire Stations	2	2	3	3
Police Stations	1	3	3	6
Emergency Operation Centers	0	0	0	0
Power Plants	7	7	8	13
Waste Water Treatment Plants	4	4	4	4

Source: Numbers based on Hazus Inventory/Coastal Flood Events, Not Baltimore City Data

Table 45: Hurricane Storm Surge Categories and Essential Facility Vulnerability

Facility Type	Name	Neighborhood	Cat. 1	Cat. 2	Cat. 3	Cat. 4
Fire	FB-1 FRB-1	Locust Point Industrial Area	Yes	Yes	Yes	Yes
Police	Headquarters	Downtown		Yes	Yes	Yes
Police	Central	Downtown				Yes
School	The Crossroads School	Fells Point		Yes	Yes	Yes
School	Sharp-Leadenhall Elementary	Sharp-Leadenhall				Yes
School	Baltimore International College	Downtown				Yes

Figure 23 illustrates the mapped locations of cultural and critical facilities within the 100- and 500-year floodplains, as well as the 500-year floodplain with projected sea level rise scenarios. This map was developed as part of the 2018 Coastal Adaptation Planning and Implementation Report (CAPIR).

Figure 22: Cultural and Critical Facilities Located within Floodplains and SLR Projections

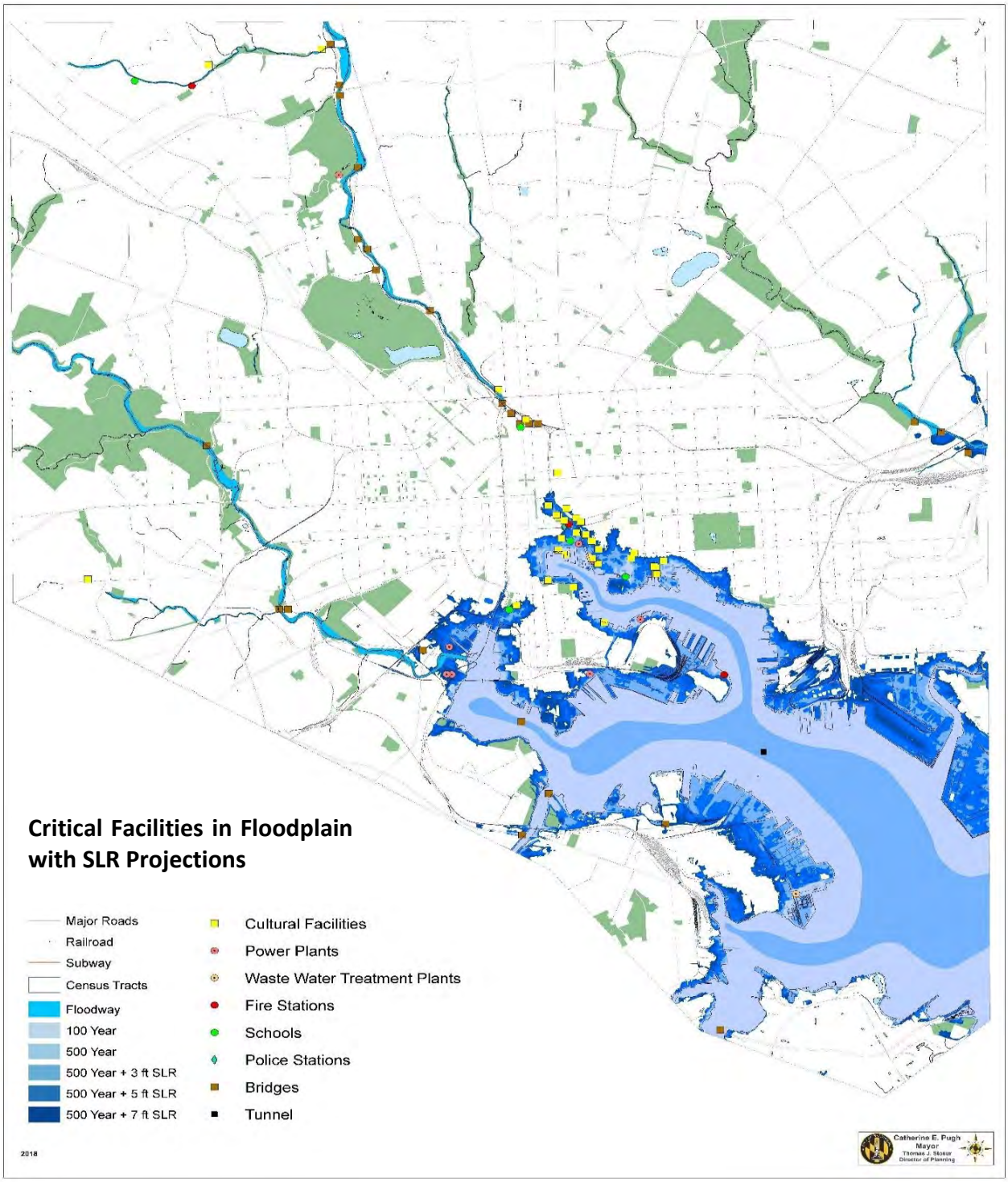
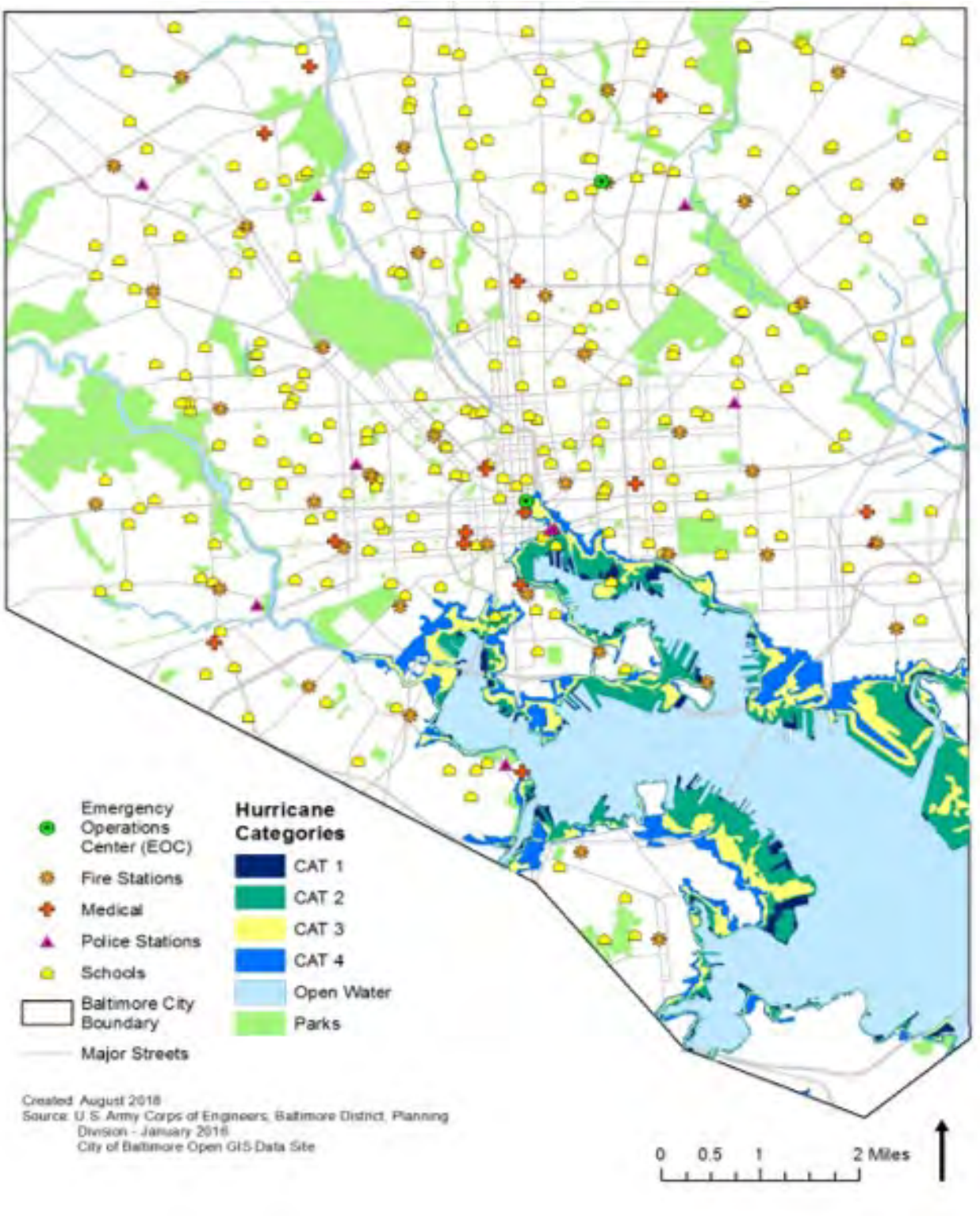


Figure 23: Baltimore City Essential Facilities and Hurricane Storm Surge



As a port city, Baltimore is very much dependent on its harbor and waterways. According to the Maryland Port Administration July 27, 2017 press release, the Port of Baltimore set new records in 2017 by handling 10.7 million tons of general cargo and the most containers and autos in its history. Business at the Port of Baltimore generates about 13,650 direct jobs, while more than 127,000 jobs in Maryland are linked to port activities. The Port is responsible for nearly $3 billion in individual wages and salary and more than $310 million in State and local tax revenues.

In order to conduct an accurate estimate of the economic losses produced by flooding, it is necessary to know the first-floor elevation for vulnerable structures, as well as the replacement costs, which are calculated using information on construction materials and square footage. Such specific information however, is not always readily available. Consequently, it is difficult to develop an accurate estimation of losses. Nevertheless, it is possible to develop specific mitigation measure to address the magnitude of potential losses within the coastal flood zones. The City will share the DP3 risk assessment with various port-related organizations. By combining the City's risk assessment with their own assumptions and site knowledge about structure size, equipment, function, these entities can respond appropriately.

Figure 24: Hurricane Isabel Flood Impacts (2003)

Flooding in Baltimore's inner harbor after Hurricane Isabel in 2003. Source: Tree Baltimore. Climate Change Preparedness in Baltimore - http://treebaltimore.org/climate-change-preparedness-in-baltimore/#.W365Ls5KjIU

Table 46 details the potential losses to structures within the 100- and 500-year floodplains and identifies the percentage of building damages. This analysis was not updated during the 2018 DP3 update, however, new mitigation strategies developed include the completion of enhanced Hazus studies using Baltimore City data points.

Table 46: Hazus-Mh Mr5 Hurricane Annualized Loss Estimates by Occupancy

Agriculture	Commercial	Educational	Government	Industrial	Religion/ Non-Point	Residential
$2,000	$351,000	$21	$18,000	$71,000	$35,000	$2,121,000

Source: Table 46, Maryland Emergency Management Agency, 2011: 132.

THE PORT OF BALTIMORE

History of the Port of Baltimore

Historically, the City of Baltimore was a major industrial city that relied heavily on port activities as an economic base. Though not all industry has remained, port activities continue to have a significant impact on the City's economy and Baltimore retains its predominance as a major port city in North America.

Business at the Port of Baltimore generates about 13,650 direct jobs, while about 127,000 jobs in Maryland are linked to port activities. The Port is responsible for $3 billion in personal wages and salary and more than $310 million in state and local taxes.

The Port of Baltimore, ranked as one of North America's top fifteen container ports, features both public and private marine terminals for handling cargo. In addition, the MPA has fostered economic development through cruise line operations since the opening of the Cruise Maryland Terminal in 2006.

In 2012, the Port of Baltimore received a Colliers International Port Award for its ability to maintain the delicate balance with surrounding ecological habitats and for its ability to demonstrate delicate engineering when maneuvering new, larger post-Panamax cranes

under the Chesapeake Bay Bridge.[1] The 2012 North American Port Analysis also noted that Baltimore

is one of only four East Coast cities expected to be post-Panamax ready for the 2015 Panama Canal Expansion. In actuality, new cranes that were installed earlier in 2013, along with the deepening and reconstruction of the Seagirt Marine Terminal, give Baltimore the distinction of being one of only two post-Panamax that have already met the conditions required for the new, larger ships.

The Maryland Port Administration

The Maryland Department of Transportation (MDOT) oversees the operations of the Maryland Port Administration (MPA), which is a public authority for managing port activities and operations. Annually, the MPA reviews and revises, if necessary, its two hurricane preparedness plans: one for Marine Terminals and another for the Baltimore City World Trade Center. The MPA hurricane preparedness plans are intended to establish policy and procedures to prepare both vessels and facilities, and the people and personnel within, for hurricane force weather.

The plans recognize the threat to life posed by extreme coastal storms and their hazards including high winds, storm surges, heavy rains, and flooding. As part of their effort to increase preparedness for such hazards, the MPA established a maritime reporting standard for describing the following conditions:

1. **SEASONAL ALERT:** Set on June 1st and remain in effect through November 30. At this time hurricane plans should be reviewed and weather reports closely monitored for any hurricane activity.
2. **STORM CONDITION:** Set when high winds 55 mph/48kts or greater are forecast. This condition includes all phases of the approaching storm.
3. **WHISKEY:** (also referred to as ***HURRICANE WATCH***). Set when gale force winds (34+mph) associated with tropical cyclone activity are expected to arrive at the Port within **72 hours**.
4. **RAY:** (also referred to as ***HURRICANE WATCH***). Set when gale force winds (34+mph) associated with tropical cyclone activity are expected to arrive at Port within **48 hours**.
5. **YANKEE:** (also referred to as ***HURRICANE WARNING***). Set when gale force winds (34+mph) from a hurricane force storm are expected to arrive at the Port within **24 hours**, and as soon as practical after the storm passes.
6. **ZULU:** (also referred to as ***HURRICANE WARNING***). Set when gale force winds (34+mph) from a hurricane force storm are expected to arrive at the Port within **12 hours**.

Baltimore's Seagirt Marine Terminal
Source: ChooseMaryland.org

The maritime hurricane alert conditions correlate directly with similar systems that are currently used by civilian and military agencies, as shown in Table 4–17 Comparison of Civilian, Maritime and Military Hurricane Conditions. Updated conditions are released by the Coast Guard Captain of the Port (COTP) throughout hurricane season — from June 1st to November 30th. The purpose of setting and reporting standard maritime hurricane conditions is to give the port community — including MPA personnel, ship captains, businesses and property owners, and other agencies, entities, and individuals — adequate time to prepare. A different series of preparation actions are recommended to be taken for each condition; these may include, to name just a few, steps such as advising tenants to remain at their posts or testing site operations and ensuring that emergency response systems are operational and prepared. Additionally, the plans identify procedures to be undertaken following hurricane events.

In each document, the MPA notes that the plan is "advisory in nature and does not supersede any directives or requirements established by the Maryland Emergency Management Agency (MEMA) State of Maryland Emergency Operations Plan (EOP) or those promulgated in the U.S. Coast Guard Captain of the Port (COTP) Upper Chesapeake Bay Hurricane Contingency Plan." Furthermore, various property owners and terminal operators in the Port of Baltimore may have their own preparedness plan and requirements to complement the MPA plans; however, while these plans may be even more strict than the MPA plan, they may not be less so.

Baltimore City World Trade Center
Source: Baltimore.CityBizList.com

Table 4-17 Comparison of Civilian, Maritime and Military Hurricane Conditions

Projected Storm Path and Seasonal Considerations	Maritime Hurricane Conditions	Civilian Hurricane Conditions	Military Hurricane Conditions
1 December - 31 May	NONE	NONE	NONE
1 June - 30 November	SEASONAL ALERT (set automatically)	HURRICANE SEASON (set automatically)	SEASONAL ALERT (set automatically)
Hurricane force winds are expected within 72 hours at (geographic point)	CONDITION WHISKEY	HURRICANE WATCH	CONDITION FOUR
Hurricane force winds are expected within 48 hours at (geographic point)	CONDITION XRAY	HURRICANE WARNING	CONDITION THREE
Hurricane force winds are expected within 24 hours at (geographic point)	CONDITION YANKEE	HURRICANE WARNING	CONDITION TWO
Hurricane force winds are expected within 12 hours at (geographic point)	CONDITION ZULA	HURRICANE WARNING	CONDITION ONE
After the storm passes or when projected storm path has storm not impacting (geographic point)	Return to SEASONAL ALERT	Return to HURRICANE SEASON	RESPONSE & RECOVERY

Source: MPA Hurricane Preparedness Plan for Marine Terminals 2018: 14

Precipitation Variability

Background

With precipitation from atmospheric rivers, as well as other storm events, precipitation variability poses a risk, particularly from hazards during and after storm events. Hazards associated with precipitation variability manifest as a thunderstorm (with lightning and hail), winter storm, or drought (for a description of flooding hazards, see the Flooding Risk and Vulnerability Assessment above; for risks associated with strong winds, see the Wind Risk and Vulnerability Assessment).

Significant thunderstorms are very difficult to predict, but based on past National Centers for Environmental Information (NCEI) records of thunderstorm occurrence, a reasonable determination of the probability of future significant hail or lightning events can be made. Table 47 indicates that Baltimore City experiences a significant thunderstorm event a little over once every 3 years.

In addition to thunderstorms, winter storms create dangerous conditions in Baltimore. Using data collected between 1993 and 2010, it is determined that Baltimore City already experiences an average of 7.39 winter storm events each year, and a little more than one ice event every 5 years (Table 48). Incidentally, 5.17 annualized winter storms were reported in the 2013 DP3, indicating winter storms events are occurring with greater frequency in the Baltimore area. This increasing trend is in line with projections for changing future conditions. Climate change is expected to bring an increase in winter precipitation, increasingly wetter weather, and more precipitation that falls in liquid form than frozen. Studies project a 25-percent decrease in snow volume by the year 2025 and a 50-percent decrease by the end of the century.

Table 47: Thunderstorm Events (Lightening and Hail) 1957-2017

County/City	Total Events	Annualized Events
Baltimore City	22	0.36

Source: National Centers for Environmental Information (NCEI)

Table 48: Winter Storm and Nor'easter Events (Winter Weather, Winter Storm, Ice Storm, Blizzard, Heavy Snow, Frost/Freeze, and Cold/ Wind Chill) 1996-2017

County/City	Total Events	Annualized Events
Baltimore City	162	7.36

Source: National Centers for Environmental Information (NCEI)

Finally, in addition to risks associated with extreme precipitation events, drought incidences may also present a risk in Baltimore. Due to the relatively short period of recorded NCEI drought data, it is difficult to accurately forecast future frequency of drought. However, upon examining available data, it is reasonable to assume that Baltimore City, despite its management of the reservoirs, is susceptible to impacts of extended drought events. Already, significant drought events occur a little more than once every 2 years (Table 49). Additionally, future droughts are expected as a result of more frequent extreme heat events due to the warming of Baltimore's climate (see the Extreme Heat Risk and Vulnerability Assessment later in this chapter). There may also be concern for accelerated sedimentation of the reservoirs from the combination of drought events (which puts stress on vegetation) and more frequent and intense precipitation events. In addition to the sedimentation, these short-duration storms do not allow for the saturation of soil and the recharge of groundwater that feed streams that in turn feed the reservoirs. Long-term climate forecast models suggest that a

warming planet will lead to changes in precipitation distribution as well as more frequent and severe drought.

Table 49: Drought Events 1998-2017

County/City	Total Events	Annualized Events
Baltimore City	9	0.45

Source: National Centers for Environmental Information (NCEI)

Vulnerability to Precipitation Variability

Precipitation variability can present a number of hazards to which Baltimore may be vulnerable. Depending on the nature of the event, the vulnerability may be quite different. Storm events accompanied by hail and lightning, as well as winter storms and droughts, could potentially impact Baltimore and its residents.

Exposure

An evaluation of exposure identifies who and what may be vulnerable to precipitation variability hazards. This analysis takes into consideration where precipitation variability may occur, in addition to what assets and facilities may be located within those vulnerable areas. However, unlike some other hazard analyses, the exposure of Baltimore to precipitation variability is not limited to specific regions or areas. Rather, exposure is extensive, and the impacts are likely to affect everyone. Sensitivity, more than exposure, presents a better understanding of Baltimore's vulnerability to precipitation variability.

Sensitivity

Sensitivity evaluates the degree to which exposed assets are vulnerable to precipitation variability hazards. Additionally, understanding sensitivity recognizes the ways in which some properties may be more vulnerable to than others.

Hazards associated with thunderstorms often include lightning and hail. Building construction, location, and nearby trees or other tall structures will have a large impact on how vulnerable an individual facility is to hail or lightning strikes. A rough estimate of a structure's likelihood of being struck by lightning can be calculated using the structure's ground surface area, height, and striking distance between the downward-moving tip of the stepped leader (negatively charged channel jumping from cloud to earth) and the object.[53] In general, buildings are more likely to be struck by lightning if the structure is located on a hilltop; is tall or is surrounded by tall structures; or has large, exposed windows. Electrical and communication utilities are also vulnerable to direct lightning strikes. Communication and power supplies may be compromised during thunderstorms, and some critical facilities might not be equipped with a backup power source.

Structural vulnerability to hail is determined by a facility's construction and exposure. Metal siding and roofing is better suited to withstand the damages of a hailstorm than many other construction materials (though it may still sustain damage by denting). Exposed windows and vehicles are also susceptible.

Winter storms pose many of the same dangers as thunderstorms but also have additional specific concerns. As in a thunderstorm, transportation and communication structures are at risk from winter storms. The type and age of construction influences a facility's vulnerability to winter storms. Building

construction type—particularly, roof span—and construction method are examples of factors that determine the ability of a building to perform under severe stress from the weight of a heavy snowfall. The potential for such damage was demonstrated by a notorious incident at the B&O Railroad Museum, a historic structure and repository of irreplaceable railroad industry artifacts and antique equipment, where heavy snow collapsed the Museum's roof.

Baltimore has several thousand row houses with flat roofs, which may be susceptible to collapse in the event of heavy snowfall. Recent experience has proven this vulnerability, and a number of roofs have collapsed in heavy winter storms. Unfortunately, the City does not maintain data on building roof type; therefore, this analysis can estimate neither the total number, nor the likely economic losses, of susceptible structures.

Winter storms may bring more than just snow. Ice storms and freezing rain events can be particularly disruptive. Freezing rain and ice can weigh down power lines, cause branches to break, and cause trees to break or become uprooted. Downed trees and power lines may disrupt traffic, hinder emergency response vehicles, and necessitate costly clean-up and disposal of debris. Damage to power lines or communication towers has the potential to cause electrical and communication disruptions for residents, businesses and critical facilities. In addition to lost revenues, downed power lines present a threat to personal safety. Furthermore, downed wires have been known to spark fires. Vulnerability to winter storm damage will vary, in large part, due to specific factors; for example, proactive measures, including regular tree maintenance and utility system winterization, can minimize property vulnerability. It is impossible to predict with certainty where lightning or hail will strike, and all counties in Maryland are susceptible to these dangers.

Likewise, while extreme precipitation may pose a danger, a lack thereof can also become a hazard. Short-term droughts can impact agricultural productivity (though not a common activity in Baltimore City), while longer term droughts are also likely to impact water supply. Groundwater is a commonly used source of water supply and is obtained from both confined and unconfined aquifers. Many individual homeowners in rural areas pump groundwater from their own wells. Public water suppliers like the Washington Suburban Sanitary Commission rely on surface waters for their water supply. About two-thirds of Maryland's citizens regularly consume water that originates from a surface water source. In general, counties that have invested in water supply and distribution infrastructure are generally less vulnerable to drought. However, communities where water supplies rely on the Potomac or Susquehanna Rivers and their tributaries are more vulnerable during a drought than those using the Chesapeake Bay for water supply. This is due to the lack of recharge from surrounding watersheds that flow into the rivers.

Adaptive Capacity

An asset's ability to respond or adjust to a hazard defines its adaptive capacity. It is possible for the City to adapt to precipitation variability, but this potential is dependent upon additional factors, including a comprehensive understanding of the risks associated with precipitation variability hazards, infrastructural and structural preparedness, and regulations for development that may be exposed or highly sensitive.

Community Assets Susceptible to Precipitation Variability

The vulnerability of Baltimore residents to precipitation variability as it specifically relates to storm events is based on factors including availability, reception, and understanding of early warnings. Once

warned of an impending storm hazard, individuals who immediately seek shelter in a sturdy building or metal-roofed vehicle are much safer than those who remain outdoors. Early warnings of severe storms are also vital for aircraft flying through the area.

Due to the wide scope of potential impacts from precipitation variability events, it is difficult to identify specific vulnerabilities in Baltimore's community assets. By recognizing key characteristics, which would increase a structure's vulnerability (as mentioned in the sensitivity segment above), residents and City agencies can increase overall resiliency by reinforcing structural integrity and developing comprehensive preparedness guidelines.

Critical and Essential Facilities Susceptible to Precipitation Variability

Critical facilities are vulnerable to the effects of heavy storms, particularly to impacts on energy and infrastructure systems. However, facilities are generally equally vulnerable, as precipitation variability events are not usually confined to certain regions. Hospitals and other essential medical facilities depend on a continuous power supply, without which the lives of thousands of patients may be in jeopardy. Ensuring that these facilities have back-up power systems is vital. Not all critical facilities have redundant power sources, and some may not even be wired to accept a generator.

With regard to extreme winter storms, future plan updates should consider a closer examination of the risk to critical facilities by looking at what type of construction was used for the critical facilities in jurisdictions considered to be at higher risk of winter storms.

Wind

Background

Wind damage can come from a storm front moving through (e.g., derecho) or a tornado. Generally, every area in Maryland is vulnerable to severe winds, especially those in central Maryland and the Chesapeake Bay region. In Maryland, however, Baltimore City is not considered an area with high wind risk. Based on historical frequency of high wind event occurrences, revealed using NCEI data, a reasonable determination of the probability of future high wind and tornado events can be made. Evaluating high wind events that were reported from 1957 to 2017 reveals that more than two high wind events occur each year (Table 50).

Table 50: Thunderstorm Wind and Derecho Events (Thunderstorm Wind, High Wind and Strong Wind) 1957-2017

County/City	Total Events	Annualized Events
Baltimore City	156	2.56

Source: National Centers for Environmental Information (NCEI)

Table 51: Tornado Events (Tornado and Funnel Cloud) 1996-2017

County/City	Total Events	Annualized Events
Baltimore City	4	.018

Source: National Centers for Environmental Information (NCEI)

Although relatively infrequent, tornadoes have had significant impacts on Maryland in the past and are likely to impact Maryland in the future. According to NCEI historical records (Table 51), Baltimore experienced four tornado events between 1996 and 2017, or approximately 0.018 tornadoes each year.

Vulnerability to High Wind Events

Tornadoes are considered low-frequency, high-impact events. Electrical utilities and communication infrastructure are most vulnerable to tornadoes. Damage to power lines or communication towers has the potential to cause power and communication outages for residents, businesses, and critical facilities. In addition to lost revenues, downed power lines present a threat to personal safety. Furthermore, downed wires coupled with lightning strikes have been known to spark fires (for details regarding vulnerability to lightning, refer to the Precipitation Variability Risk and Vulnerability Assessment).

Exposure

An evaluation of exposure identifies who and what may be vulnerable to high wind hazards. This analysis takes into consideration where high wind events may typically occur, in addition to what assets and facilities may be located within those vulnerable areas. Wind events, by their nature, are randomly occurring events; no particular region within a local area such as Baltimore City is more or less at risk of occurrence. However, the impacts from these events could cause windows to break, damage to exterior building features, and loss of power.

Sensitivity

Sensitivity evaluates the degree to which exposed assets are vulnerable to high wind hazards. Additionally, understanding sensitivity recognizes the ways in which some properties may be more vulnerable to high wind events than others. For instance, a structure's vulnerability to a tornado is based, in large part, on building construction methods and standards. In general, mobile homes and wood-framed structures are more vulnerable to damage in a tornado than steel-framed structures. (Baltimore, however, has a limited number of such structures.) Other factors, including location and the condition and maintenance of trees, also play a significant role in determining vulnerability.

The factors affecting the sensitivity of Baltimore residents to a tornado are related to availability, reception, and understanding of early warnings. Once residents are warned of an impending tornado hazard, seeking shelter indoors on the lowest floor of a substantial building, away from windows, is recommended as the best protection against bodily harm.

Adaptive Capacity

An asset's ability to respond or adjust to a hazard defines its adaptive capacity. It is possible for the City to adapt to future high wind events, but this potential is dependent upon additional factors, including a comprehensive understanding of the risks associated with high wind, an evaluation of the projected increased intensity and frequency of high wind events, infrastructural and structural

resiliency and preparedness, and regulations for structures and development that may be exposed or highly sensitive.

Vulnerability to High Wind Events

A majority of Baltimore City's structures were built in the late 19th or early 20th century and are primarily constructed of heavy brick or stone. Wood-frame structures that were built in the middle of the 20th century were also constructed from heavy materials. Additionally, these later structures were built according to Baltimore's building inspection professional standards and are thus expected to handle a significant wind load. Baltimore's newer buildings, while not constructed with materials of the same density as the older building stock, have been subject to the International Building Code, which dictates that all construction have a wind resistance to winds of up to 160 mph.

However, two primary building classifications stand out as potentially vulnerable structures in the event of a tornado or high wind event. These structures include:

- Dilapidated structures: Well-maintained, older properties are expected to fare reasonably well in the event of a tornado or windstorm; however, numerous vacant and/or dilapidated structures in Baltimore City sustain damage from wind events on a regular basis. The City expends resources by securing the area, which often means "finishing" the demolition and buttressing neighboring properties when the failure is an adjoining structure (e.g., rowhouse). These compromised structures are usually in economically stressed areas and exacerbate an already difficult situation. Baltimore City Housing Authority, Baltimore Development Corporation, and the Department of Planning are assessing areas with a significant number of dilapidated structures to identify and prioritize actions that can address this hazard.
- Gable-roofed structures: Gable-roofed structures are primarily found in Baltimore City's low-density residential neighborhoods. While most of these areas are fairly well-maintained, and residents should have little reason to expect significant damage, the physical nature of gabled roofs makes them more susceptible to damage in the form of de-shingling or, in extreme events, de-roofing.

Additionally, vacant structures may be more vulnerable. Abandoned or vacant properties are not likely to be insured or rebuilt if significant damage is sustained. If the damage is so severe that the City resolves to demolish a vacant structure, it would have an aesthetic impact on the community. Having empty lots among the remaining houses yields a "gap-tooth" appearance, which is a characteristic usually found in (and contributing to) blighted neighborhoods. This is an example of a secondary negative effect of hazard events.

Inventory of Critical Facilities Susceptible to High Wind

During a tornado or high wind event, critical facilities serve as shelter and help to ensure a safe and effective emergency response. Fortunately, most police, fire, school, and major hospital facilities in the City are constructed of heavy materials. However, some critical facilities in Baltimore may still be vulnerable to strong winds. In particular, structures that were built prior to the use of building codes and consideration of construction design wind speeds for corresponding zones may be vulnerable to wind damage.

Furthermore, not all critical facilities have redundant power sources, and some might not even be wired to accept a generator. Mitigation strategies include closer examinations of critical facilities, with priority given to the five essential facility types.

Estimated Losses

To estimate the potential dollar losses for a high wind event, planners used scenario planning, which demonstrates possible effects of a tornado. Tornadoes, by their nature, are randomly occurring events; no particular region within a local area such as Baltimore City is more or less at risk of a tornado occurrence. However, the damage that a tornado could potentially wreak on structures within a particular area varies significantly based on the quality and density of structures within it.

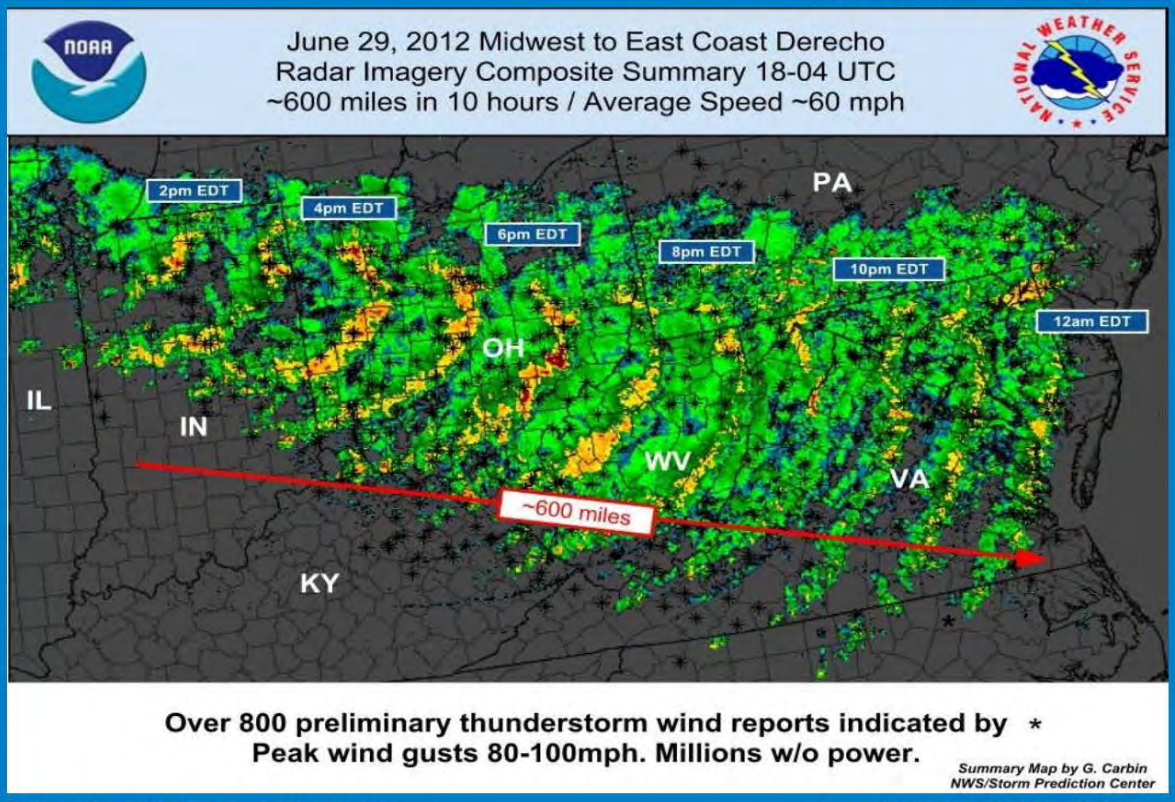
June 2012 Derecho

A derecho is a widespread, long-lived wind storm that is associated with a band of rapidly moving showers or thunderstorms. Although a derecho can produce destruction similar to that of tornadoes, the damage typically is directed in one direction along a relatively straight swath.

By definition, if the wind damage swath extends more than 240 miles (about 400 kilometers) and includes wind gusts of at least 58 mph (93 km/h) or greater along most of its length, then the event may be classified as a derecho. Derechos are most common in warm weather conditions, with more than 75% occurring between April and August. Maryland is expected to experience one derecho every four years.

The June 2012 derecho was one of the most destructive and deadly fast-moving severe thunderstorm complexes in North American history.

-Capital Weather Gang



Path and timeline of the June 2012 Derecho

Source: NWS/Storm Prediction Center

Typically, derecho-producing storm systems move at speeds of 50 mph or greater, and a few have been clocked at 70 mph. Such rapid movement means that darkening skies and other visual cues that serve to alert one to the impending danger (e.g., gust front shelf clouds) appear on very short notice. Advance notice given by a derecho often is not sufficient for one to take protective action.

Extreme Heat

Background

Extended periods of extreme heat can tax the energy delivery system, leading to high cooling costs and even blackouts or "brownouts." Extreme heat may adversely affect the integrity of structures or infrastructure, and other harmful costs of extreme heat are associated with human health and natural systems (Figure 26).

The Intergovernmental Panel on Climate Change (IPCC) Fifth Assessment Report indicates that it is very likely that hot extremes and heat waves will become more frequent as the Earth warms.[54] By the end of the century, the number of days above 90°F in Maryland is projected to more than double under lower greenhouse gas emissions scenarios, and roughly triple under higher emissions scenarios. Extended heat waves (temperatures above 90°F for at least three consecutive days) are expected to be much more frequent and longer lasting, particularly under higher emissions scenarios. Scientific predictions for increasing heat waves and temperature extremes are likely, with moderate confidence.[55]

Figure 25: Heat Wave Impacts on Baltimore's Inner Harbor 2013

Baltimore City's Inner Harbor turned a milky green color in Summer 2013 after a heat wave. Extended periods of heat reduce oxygen, killing marine life. During this July event, it was estimated that more than 200 fish were killed. Vulnerability to Extreme Heat. *Source: WJZ CBS Baltimore-Heat Wave Blamed for Inner Harbor Fish Kill?; July 29, 2013 at 5:35pm*

Extreme heat events have been more frequent in recent years and are expected to increase by the end of the century. Energy and utility systems, transportation infrastructure, natural systems, and residents are all vulnerable to extreme shifts in temperature. Sensitivity to extreme heat depends on location-related characteristics including tree canopy coverage, impervious surface area, and resident demographic information (for resident vulnerability). Additionally, neighborhoods near urban centers are more exposed to high heat conditions due to the Urban Heat Island effect.

Exposure

An evaluation of exposure identifies who and what may be vulnerable to extreme heat. This analysis takes into consideration where extreme heat may be most severe, in addition to what assets and facilities may be located within those vulnerable areas. Extreme heat may lead to power outages due to the increase demand on the electrical power supply infrastructure. During extreme heat events, people rely heavily on air conditioners, thus increasing the power demand. this increased demand may adversely affect power supply. Government facilities, especially those categorized as essential that do not have emergency back-up power are at-risk. These facilities must remain operational for the City to be considered resilient. Essential facilities have been identified in Table 31.

Sensitivity

Sensitivity evaluates the degree to which exposed assets are vulnerable to extreme heat hazards. Additionally, understanding sensitivity recognizes the ways in which some properties may be more vulnerable to extreme heat than others. For instance, a resident, structure, or asset may be more vulnerable if located in an area with minimal tree coverage. Additional characteristics, such as resident age or income, may influence sensitivity even further.

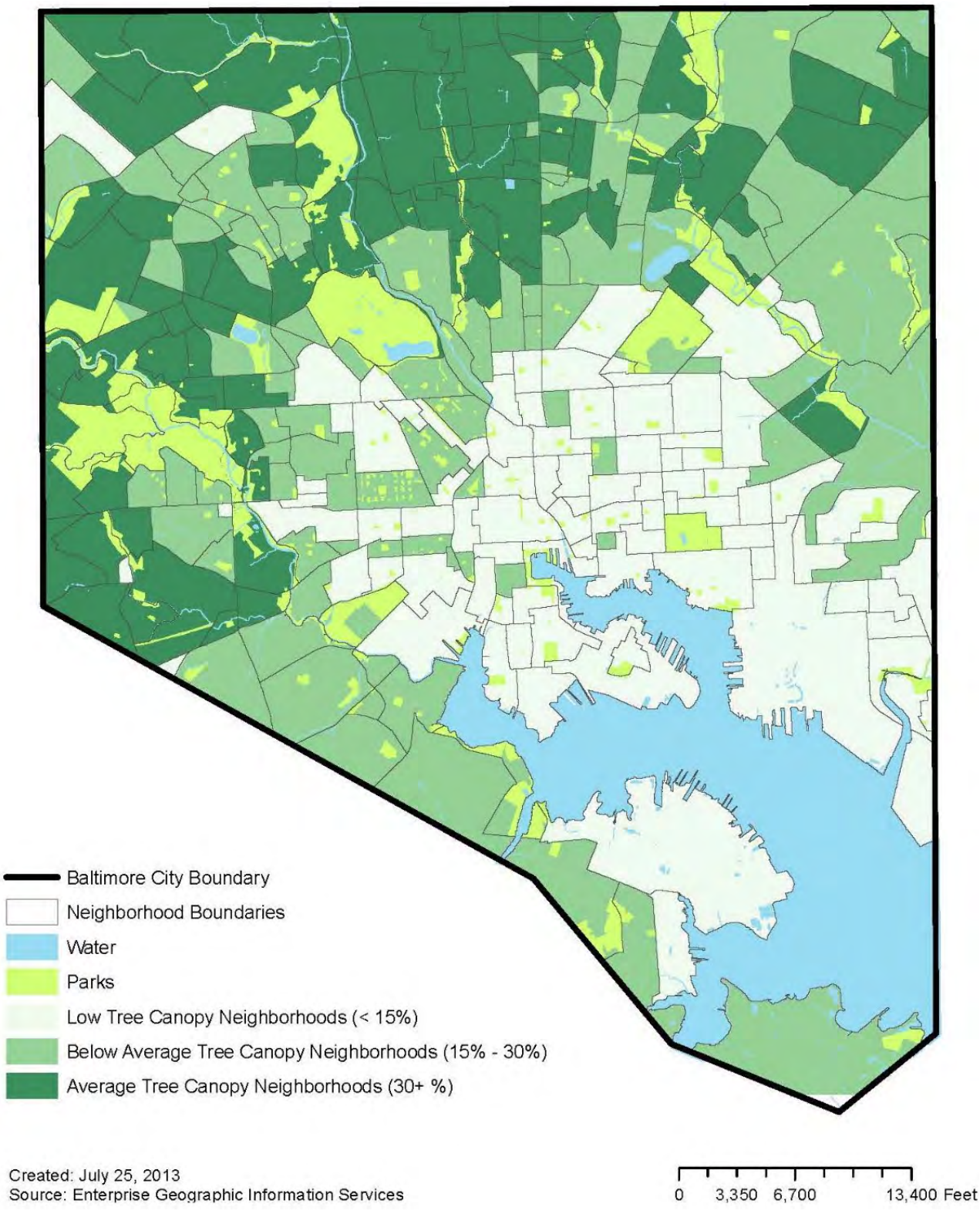
Adaptive Capacity

An asset's ability to respond or adjust to a hazard defines its adaptive capacity. It is possible for the City to adapt to extreme heat, but this potential is dependent upon additional factors, including a comprehensive understanding of the risks associated with heat-related hazards, programs to increase vegetative cover throughout the City, infrastructural and structural preparedness, and regulations for development that may be exposed or highly sensitive.

Community Assets Susceptible to Extreme Heat

During Baltimore's hottest and most humid days, elderly residents living in neighborhoods with little tree cover are at a greater risk of suffering from heat-related impacts than are most other residents. Baltimore's neighborhoods with the lowest tree cover are shown in Figure 27. Resident income, in addition to resident age, may play a factor in an individual's ability to cope with extreme heat. For instance, when comparing the distribution of poverty throughout Baltimore's neighborhoods along with the location of low tree canopy areas, it becomes clear that areas with lower tree coverage are typically neighborhoods where residents have lower income. While it is more likely that lower income residents will not have air conditioning, those who do may experience rising electricity costs as a result of the higher energy use required to cool their homes.

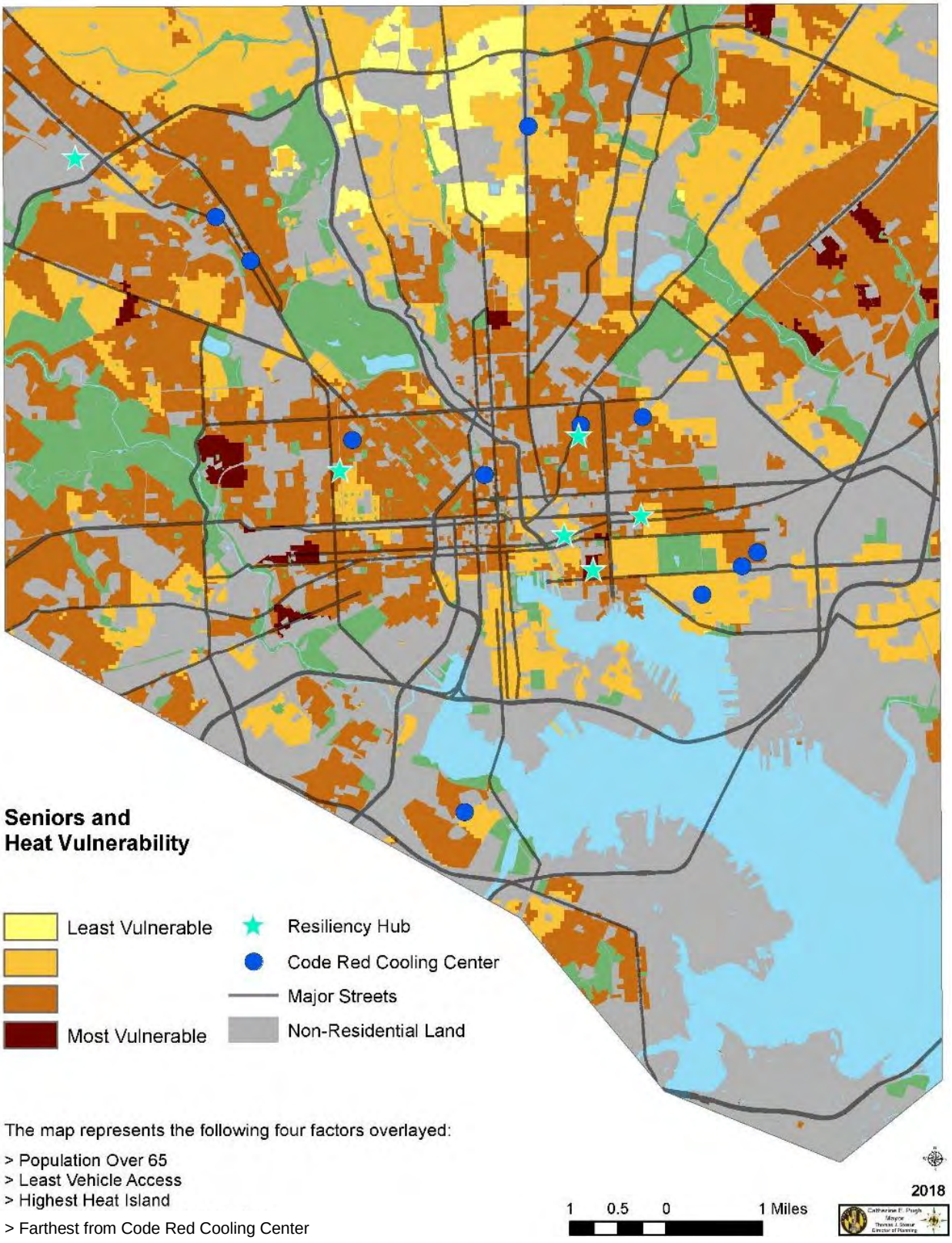
Figure 26: Baltimore Tree Canopy Cover



On high heat days, residents may choose to remain indoors. However, not only will this raise the risk of heat-related health impacts if homes are not equipped with or utilizing air conditioning, but this behavior also limits economic activity. As people remain indoors, the active workforce is decreased and foot traffic in commercial areas is diminished. Likewise, business owners may find their operating budgets have increased due to electricity usage at the same time as revenues are dwindling.

In addition, senior populations can be vulnerable to heat-related hazards due to physical conditions and isolation. In this analysis from the 2018 Coastal Adaptation Planning and Implementation Report, the factors utilized are population over 65 and vehicle access from the Census American Community Survey, and the concentration of heat islands as a measure developed through Landsat ETM thermal measurement. In addition, distance from Code Red Cooling Center is utilized to indicate locations where a local cooling center is less likely to be accessed. The map (Figure 28) highlights only a few areas of the City, which have the highest concentration of these factors. Conducting community resiliency planning in the Rosemont neighborhoods south of North Avenue and just east of Leakin Park, for example, should take into account the need for outreach and support for seniors in heat events as future mitigation strategies and actions.

Figure 27: Senior Heat and Vulnerability Map



Finally, extreme heat will also impact natural systems. Trees have long been considered an asset for their ability to absorb ozone pollution, and recent studies have been able to quantify that capacity.[56] In the past decade, however, Baltimore's tree canopy has been shrinking. Currently, trees cover only about 28 percent of Baltimore's landscape. Furthermore, 16–20 percent of that canopy is considered to be unhealthy; and while we benefit from a tree's ability to absorb pollution, trees are significantly damaged by excessive pollution.[57]

Critical Facilities Susceptible to Extreme Heat

Baltimore's exposure to extreme heat is extensive. Aside from local characteristics, which may lessen the intensity of an extreme heat event (see the discussion of tree canopy above), extreme heat has the potential to impact all areas of the City equally. For this reason, it is not possible to map particular critical facilities that may be most exposed to extreme heat. However, certain urban systems or building types are highly sensitive to the impacts associated with high heat. Infrastructure systems are quite sensitive to extreme heat. Energy systems will be taxed, which will have additional impacts on other systems and structures. Understanding this, certain facilities, including hospitals, emergency shelters, and schools, are likely to endure increased financial burdens as normal operating conditions must be maintained under more demanding circumstances. Additionally, impacts on critical facilities may be exacerbated by damage to transportation systems.

Estimated Losses

For the same reason, as it is difficult to estimate the exposure of specific facilities, it is challenging to estimate potential economic losses due to extreme heat. Energy and other infrastructure systems (transportation and utility) are likely to be impacted by extreme heat. Further evaluation of existing conditions will indicate the locations of existing vulnerabilities and the potential cost to increase the resiliency of these areas.

Land

Background

Earthquakes can, and occasionally do, occur in Maryland; though they are much less intense than those that occur elsewhere in the region or on the west coast. Although the area has experienced a handful of earthquakes from both inside and outside the State, this land movement is more likely to be the result of an earthquake that occurs in the surrounding region, rather than originating within Baltimore City or Maryland. The small magnitude and minimal economic damage of previous earthquake events have not warranted the need for considerable structural retrofits or similar mitigation programs. At the regional scale, localized land subsidence, though less noticeable, can have considerable effects on urban systems.

The U.S. Geological Survey (USGS) recognizes four major impacts caused by land subsidence:

- Changes in the elevation and slope of streams, canals, and drains
- Damage to bridges, roads, railroads, storm drains, sanitary sewers, canals and levees
- Damage to private and public buildings
- Failure of well casings from forces generated by compaction of fine-grained materials in aquifer systems

The direct consequence of regional subsidence does indeed pose a risk to Maryland. However, due to the lack of historical data and detailed mapping, risk cannot be fully estimated for subsidence. Consequently, the probability of land subsidence is not as easily expressed in terms of specific intensity and frequency as it is for other hazards.

A more quantifiable analysis of land-related hazards may instead evaluate potential risk from karst or sinkholes. Karst formations develop in specific ways that are influenced by unique local conditions. Sinkholes can be induced through natural or human causes. Sinkholes that occur naturally usually form by the slow, downward dissolution of carbonate rock though a bedrock collapse in areas that overlie caverns. Human-induced sinkholes can be triggered by even a minor alteration in the local hydrology. Inadequate drainage along highways, or increased runoff from hard surfaces like concrete and pavement, can also contribute to sinkhole development. Sinkholes in Baltimore in recent years have resulted in water and sewer line damage as well as prolonged road closures.

The most important environmental issue with respect to karst is the sensitivity of aquifers to groundwater contamination. This problem is universal among all karst regions in the United States that underlie populated areas.

Vulnerability to Land Hazards

Earthquakes are low probability, high-consequence events. Although earthquakes may occur infrequently, they can have devastating impacts. Ground shaking can lead to the collapse of buildings and bridges and could disrupt gas, lifelines, electric, and phone service. Deaths, injuries, and extensive property damage are also possible vulnerabilities from this hazard. Some secondary hazards caused by earthquakes include fire, hazardous material release, landslides, flash flooding, avalanches, tsunamis, and dam failure. Moderate and even very large earthquakes are possible, although usually infrequent, in areas of normally low seismic activity. Consequently, buildings in these regions are seldom designed to deal with an earthquake threat; therefore, they are extremely vulnerable.

Exposure

An evaluation of exposure identifies who and what may be vulnerable to land hazards. This analysis takes into consideration where seismic activity may occur, in addition to what assets and facilities may be located within those vulnerable areas.

Sensitivity

Sensitivity evaluates the degree to which exposed assets are vulnerable to land-related hazards. Additionally, understanding sensitivity recognizes the ways in which some properties may be more vulnerable to than others. For instance, a structure may be more vulnerable if it was not designed to withstand intense seismic activity, which is minimal. Additional characteristics may influence sensitivity even further.

Adaptive Capacity

An asset's ability to respond or adjust to a hazard defines its adaptive capacity. It is possible for the City to adapt to the impacts of potential land hazards, but this capacity is dependent upon additional factors, including a comprehensive understanding of the risks associated with land hazards, infrastructural and structural preparedness, and regulations for structures or developments that may be exposed or highly sensitive.

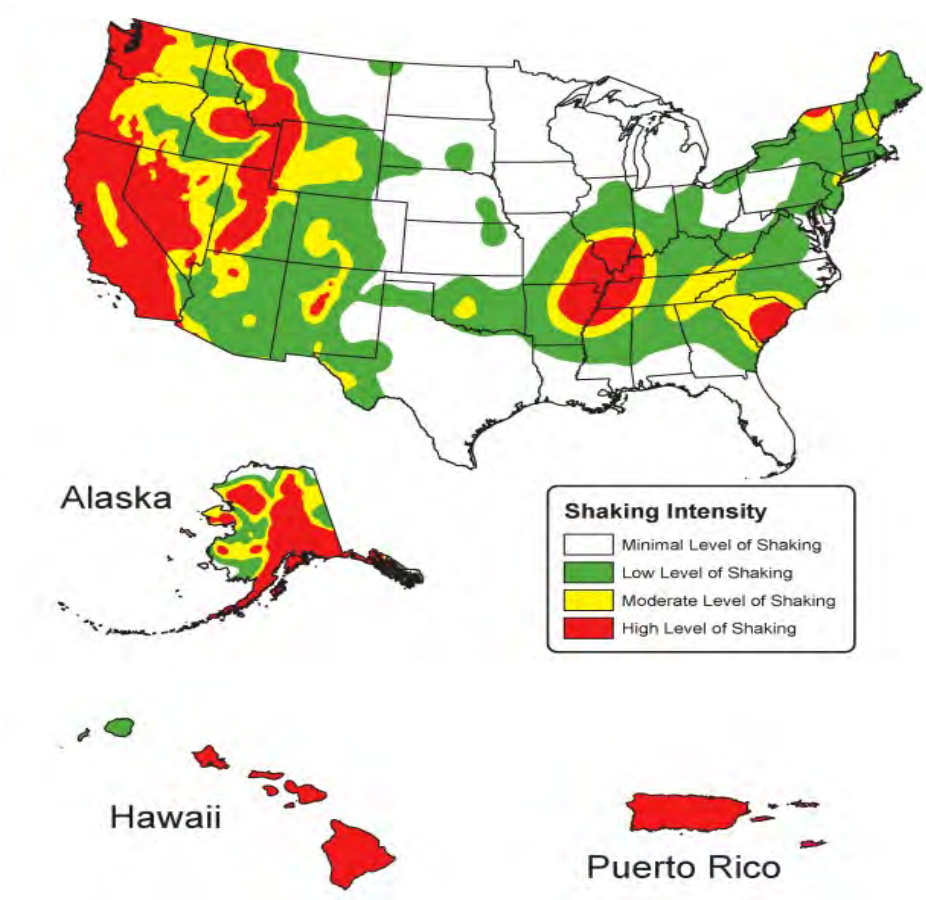
Community Assets Susceptible Land-Related Hazards

Most earthquake-related property damage, injuries, and fatalities are caused by the failure and collapse of structures due to ground shaking. The level of damage depends upon the amplitude and duration of the shaking—both of which are directly related to the earthquake's size, location and distance from the fault, and regional geology. All of Baltimore is considered to be within an expected peak acceleration zone of 8%. At this level, any potential damage is expected to be very light.[58]

According to *FEMA E-74, Reducing the Risk of Nonstructural Earthquake Damage –a Practical Guide,* dated December 2012, due to the low risk of earthquake and minimal to low potential for shaking due to seismic activity, the need for seismic anchorage and bracing of non-structural components is not necessary. However, if a facility is located in a low level of shaking area and if it is not an essential facility, then only parapets and exterior unreinforced masonry walls should be considered for seismic retrofit. Refer to Figure 29.

In Baltimore, sinkhole formation may be more likely than a major earthquake event. Vulnerable to urban karsts and sinkholes, however, cannot be easily associated with particular regions.

Figure 28: Map of Probable Shaking Intensity in the United States



Critical Facilities Susceptible Land-Related Hazards

According to the *FEMA E-74, Reducing the Risk of Nonstructural Earthquake Damage –a Practical Guide,* dated December 2012, essential facilities located in a low-level shaking area may want to consider seismic retrofit.

The first step toward reducing the nonstructural hazards in an existing building is to perform a survey to assess the extent and magnitude of the potential risks. This chapter includes survey guidelines for nonstructural components and describes the inventory form, the checklist, and the risk ratings that are included in the appendices. In order to make informed decisions regarding nonstructural seismic risks, owners and managers will need to address the following questions:

- What types of nonstructural components are present in a particular facility?
- Are these items adequately braced or anchored?
- How will a specific nonstructural item perform in an earthquake, and what are the consequences of failure of that item in terms of life safety, property loss, and functional loss?
- If the decision is made to upgrade a facility, which problems should be addressed first?

The focus of this guide is on reducing nonstructural seismic hazards, particularly in those areas where the seismic shaking intensity is expected to be moderate or high and where significant structural hazards do not exist or will be addressed independently. A simplified map of probable shaking intensities is presented in Figure 4-16. If the expected shaking for the facility in question is minimal, then the survey procedures and seismic protection measures described in this guide might be undertaken on a voluntary basis but may not be necessary, and in most cases, they would not be required for new construction.

Following the review of the above-reference technical guide, Baltimore's vulnerability to the earthquake hazard is low. A new mitigation strategy for the examination of proper anchorage and bracing of non-structural components at critical facilities has been included in the 2018 DP3 update.

Loss Estimations

While the value of the facilities that are vulnerable to land-related hazards may be none, it is nevertheless challenging to accurately monetize the potential damages from an earthquake. Using Hazus-MH Software, the 2011 Maryland Hazard Mitigation Plan reported that annualized direct economic losses from earthquake events totaled $933,000 (as shown in Table 52).

Table 52: Hazus-Mh Mr5 Earthquake Annualized Losses and Direct Economic Losses Based on a Deterministic Scenario

Annualized Direct Economic Losses	Direct Economic Losses for 1998. Event in PA with a Mag. 5.2 and Depth 10km
$933,000.00	$588,000.00

Source: Table 52, Maryland Emergency Management Agency, 2011: 261.

Note: This analysis was not completed for in the 2016 State of Maryland Hazard Mitigation Plan.

Selecting Key Vulnerabilities for DP3 Update

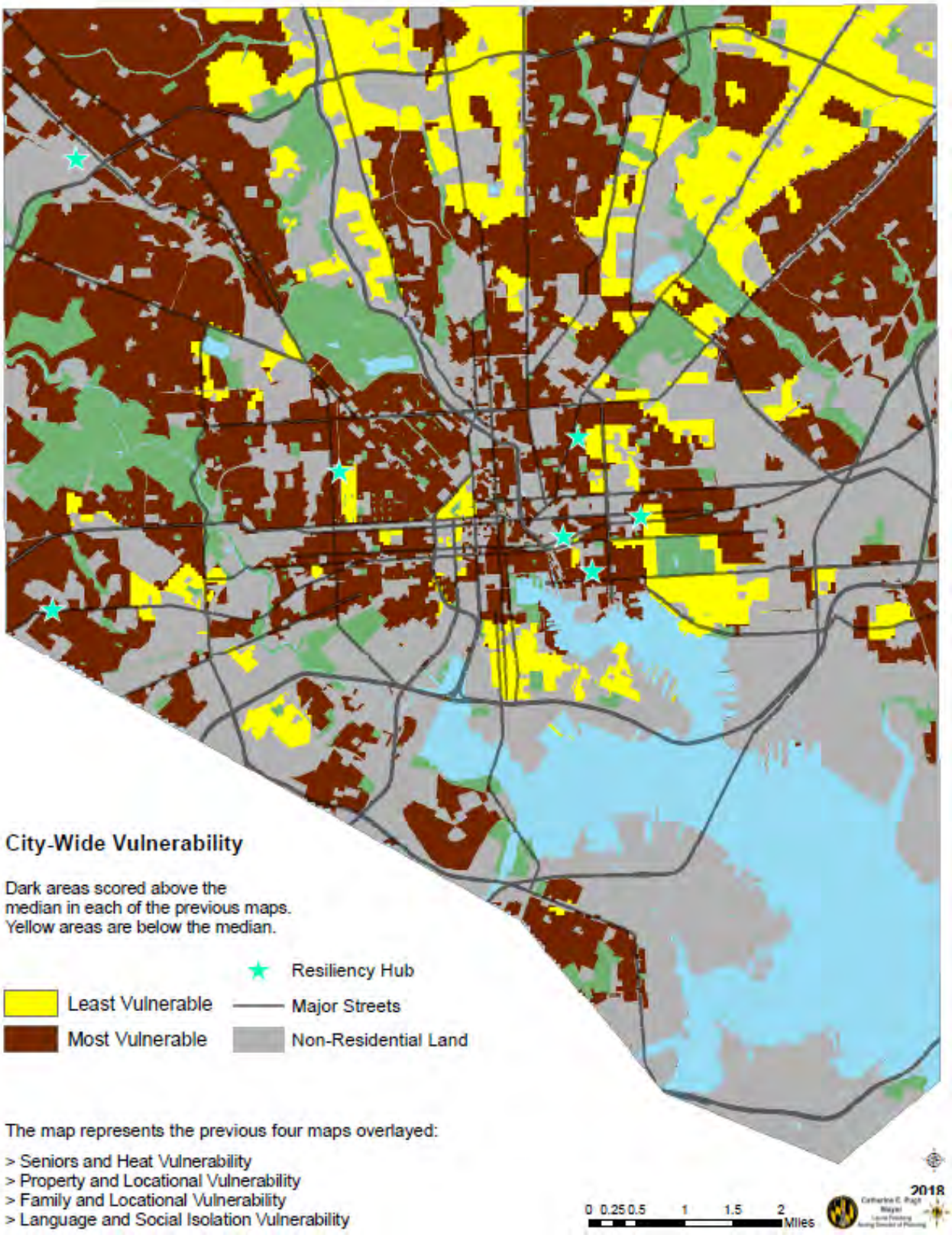
This plan recognizes that a number of tools for understanding natural hazard and climate impacts already exist. While some information and tools used in the 2013 DP3 were retained, as warranted, in many instances new tools and approaches were added to the plan. During the 2018 DP3 update, several tools were used to develop the 2018 Hazard Identification Risk Assessment (HIRA). Information such as past occurrence data, future risk (probability), and impact data (deaths, injuries, and damages) was used to conduct a standard HIRA. However, the addition of the local risk perspective from both the Advisory Committee Survey and the Public Survey enhanced and provided a higher level of validity to the 2018 HIRA. Also, FEMA Hazus modeling, FEMA and MEMA hazard mitigation guidebooks, GIS mapping and data analysis, as well as climate adaptation planning tools were used during the plan update process. These tools and resources helped to establish a thorough framework for guiding the risk and vulnerability process of this plan. Learning from such tools, DP3 created an approach that was most appropriate for issues specific to Baltimore.

Specific facilities, assets, or neighborhoods within Baltimore may require additional care and attention when planning for natural hazards. Varying levels of sensitivity may be caused by general characteristics, such as the age of a structure, or specific conditions, including location or other external factors. For instance, for flooding and impacts from coastal hazards, Fells Point and Baltimore's Inner Harbor are highly vulnerable, but historic structures within those areas are even more so. During the 2018 DP3 update planning process, a special emphasis was placed on critical facilities, especially those classified as essential facilities, such as emergency operation centers, schools, medical, fire and police. These facilities must remain operational before, during, and after emergency incidents to ensure a basic level of community resiliency. Results of analysis conducted during the plan update indicated that the following essential facilities are at risk from the 1-percent-annual-chance (or 100-year) flood event: two fire, two police, and two school buildings. Detailed information was provided in Table 36 of this chapter. In addition, results indicate that essential facilities are at-risk from hurricane storm surge (Table 45) and sea level rise (Table 43 and Table 44).

Finally, impacts of extreme heat result in dangerous conditions to City residents and/or workers, specifically vulnerable populations. As part of the planning effort to assess the vulnerability of people to various hazards, the identification of social vulnerability factors was identified. Data was collected and presented within various mapping products.

Figure 30 is a composite map of various social vulnerability mapping products, which was aggregated to display all data into two categories "More Vulnerable" and "Less Vulnerable." This data included Family and Location Vulnerability, Language and Social Isolation Vulnerability, Property and Locational Vulnerability, and Senior and Heat Vulnerability. Aggregation of these mapping products was completed in an attempt to provide a sense of overall vulnerability and perhaps prioritization for further analysis and investment. Note: In this instance, the result may not be particularly rich: the "parameters" that were developed are not meant to be comprehensive, and no weighting was done to provide relative levels of importance. However, the concept is worth continuing to develop as other data sets are added. GIS and data tools could also assist in building a composite index of the factors, allowing future planning efforts to provide different weights according to, for example, different types of hazards.

Figure 29: Map of City-Wide Vulnerability



Adaptive capacity is the ability of a system (in this case, the City of Baltimore) to adjust to changes in the environment, including climate variability and extreme shifts in weather, in order to moderate potential damages or cope with the consequences of those changes.[59] Adaptive capacity informs, and is informed by, a vulnerability assessment through important insights into the factors, processes, and structures that promote or constrain the system's (City's) ability to respond to climate change or natural hazard events.[60] Systems that are resilient to climate stressors are more adaptable and flexible and generally have a higher adaptive capacity. Relatively similar hazards could have vastly different consequences depending on a system's level of adaptive capacity. While a low adaptive capacity can increase a system's vulnerability to natural hazards, a high level of adaptive capacity may lessen the degree to which a system is vulnerable.

There are two types of adaptive capacity: generic and specific. Generic adaptive capacity includes assets and entitlements that enable a system to cope and respond to a variety of stressors.[61] For example, having a well-educated and engaged community can contribute to generic capacity. On the other hand, specific adaptive capacity is the ability to respond to and recover from a specific climatic event, such as a flood, tornado, or hurricane.[62]

Adaptive capacity, of either generic or specific dimensions, can be influenced by a number of factors. In addition to the examples noted above, resource availability, socio-political barriers, and institutional responsibility, among other characteristics, can shape adaptive capacity.

While the DP3 has considered adaptive capacity of the City of Baltimore as a whole, it has needed to recognize that capacity to adapt to climate change may not be equal across all populations. Research shows that adaptive capacity among individuals may be differentiated along the lines of age, race or ethnicity, religion, and gender.[63]

Determinants of adaptive capacity are used to indicate opportunities and constraints for adaptation, as well as current assets and resources from which the City may benefit. The eight determinants of adaptive capacity that are most frequently cited in scientific literature are described here.

Institutions | Includes norms and rules, both formal and informal. This may be governance mechanisms at city, State, regional, Federal, or international levels, or institutional and policy frameworks. Additionally, this might include local ordinances, city plans, State and Federal incentives and regulations, as well as inter-jurisdictional collaboration.

Infrastructure | Describes the basic physical structures needed for a City to function. Examples include water and sanitation systems, green infrastructure, traditional built environment, transportation networks (roads, bridges, public transportation), and energy supply systems.

Wealth and Financial Capital | Considers the accessibility and availability of financial wealth or wealth management instruments, including fiscal incentives for risk management. For example, revolving funds, philanthropic initiatives, insurance, and credit can all be viewed as wealth and financial capital.

Social Capital Networks | Focuses on access to and engagement with social groups, businesses, and organizations. Examples include public-private partnerships, organized community leadership, and interpersonal connections between city staff and external organizations.

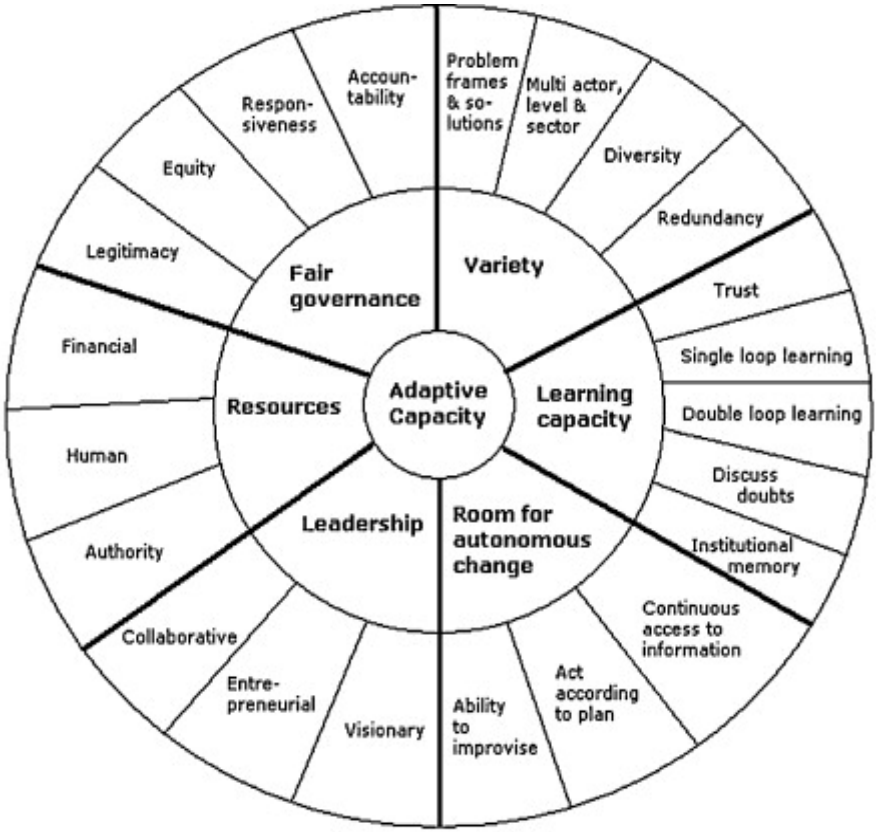
Political Capital | Includes political leadership, political climate, decision and management capacity, and public engagement. Examples of political capital include leadership, motivation and vision, electoral and local politics, reputation and legitimacy, public perceptions of political leadership, and political support gained through public participation and engagement efforts.

Human Capital | Focuses on education levels, community risk perception, human labor, and capacity of the human population. Some of the best indicators of human capital may be a community's overall education level, or the skills and knowledge of city staff.

Information | Considers access to information sources and the efficiency of early warning systems. Examples include scientific understanding of climate change impacts and associated adaptation strategies, and an effective system for sharing, discussing, and conveying climate change information, as well as adaptation strategies, at various levels.

Technology | Includes technology sources, access and transmission, and technological innovations. Examples of technology include the use of GIS or Doppler Radar.

Figure 30: Adaptive Capacity Wheel and Scoring

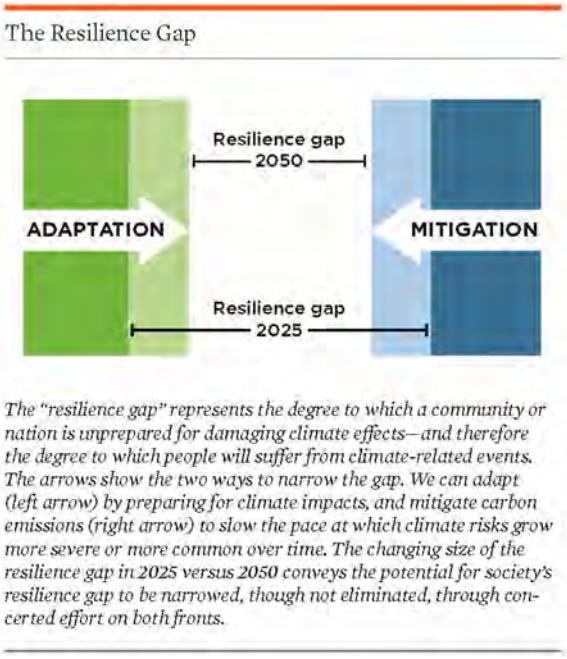


Source: Sciencedirect.com

Additionally, the Union of Concerned Scientists has developed a climate resilience framework and adaptive principals to assist decision makers and citizens with becoming more resilient to climate change. The planning guide, "Toward Climate Resilience," discusses the concept of a climate resilience gap. The gap refers to the scope and extent of climate change are the driving conditions for which people remain unprepared, leaving them open to potentially harmful impacts. [64]

> Responding effectively to climate change requires us to narrow the climate resilience gap through aggressive action on both climate mitigation and adaptation.
>
> Source: 2016 Toward Climate Resilience

Figure 31: Resilience Gap



Source: UCSUSA, Toward Climate Resilience, 2016.

"Adaptation and mitigation measures are tightly bound, and it is critical to appreciate the connection between the two. Stronger mitigation efforts will not only moderate the long-term climate impacts for future generations but will also make preparedness efforts today more enduring and worthwhile. Aggressive mitigation measures can increase the confidence that the preparations made will not be quickly overwhelmed by an increasingly disrupted climate."[65]

Building Adaptive Capacity

Hazard mitigation and climate adaptation processes help to build the City's adaptive capacity. First and foremost, by creating, maintaining, and updating the 2018 DP3 Plan, Baltimore is compliant with FEMA's requirement for an All Hazards Mitigation Plan (AHMP) and is therefore eligible for Federal assistance in the event of an emergency. Such assistance leverages Baltimore's ability to respond to hazard events.

Improved adaptive capacity can ensure that a system is able to maintain ongoing functions throughout shifting conditions or hazard events. According to the Intergovernmental Panel on Climate Change (IPCC), strengthening adaptive capacity may require adjustments in behavior, as well as in resource and technology use. For each determinant, there may be room for improvement:

- Incorporate mitigation and adaptation measures into institutional framework
- Enhance the resiliency of City infrastructure
- Ensure a robust, underlying network of financial capital exists across all of Baltimore
- Educate and empower residents to increase their ability to avoid and respond to hazards
- Establish policy and procedures which support hazard mitigation and climate adaptation
- Support resident growth through educational and workforce training

- Establish an effective program for communicating hazard information
- Utilize technological tools to more accurately predict accurately vulnerability to hazards

Finally, although a considerable amount of attention is often focused on risks associated with climate change, it is important to think positively. Adaptive capacity can also help Baltimore and its residents take advantage of new opportunities or benefits that will arise because of climate change. This may be challenging to grasp. However, consider, for instance, the potential for a longer growing season that may present opportunities to cultivate new kinds of produce. Seeing climate change from both perspectives encourages flexibility and a greater propensity to adapt.

Chapter 5

Strategies and Actions

Summary of Changes

- Update and revision of actions to better reflect prioritization
- Adjustment of 2013 DP3 Priority Scores to exclude values for "Climate Action Plan Overlap"
- Inclusion of HIRA rankings into priority scoring methodology
- Consolidation of similar/duplicative actions
- Designation of 86 priority actions based on adjusted 2012 priority score and new HIRA rankings
- Extraction of completed actions and actions that had State or Federal responsibilities

Regulatory Checklist

C3. Does the plan include goals to reduce/avoid long-term vulnerabilities to the identified hazards? 44 CFR 201.6(c)(3)(i)

C4. Does the plan identify and analyze a comprehensive range of specific mitigation actions and projects for each jurisdiction being considered to reduce the effects of hazards, with emphasis on new and existing buildings and infrastructure? 44 CFR 201.6(c)(3)(ii) and 44 CFR 201.6(c)(3)(iv)

C5. Does the plan contain an action plan that describes how the actions identified will be prioritized (including cost benefit review), implemented, and administered by each jurisdiction? 44 CFR 201.6(c)(3)(iii) and 44 CFR (c)(3)(iv)

D3. Was the plan revised to reflect changes in priorities? 44 CFR 201.6(d)(3)

Introduction and Vision

Baltimore will be a city whose daily activities reflect a commitment shared by government, business, and citizens to reduce or eliminate impacts from current and future natural hazards.

Goals

Mitigation goals are the general guidelines that explain what Baltimore City aspires to achieve. Goals are usually expressed as broad policy statements representing desired long-term results. There were six goals identified in the 2013 DP3 hazard mitigation plan. The 2018 update has carried through the six goals with an adjustment to Goal #6 as it has been completed. The new goal reads "Provide support to increase efforts toward a better Community Rating System (CRS) community rating." The goals were presented and reviewed during the July 18, 2018 advisory committee meeting.

The Disaster Preparedness and Planning Project 2018 goals are:

- Goal 1: Protect the health, safety and welfare of Baltimore City residents and visitors.
- Goal 2: Prevent damage to structures, infrastructure, and critical facilities.
- Goal 3: Build resilience and disaster prevention and planning into all programs, policies, and infrastructure (public and private).
- Goal 4: Enhance the City of Baltimore's adaptive capacity and build institutional structures that can cope with future conditions that are beyond past experience.
- Goal 5: Promote hazard mitigation and climate adaptation awareness and education throughout the City of Baltimore.
- Goal 6: Provide support to increase efforts toward a better Community Rating System (CRS) community rating.

The National Flood Insurance Program's (NFIP's) CRS recognizes community efforts that go beyond the NFIP minimum standards by reducing flood insurance premiums for the community's property owners. The CRS program is voluntary, and discounts may range from 5 to 45 percent, depending on the CRS level attained. The discounts provide an incentive for new flood mitigation, planning and preparedness activities that can help save lives and protect property in the event of a flood as highlighted in the strategies and actions. Baltimore currently has a rating of "5."

Current Hazard Mitigation and Climate Adaptation Actions in Baltimore City

Recognizing the potential risks associated with projected changes in climate, the City of Baltimore has already begun to establish initiatives to reduce its impact on the environment and increase resiliency to hazardous events. Many of these programs are reviewed in Baltimore's Sustainability Plan and other key programs are highlighted below.

- Stormwater Utility and Clean Water Baltimore Program: The City of Baltimore, as mandated by the State of Maryland in April 2012, must raise funds to support a comprehensive stormwater management program. Stormwater remediation projects will reduce the impacts of flooding hazards.

- Urban Tree Canopy initiatives: With a number of forestry and "green" organizations and agencies, Baltimore is pursuing its goal of increasing the Urban Tree Canopy to 40 percent by 2037. DP3 recognizes the potential for trees and other natural features to mitigate damage from hazard events.
- Baltimore Food Policy Initiative: The Baltimore Food Policy Initiative (BFPI) is an inter-governmental collaboration aimed to increase access to healthy and affordable foods in Baltimore's food deserts. Ensuring adequate supply of healthy food will reduce negative health impacts during hazard events.
- Green Building Standards: Baltimore Green Building Standards for commercial and multi-family buildings over 10,000 square feet aims to increase the efficiency and reduce the environmental impact of all new or extensively modified structures. Many of the DP3 actions below recommend enhancing or incorporating these standards into disaster planning efforts.
- Climate Action Plan: Baltimore's Climate Action Plan (CAP) was established to reduce Baltimore's greenhouse gas (GHG) emissions through a range of strategies targeted at reducing the amount of fossil fuel needed for everyday living. Its recommendations are critical steps to preventing additional climate impacts.
- Energy Office: The Baltimore Energy Division strives to increase the energy efficiency, comfort, safety, healthy and durability of buildings throughout the City by upgrading and retrofitting them.

While this list is by no means exhaustive, it is indeed illustrative of some of the key efforts underway in Baltimore. Additionally, many of these initiatives and programs will be incorporated in the actions and carried out through the implementation of the plan.

Urban Sectors for Consideration of Hazard Mitigation Actions and Climate Adaptation Actions

The strategies put forth in this plan are grouped according to corresponding urban sectors—infrastructure, buildings, natural systems, and public services. In the hazard mitigation and adaptation process, each sector plays an important role as they are understood to be significantly impacted by the consequences of hazard events and a changing climate. While impacts may vary, most urban systems are vulnerable to more than one hazard. Sorting the action plan by sector, rather than by individual hazard, allows for strategies to address multiple vulnerabilities simultaneously.

Furthermore, the DP3 will be viewed by a diverse range of agencies, businesses, industries, or other individuals. Depending on the viewer, one sector may be more relevant than another. For example, the owner of a gas station will be more concerned with the infrastructure section and will be interested to learn how infrastructure systems are most vulnerable, as well as what can be done to increase the resiliency of their property. The sector organization recognizes the far-reaching scope of this plan and presents a more readily understandable and flexible framework. In this way, the DP3 plan becomes a resource and reference tool.

Infrastructure

One of the most pressing challenges facing States and municipalities today is the quality and capacity of built public infrastructure—the water systems distribution and treatment, schools and municipal

buildings, transit systems, and other core assets upon which we all depend. The links between well-functioning infrastructure and economic growth are well documented. Inadequate or failing public infrastructure disproportionately hurts low-income people. As seen in New Orleans after Hurricane Katrina, and in New York and New Jersey after Superstorm Sandy, low-income communities are often located in the flood-prone sections of cities and thus more likely to experience the prolonged health issues associated with mold and moisture after flooding. The 1995 Chicago heat wave resulted in 750 deaths, most of which were elderly low-income residents who could not afford air-conditioning and were afraid to open windows for fear of crime. However, as NOAA has stated, "heat is the number one weather-related killer in the United States." In fact, NOAA's National Weather Service statistical data revealed, "Heat causes more fatalities per year than floods, lightning, tornadoes, and hurricanes combined."[66] In New York City, when public transportation failed, transit-dependent low-income residents could not get to work and, because they were not salaried, could not earn wages to support their families. In Baltimore, many residents might face the same risks if the City does not sustain a system of efficient, reliable infrastructure.

Climate change should be a key consideration in the development and maintenance of existing or future infrastructure. Already, infrastructure in Baltimore has been proven vulnerable to unpredictable, extreme weather events. Extreme heat, for instance, leads to the buckling of roads, melting asphalt, and warped railroad tracks. In July 2012, a heat wave led to buckling train tracks and pavement in the Baltimore region, and a US Airways jet became stuck in melted pavement at Baltimore Airport.[67] Additionally, heat, accompanied by the concentrated use of air conditioning, may overheat and overwhelm electrical supplies, leading to a significant power outage. In a hazard event, this increased electric cooling demand may be combined with reduced energy supply reliability, which can result in rolling brown-outs or black-outs. Similarly, a flooding event could submerge underground power generators, rendering them useless. Other hazards may contribute to inoperative public transportation, severed utility or communication lines, overflowing sewer systems and the inundation of waste management facilities, and much more. Additionally, extreme events threaten linkage infrastructures such as bridges, roads, pipelines, and transmission networks. Different forms of infrastructure are vulnerable to climate change in distinct ways and to varying degrees, depending on their state of development, resilience, and adaptability. Furthermore, infrastructure may face an immediate physical impact, or the damage may be more indirect.

Baltimore's existing infrastructure was built for the City's past conditions. However, current weather is already presenting a challenge, and a changing climate will increase the City's infrastructure vulnerabilities. Climate change could have significant implications for infrastructure. While infrastructural elements are sensitive to the climate existing at the time of their construction, due to their generally long operational lifetimes, infrastructural elements are also sensitive to climate variations over the decades of their use. For example, a substantial proportion of infrastructure built in the next 5 years will still be in use long after 2030. Therefore, increasing infrastructure's resilience to the impacts of climate change is a top priority.

To increase the resilience of both new and existing infrastructure, we must be prepared to mitigate and adapt to the impacts of climate change. Preparing infrastructure for these changes will not only minimize Baltimore's risk and vulnerability, it will also maximize potential opportunities. Baltimore's infrastructure, which is an interconnected network of highly valuable assets, enables the City to grow and prosper. By proactively mitigating and adapting to climate change, Baltimore will advance its goals of reducing carbon emissions and becoming a sustainable city. This, in turn, will enhance the City's overall competitiveness, increase its resilience, and open the door to robust social, economic, and

environmental growth. The proposed strategies relating to this sector will help Baltimore establish an infrastructure network that is able to endure or adapt to the impacts of climate change.

Buildings

Baltimore's buildings, some of which have been significant features in their communities for decades or even centuries, add vibrant charm to the City. Baltimore City has an extensive and diverse collection of buildings. These structures are homes, cultural institutions, offices, schools and universities, historic landmarks, critical facilities, community establishments, and places of worship.

In the past, Baltimore's building stock has been subject to weather-related risks. In particular, flooding associated with extreme precipitation events has caused a great deal of damage (for a description of historical occurrences, see the "Flooding" Hazard Profile). During extreme events, buildings may be destroyed—entirely or in part—or rendered unstable due to the impacts from storm surges and flooding waters. A changing climate is likely to intensify this impact. For instance, storm surge, when combined with projected sea level rise, will pose a greater threat to Baltimore's existing coastal building stock. Additional hazards, including earthquakes, may further weaken a building's structural integrity.

Resilience of Baltimore's building stock is particularly important considering that many structures serve as refuge for City residents during severe storms and other extreme weather events. Similarly, critical emergency facilities- hospitals, fire stations, police stations, government buildings, and the like- perform essential functions during these events and increase the City's capacity to respond to, and alleviate, the impacts of a hazard. The strategies within this plan aim to protect buildings from current and future climate risks by increasing their resiliency. Additionally, the recommended actions are intended to mitigate the effects of those buildings—which, as well as using the energy needed to operate them, produce considerably high greenhouse gas (GHG) emissions—by improving their energy and resource conservation.

Natural Systems

Although natural systems will suffer adverse consequences as a result of climate change (and environmental health should therefore be given particular attention), this plan embraces nature for its potential as a hazard mitigation and climate adaptation tool. In many cases, natural features are capable of offsetting GHGs, as well as alleviating the severity of weather events, effectively reducing long-term risks from climate change and hazards. On the other hand, if not properly maintained, natural elements such as trees and streams may themselves become a danger during an extreme weather event.

As Baltimore attempts to reduce GHG emissions and curb the effects of climate change on the City, natural systems are increasingly seen as a mitigation strategy. Trees and vegetation are valuable for their ability to absorb carbon dioxide and transform it into oxygen. This process, known as carbon sequestration, reduces GHGs in our atmosphere and mitigates the extent of changes in our climate future. At the same time, this process reduces the probability of respiratory health problems during days with extreme heat. Additionally, the same trees can help to cool the City (and its water habitats), reducing the impact of the urban heat island effect.

Although trees and natural systems provide extensive benefits in an urban setting, it is important to recognize that these same systems could become a risk during a hazard event if not properly maintained. In heavy winds, trees may lose limbs or be uprooted entirely. Alternatively, a warming climate may welcome new pests or invasive species which may devastate native species of the local

ecosystem. Likewise, streams without a natural buffer can become dangerous channels of flooding water during heavy precipitation events. Proper maintenance of Baltimore's natural systems will be necessary to ensure that benefits are maximized while risks are reduced. Planting dense vegetation along riparian corridors, for instance, creates a buffer from intensely flowing waters during flood events.

In addition to protecting the health and safety of Baltimore's residents, natural elements should also be maintained for their own health. The damage or destruction of trees can cause loss of valuable ecosystem services, which can be accompanied by other challenging consequences, including removal and replacement costs, and the considerable amount of time needed for a replacement tree to reach its full potential and value. According to the U.S. Forest Service, a mature tree with a trunk 10 times larger than a small tree produces 60-70 times the amount ecological services.[68]

Lastly, urban biodiversity contributes to the health of the entire ecosystem. In a regional study, conducted at the University of Delaware, native and alien plant species of the mid-Atlantic region were evaluated for their ability to support insect biodiversity. The results (the database is available for download online) can be used to determine which plants should be encouraged and which should be avoided. The strategies proposed in this plan aim to identify how and where nature may be managed to the City's benefit, and what actions must be taken to eliminate all avoidable risks associated with neglected natural systems.

Public Services

A major role of this plan is to expand Baltimore's preparedness for future hazards. Therefore, strategies relating to public health and human services are concerned with distributing information, building resources, improving communication, and establishing response plans.

Baltimore needs to encourage behavioral and other changes that will reduce GHG generation. At the same time, the City must pursue education and outreach efforts that will raise hazard awareness among residents, business owners, employees, institutions, and others. Furthermore, hazard mitigation efforts should be incorporated into all future planning documents and across all City agencies.

Additionally, strategies should be in place to prevent or limit health risks—including disease outbreak, physical exhaustion, and respiratory conditions, to name a few—that are triggered by extreme events. It will be necessary for the City to build its emergency preparedness. This will require, for example, coordination between local government, non-governmental organizations, and private entities, to establish procedures that will be employed during hazard events. Community involvement today will ensure that all of Baltimore's population is prepared, well-informed about the risks and procedures, and able to safely respond to early warnings.

Update Process

The strategies and actions in the 2018 DP3 define the programs, policies, and projects that the City will undertake to accomplish its resiliency goals. Originally, 50 strategies and 231 related actions were identified in the 2013 DP3. As part of the 2018 DP3, these strategies and actions were revisited and are included in Appendix 5-1: All Strategies and Actions by Category.

Advisory Committee members were notified of the schedule to submit updates to existing mitigation actions and encouraged to provide new mitigation actions that could be incorporated into the plan. Agencies were provided copies of their previously submitted mitigation actions and asked to determine if the projects were still valid. The 2013 actions were divided by lead agency and reviewed by staff members who served on a strategy subcommittee. The strategy subcommittee was composed of the following members:

- Lisa McNeilly, DOP
- Aubrey Germ, DOP
- John Quinn, BGE
- Kimberly Eshleman, BCHD
- Ed Strouse, MOEM
- Ryan McByrne, DPW
- Mikah Zaslow, DOT
- Craig Keenan, DGS
- Phil Lee, Moffatt & Nichol

Invitations to participate on the strategy subcommittee were distributed during the July 18, 2018, advisory meeting, and a strategy subcommittee meeting was held on August 26. Participants were asked to review the actions that correspond to their agency and report updates by August 5. Updates to actions are identified for each with purple bold text. The review of actions involved the following discussion points:

- Corrections to or deletion of the action
- Are you still the lead agency for the actions?
- Has there been any change in the timeframe?
    - Short
    - Medium
    - Long
- Has the Status of the action changed? Provide reasons for why there was no movement in past five years or lessons learned from progress made.
    - Still pending
    - Very early stages
    - Early stages

    - Mid stages
    - Advanced
    - Implemented/Ongoing
- Are there Performance Metrics that were developed and were implemented in the past 5 years?
- Are there any known changes to the priority of this action?

Evaluating mitigation actions involves judging each action against certain criteria to determine how well it can be executed. The 2018 DP3 update utilizes the same scoring mechanism that was used to score 2013 DP3 actions. Two minor adjustments were made to account for inconsistencies and disparities in the data.

1. The priority scores were adjusted to exclude values for Climate Action Plan overlap. These adjustments resulted in a reduction in the number of low-priority actions and an increase in the number of medium- and high-priority actions for the 2018 plan. Priority scoring otherwise used the same measures (financial feasibility, political feasibility, impact, and public support, with individual values ranging from a low rating of '1' to a high rating of '3') as in the 2013 plan. The rating scale was adjusted accordingly, and subsequently, the new aggregate ratings are 5 to 7 for low priority, 8 to 9 for medium priority, and 10 to 12 for high priority.

2. The results of the HIRA were introduced as an additional ranking factor, producing a list of priority actions for the 2018 DP3. This analysis identified 87 actions that were classified as first, second, or third priority. First-priority actions were defined as having existing high-priority scores and supporting "all hazards;" second-priority actions were defined as having high-priority scores and supporting "2 or more hazards;" third-priority actions were defined as having actions that addressed "2 or more hazards" only. New actions were also defined as first priority.

A number of administrative actions were also completed as part of the review process to lessen both the size and complexity of the strategy section. Due to difficulties in tracking and documenting shifts in agency responsibilities, it was determined to limit the actions description to the title only. Secondly, after an intensive review for duplication, 51 actions were consolidated into 23 new actions that combine descriptions of the actions. The results of the consolidated actions are identified in Appendix 5-2: Consolidated Actions. Adjustments and modifications to actions through consolidation resulted in renumbering and reclassification of actions and strategies. Please note, the numbers associated with the action in the 2013 DP3 plan do not correspond to the action numbers identified in this update.

The strategy subcommittee also identified a list of new actions, which have been listed below and in Appendix 5-1.

- Develop training and guidance documents for Resiliency Hub leaders that detail the scope of services (include checklist and instructions for opening, running, and closing)
- Increase the number of Resiliency Hubs
- Initiate community resiliency planning, outreach, and support
- Increase the amount of land permanently secured for food production, from community gardens and market gardens to commercial urban agriculture
- Implement the Plan for Food Access During Incidents and Disasters

- Increase food system resilience over the long term
- Pursue grants to acquire floodprone properties, when and where feasible
- Pursue grants to elevate floodprone properties, when and where feasible
- Pursue grants and technical assistance to conduct hydrology and hydraulic studies on floodprone areas within the City, to include Maidens Choice Branch, when and where feasible
- Evaluate potential for completion of Maidens Choice stream restoration project (U.S. Army Corps of Engineers, Baltimore District identified project)
- Pursue grants for flood control measures to alleviate flooding in the most floodprone areas when and where feasible
- Pursue grants for floodplain storage and diversion projects to alleviate flooding in the most floodprone areas, when and where feasible
- Pursue grants for dry floodproofing of commercial and historic structures in the most floodprone areas, when and where feasible
- When and where feasible, pursue grants to complete any project eligible under FEMA's Hazard Mitigation Unified Guidance and its addendum that will contribute to the reduction of hazardous conditions in the City

After reviewing risks and vulnerabilities associated with natural hazards in Baltimore, the 2018 DP3 process developed a comprehensive list of strategies and actions to ensure the City's ability to adapt to and mitigate the potential impacts of hazards. The following section includes sets of strategies for each sector. Individual actions associated with each strategy are included, as is information regarding intent, benefit, and stakeholders, as well as some additional details. Finally, the list below defines acronyms for the agencies and organizations noted as possible stakeholders.

- BARCS: Baltimore Animal Rescue and Care Shelter, Inc.
- BCFD: Baltimore City Fire Department
- BCHD: Baltimore City Health Department
- BCPD: Baltimore City Police Department
- BCPSS: Baltimore City Public School System
- BCRP: Baltimore City Department of Recreation and Parks
- BDC: Baltimore Development Corporation
- BDW: Baltimore Development Workgroup
- BGE: Baltimore Gas and Electric
- CDC: Centers for Disease Control and Prevention
- CGRN: Community Greening Resource Network, a support program of P&P
- CHAP: Commission for Historic and Architectural Preservation
- CoS: Commission on Sustainability
- CSX: CSX Corporation

- DES: Department of Environmental Services
- DGS: Department of General Services
- DHCD: Department of Housing and Community Development
- MDH: Maryland Department of Health
- DOIT: Department of Information Technology
- DOP: Department of Planning
- DOT: Department of Transportation
- DPW: Department of Public Works
- FEMA: Federal Emergency Management Agency
- FHWA: Federal Highway Administration
- MCC: Maryland Conservation Corps
- MDA: Maryland Department of Agriculture
- MDE: Maryland Department of the Environment
- MDNR: Maryland Department of Natural Resources
- MDTA: Maryland Transportation Authority
- MEMA: Maryland Emergency Management Agency
- MOEM: Mayor's Office of Emergency Management
- MON: Mayor's Office of Neighborhoods
- MOIT: Mayor's Office of Information Technology
- MTA: Maryland Transit Administration
- NAHB: National Association of Home Builders
- NGO: Non-governmental Organization
- OEM: Office of Emergency Management
- P&P: Parks and People
- PSC: Public Service Commission
- SHA: Maryland State Highway Administration
- USACE: U.S. Army Corps of Engineers

Mitigation and Adaptation Strategies by Sector

Infrastructure(IN)

Energy

IN-1: Protect and enhance the resiliency and redundancy of electricity system

The City's electricity supply and power grid system ensures that Baltimore's residents are not left without power in a hazard event. Most importantly, critical facilities that perform emergency response activities throughout the duration of a hazard event need reliable power supplies. Forward-thinking actions facilitate a Continuity of Operations Plan (COOP) during hazard events and prevent power outages of any significant scale. Beyond strengthening existing systems, increasing system redundancy is a vital measure for protecting critical infrastructure from power outages. The City will explore options for creating a redundant electrical infrastructure, including coordinated efforts with Federal programs to enhance grid resiliency.

This strategy intends to protect and support resilient energy systems, addressing power supply through both adaptation and mitigation actions. This strategy is relevant for all hazards, with particular actions targeting impacts from predicted relative sea level rise.

Maryland's Public Service Commission (PSC) regulates the State's public gas, electric, telephone, water, and sewage disposal utilities, as well as certain passenger transportation companies. Electricity and gas suppliers, like Baltimore Gas and Electric (BGE), are subject to the jurisdiction of the PSC. The Commission is recognized for its role in setting utility rates but has much broader authority for supervising and regulating the activities of public service companies like BGE. This relationship will have implications for some of the strategies below.

BGE, headquartered in Baltimore, is Maryland's largest gas and electric utility, delivering power to more than 1.2 million electric customers and more than 640,000 natural gas customers in Central Maryland. It is a wholly owned subsidiary of Constellation Energy, also headquartered in Baltimore, with subsidiaries that generate, sell and deliver energy and provide other energy-related services to customers throughout North America. The company has approximately 3,000 employees.

Implementation Actions:

1. Work with the Maryland Public Service Commission (PSC) to minimize power outages from the local electric utility during extreme weather events by identifying and protecting critical energy facilities located within the City
2. Evaluate the City of Baltimore's utility distribution system, and identify "underground utility districts" using BGE's May 2013 short-term reliability improvement plan
3. Support BGE's collaboration with the Maryland Public Service Commission to implement various smart grid solutions that will provide the City with real-time access to data during events
4. Identify, harden, and water seal critical infrastructure relative to pump stations, treatment plants, electrical, heating, and ventilation facilities within the floodplain
5. Work with stakeholders to encourage facility owners to develop decentralized power generation and fuel flexibility capabilities
6. Develop a comprehensive maintenance and training program for City employees at facilities with backup generators to ensure proper placement, hook-up and function during hazard events

7. Install external generator hookups for critical City facilities that depend on mobile generators for backup power
8. Partner with utility to evaluate protecting power and utility lines from all hazards
9. Determine low-lying substation vulnerability and outline options for adaptation and mitigation

Stakeholders: BCRP (Forestry), BDC, BGE, Building Owners, DGS, DOT, DPW, Exelon, PSC, Utility customers, Veolia, Wheelabrator

IN-2: Increase energy conservation efforts

While Baltimore intends to accommodate rising energy demand by increasing the available energy supply, a more effective—and far less expensive—strategy is to manage energy demand. This strategy increases the adaptive capacity of the City's power supply through adaptation and mitigation actions by reducing the demand for, and consumption of, energy resources. It is relevant for all hazards, for managing energy supplies and preventing service disruptions.

Implementation Actions:

1. Increase energy efficiency across all sectors through education, efficiency retrofits, and building management systems
2. Encourage critical facilities and institutions to connect to existing cogeneration systems, or develop new cogeneration systems
3. Continue the City's electricity demand-response program during peak usage or pre-blackout periods

Stakeholders: BGE, Building owners, City Delegates, DOP, DPW, Energy Office, PSC

IN-3: Ensure backup power generation for critical facilities and identified key infrastructure during power outages

During a power outage, it is essential that critical facilities have backup power supplies in-place. Hospitals, nursing homes, and adult care facilities rely on extensive equipment and utility services to diagnose, treat, and care for patients. These facilities, in addition to police and fire stations, and wastewater treatment plants, tend to already have backup generation systems installed. However, generators will sometimes fail or may be placed in high-risk areas. This action builds recommended resilience and disaster prevention and planning into infrastructural and energy systems through mitigation and adaptation actions. It ensures that critical and key facilities maintain continuous power supply.

Implementation Actions:

1. Investigate off-grid, on-site renewable energy systems, generators, and technologies for critical facilities to ensure redundancy of energy systems
2. Seek funding to purchase and install generators for all city buildings designated as critical to agency functions
3. Evaluate and ensure backup power generation is available to healthcare facilities (nursing homes, critical care facilities, hospitals, etc.)

Stakeholders: DGS, DOP, DOT, DPW, MOEM

Liquid Fuels

Liquid fuels include the gasoline and diesel fuel necessary to transport people, goods, equipment and supplies into, out of, and throughout Baltimore City. Fuel is used to run city buses, taxis, personal motor vehicles, planes and the large ships that bring goods into and out of the harbor. Beyond transportation, liquid fuels are used for a variety of other needs, including heating water and homes and enabling backup generators to function. It is essential to evaluate the vulnerability of our liquid fuel system to the impacts of natural hazards in order to strengthen the supply chain and increase redundancy.

IN-4: Protect and manage compressed liquefied natural gas sites and (City) fueling stations before and during hazard events

Fuel supply infrastructure is vulnerable to extreme weather events. Natural and man-made disasters due to storm surge and flooding, storm- and heat-related power outages, or other events can cause disruptions in the supply of liquid fuels. Hardening of fuel assets, facilities, and stations would decrease disruptions and allow for faster restoration of operations. These efforts will reduce the likelihood of fuel shortages during hazard events.

The City will increase damage prevention and adaptive capacity of stormwater and liquid fuel cells systems, particularly in relation to flooding and sea level rise. This will be accomplished through implementing adaptation and mitigation actions for stormwater systems and liquid fuel cell facilities and sites.

Implementation Actions:

1. Work with BGE to ensure existing preparedness plans for Spring Gardens liquefied natural gas site incorporate its vulnerability to present and predicted flooding, storm surge and sea level rise
2. Adopt building code that requires anchoring of 50-gallon storage tanks or larger
3. Support the Maryland Public Service Commission's effort to accelerate replacement of aging natural gas infrastructure, which will harden the system against flooding

Stakeholders: BGE, DGS, DOP, DOT, DPW, Veolia

IN-5: Evaluate and improve resiliency of liquid fuels infrastructure

Hazard events can place considerable stress on liquid fuel supplies. To improve the resiliency of energy systems and ensure that City systems receive adequate power supply, it will be important to address liquid fuel cell infrastructure and mitigate disruptions and loss of power caused by hazard events. The City will work with utilities, the PSC, stakeholders and the State to develop and build upon existing strategies that will harden refineries, pipelines and terminals essential to sustaining liquid fuel supplies.

Implementation Actions:

1. Design and implement a generator program that assists private gas stations in securing backup generators, especially those stations along major evacuation routes. Exchange for a commitment to fueling emergency response vehicles during a hazard event
2. Increase and ensure fuel availability during distribution disruptions. Priority given to critical facilities and emergency responders

Stakeholders: BCFD, BCPD, DES, DOT, DPW, MOEM, BGE, DGS, MOE

Communication Systems

IN-6: Evaluate and improve resiliency of communication systems that are in place for sudden extreme weather events

Storm surge, heavy precipitation, and high winds all pose major threats to the power grid upon which communication systems rely. Communication systems include phone, internet, and television—all of which are used to provide information and connect people before, during, and after a hazard event. These systems are made up of an intricate network of cables, towers, and equipment-—including distribution and switching centers—that all people rely on in some capacity. In Baltimore, major power outages may result in significant disruption to business and personal communication, especially in areas where copper and coaxial cables have not been upgraded to fiber cables, which are more resilient to water damage.

Communication systems play an essential role in everyday life but are even more critical during hazard events. These systems connect emergency responders to individuals in need of assistance, allow citizens to check in with their families and friends, provide healthcare facilities with access to essential information, and assist emergency response workers in providing aid. It is vital to protect the health and welfare of residents by building resilience and disaster prevention and planning—as related to all natural hazards—into communication systems. Presently, much of Baltimore City's communication equipment is located in building basements and on rooftops, making it more susceptible to hazards.

Implementation Actions:

1. Utilize new technologies such as fiber optics, external hook-ups, and mobile generators to improve resiliency
2. Evaluate, improve and build redundancy into all public and inter-agency warning and communication systems
3. Identify best practices for the installation and management of floodproofing for all communication infrastructure at risk of water damage
4. Implement additional nurse triage phone lines and community health centers to reduce medical surge on hospitals
5. Ensure continued operation of City government's various computer mainframes for email, control systems, and internet service by having stand-by batteries for each with a capacity sufficient for backup generation to operate

Stakeholders: BGE, DOT, Energy Office, FCC, MOIT, Private Entities, PSC, BCPD, BCFD, MOE

Transportation

IN-7: Integrate climate change into transportation design, building and maintenance

Baltimore's transportation system is made up of 2,000 miles of roadway, 7 miles of interstate highway, and around 300 bridges and culverts, in addition to light rail, subway, bus, train, and boat systems. Much of the interstate system, roadways and rail lines fall within the City's floodplain. Low-lying areas such as Fells Point have the potential to be easily inundated by heavy precipitation events and high tides. Impacts from hazards and climate change will affect the construction, maintenance, and operations of many of the City's transportation systems.

Baltimore's roadways and transportation networks are vulnerable to climate change threats and natural hazards in a number of ways, including surface flooding, wave action from storm surges, and asphalt damage due to heat waves. To mitigate the impact of these threats on streets and other infrastructure, Baltimore will integrate climate resiliency features into future design, construction, reconstruction, and maintenance projects.

Implementation Actions:

1. Determine the coastal storm vulnerability and complete an exposure assessment of City transportation assets
2. Improve stormwater management, operations and maintenance for stream flooding that erodes bridge supports
3. Incorporate compliance with earthquake standards to withstand a magnitude 8 earthquake for all new, improved and rebuilt bridges
4. Design bridge expansion joints for longer periods of high heat, and develop a more robust inspection and maintenance process
5. Research utilizing existing and new rating systems for all new infrastructure and road projects
6. Identify, investigate, and incorporate Best Management Practices related to transportation design, construction and maintenance
7. Require that backup solar-powered street lights and signals be integrated along evacuation routes and high-traffic areas

Stakeholders: CSX, DOT, DPW, MTA, Private Contractors

IN-8: Identify additional alternative routes and modes for effective transport and evacuation efforts during emergency situations

Much of Baltimore's ability to respond effectively to a disaster is vulnerable to disruption and damage of critical transportation facilities. Road closures may impair the delivery of emergency services or supplies of food, fuel, and medicine. Similarly, inoperable transportation networks prevent efficient evacuation and may require more time to restore, thus limiting non-transportation infrastructure and economic activity.

Implementation Actions:

1. Evaluate existing systems and coordinate a comprehensive evacuation plan with regional partners
2. Develop and prioritize clearance of specified transportation routes for delivery of emergency response supplies
3. Educate the public on the dangers of driving through flooded roads
4. Make available a network of dedicated pedestrian and bicycle transportation routes leading into and throughout the City

Stakeholders: BCFD, BCHD, DOP, DOT, MOEM

IN-9: Alter transportation systems in floodprone areas to effectively manage stormwater

Flooding can cause considerable damage to transportation systems. To prevent this damage and build resiliency to flooding hazards into transportation systems, particularly highways, roads, and tunnels, the City will consider both adaptation and mitigation actions that may be taken. This will prevent

vulnerability to flooding, including the consideration of stormwater management programs for their potential to reduce the significance of flooding.

Implementation Actions:

1. Prioritize infrastructure upgrades for roads identified at risk of flooding through the use of elevation data and Sea, Lake and Overland Surges from Hurricanes (SLOSH) model results
2. Raise streets in identified floodprone areas as they are redeveloped
3. Encourage development of Green Streets in floodprone areas and throughout the City
4. Encourage use of permeable pavement in non-critical areas–low-use roadways, sidewalks, parking lots and alleys where soils permit proper drainage
5. Add pumps or other mitigation alternatives to streets as they are redeveloped (if needed)
6. Assess need for new culvert capacity and identify where upgrades are needed
7. Conduct an in-depth analysis of the impacts of drain fields that feed the harbor
8. Expand and reinforce existing stormwater education programs
9. Design and implement floodgates and barriers in transportation tunnels
10. Encourage Federal and State Government to design and install floodgates and barriers at vulnerable transportation tunnels
11. Upgrade existing floodgate hardware and mechanisms to control rise rate of water into all city tunnels

Stakeholders: Amtrak, BCRP, CSX, Developers, DOT, DPW, FHWA, MDTA, MON, NGOs

IN-10: Ensure structural stability of all transportation tunnels to reduce impact from seismic activity

Tunnels are vulnerable to the impacts of seismic activity, which could damage structural integrity. Damage or failure at one of the City's tunnels would significantly disrupt the regional transportation network. The City will investigate a number of structural resiliency strategies for reducing the vulnerability of tunnels to seismic hazard events. Use both mitigation and adaptation actions to reinforce structural resiliency.

Implementation Actions:

1. Repair cracks and leaks in all tunnels to reduce impact of seismic activity
2. Follow Federal, State and local criteria for the stabilization of historic transportation tunnels (e.g., Howard Street)
3. Install a seismically resistant fire standpipe, air monitoring, and automatic valve system in all tunnels to provide a fully automated and monitored fire suppression system

Stakeholders: Amtrak, CSX, DOT, DPW, FHWA, MDTA, OEM

IN-11: Evaluate changes to road maintenance and construction materials based on anticipated changes in climate

Recognizing future conditions, current transportation systems may require renovation or modification. In order to prevent damage to highways and roads from extreme heat events or other hazardous conditions, road construction projects should use both adaptation and mitigation actions to address potential damage to roadway surfaces.

Implementation Actions:

1. Implement a repaving strategy that reduces heat-related damage to asphalt and incorporates maintenance and operations that extend the life of the road surface
2. Develop deicing strategies and materials that are effective in extreme cold temperatures and prolonged events to stabilize roadway and bridge surfaces

Stakeholders: DOT, SHA

Waterfront

IN-12: Enhance the resiliency of the City's waterfront to better adapt to impacts from hazard events and climate change

Baltimore's waterfront properties are vulnerable to the impacts of coastal storms and other natural hazards. The majority of Baltimore's waterfront consists of bulkheads, which are structures typically made of stone or concrete that hold shorelines in place. Adaptation and mitigation actions will increase resiliency and reduce damage.

Implementation Actions:

1. Raise bulkhead height along shoreline areas most at risk
2. Encourage the development of integrated flood protection systems that use structural (engineering) and non-structural (wetlands) measures
3. Review and enhance coastal area design guidelines to better mitigate the impacts of flooding
4. Enhance and strengthen waterfront zoning and permitting

Stakeholders: BDC, Development Community, DGS, DHCD, DOP, DOT, MDE, MDNR, OEM

Wastewater

IN-13: Increase the resilience of all wastewater systems and protect them from current and projected extreme weather events

A number of wastewater treatment assets are at risk of flooding or other damage from extreme weather events. To minimize disruptions to these systems, efforts must be implemented to protect vulnerable wastewater systems and facilities from current and projected extreme weather events.

Implementation Actions:

1. Ensure all water and wastewater pumping stations have off-grid, on-site energy sources and/or reliable backup power sources by increasing the number of backups and pulling electricity from different grids
2. Develop and adopt increased level of protection for construction, redevelopment, and design of all water and wastewater facilities that incorporate future climate projections
3. Establish protocols and ensure effective operations and security for wastewater treatment plants when facilities are overwhelmed during large storm events
4. Increase stormwater recharge areas and quantity management to prevent flooding from overflows
5. Conduct a risk assessment of the City's current water and sewer systems to identify age, condition of infrastructure, capacity, weaknesses and areas for priority upgrades

6. Conduct and utilize a detailed risk assessment to determine vulnerability of the sewage treatment plant to prevent overflows from extreme storm events
7. Determine the elevation of sewage treatment buildings, tank construction details, and if the plant is at risk of back flow, for improvements to withstand coastal storm events
8. Retrofit wastewater treatment facility and methane gas storage system to withstand seismic activity to protect against earthquakes. Design facility to exceed current building codes

Stakeholders: DPW, MOE MOEM

IN-14: Integrate resiliency, redundancy, and structural stability into the City's drinking water system to ensure safe and reliable water storage and distribution

This strategy is designed to protect the health of residents through enhanced resiliency, redundancy, and structural stability of the City's drinking and water supply systems, including dam facilities and infrastructure systems, from all natural hazards.

Implementation Actions:

1. Repair leaks and improve connection from all City reservoirs and the Susquehanna River
2. Provide water conservation education, and continue to protect our watersheds to assist in maintaining water quality
3. Ensure dam emergency plans account for impacts of climate change
4. Identify and document post-damage responsibilities in memorandums of understanding as addendums to the Reservoir Watershed Management Agreement
5. Review dam capacity, load and failure points and review them against 1,000-year and 10,000-year precipitation events
6. Conduct a study to determine seismic design standards and seismic resiliency of drinking water distribution system (tunnels, piping, clean water pump stations, dams, shafts, and tanks)
7. Increase stormwater recharge areas and quantity management in watersheds feeding the reservoirs
8. Evaluate the impacts of sediment loading on reservoir capacity
9. Manage watershed forests to provide maximum benefits for water quality and to maintain resiliency during extreme weather events
10. Adopt new policies on salt application to prevent high salinization of drinking water supplies
11. Establish a structured Firming Program to maintain adequate storage and water quality in the source-water reservoirs during drought conditions
12. Maintain appropriate agreements with Susquehanna River Basin Commission (SRBC) and Exelon Power Company to ensure adequate water withdrawals from the Susquehanna River during drought emergency

Stakeholders: BCHD, BCRP, DHCD, DOP, DOT, DPW, MCC, MDE, Regional Watershed Groups, Reservoir Watershed Management Committee, SHA, Water Utility

IN-15: Conduct an assessment that evaluates and improves all pipes' ability to withstand extreme heat and cold

Much of Baltimore's water system is dated and in need of upgrades. It is important to build extreme weather resilience and disaster prevention into water and wastewater systems by using both adaptation and mitigation actions. Additionally, structural and infrastructural upgrades must be made to reduce loss of water supply from the distribution system.

Implementation Actions:

1. Replace old and malfunctioning pipes with new pipes and pipe-lining technologies

Stakeholders: DOT, DPW

Stormwater

IN-16: Enhance and expand stormwater infrastructure and systems

Future changes in precipitation frequency and intensity may require reconsideration of the design of existing stormwater infrastructure systems. This strategy aims to increase resiliency and disaster prevention measures related to stormwater systems by enhancing drainage systems in stream corridors and improving and repairing stormwater conveyance pipes and outfalls.

Implementation Actions:

1. Implement the requirements of Baltimore's MS4 (separate stormwater and sewer system) permit
2. Prioritize storm drain upgrades and replacement in areas with reoccurring flooding
3. Install backflow-prevention devices or other appropriate technology along waterfront to reduce flood risk
4. Preserve and protect natural drainage corridors
5. Review and revise storm drain design on a continuous basis, to accommodate projected changes in intense rainfall
6. Pursue grants for Flood Control measures to alleviate flooding in the most flood prone areas when and where feasible

Stakeholders: Community Groups, DOT, DPW, MOEM, MDNR, NGOs, Private Developers, Stormwater Utility, USACE

IN-17: Modify urban landscaping requirements and increase permeable surfaces to reduce stormwater runoff

Proper landscaping increases resilience of stormwater systems and reduces potential damages related to flooding. It also provides opportunities for improved rainwater absorption and increased vegetative surface area while simultaneously reducing impervious surfaces.

Implementation Actions:

1. Support existing stormwater requirements and continue to evaluate and improve Best Management Practices
2. Encourage urban landscaping requirements and permeable surfaces into community-managed open spaces
3. Utilize water conservation elements such as green roofs, rain gardens, cisterns, and bioswales on residential, commercial, industrial, and City-owned properties to capture stormwater
4. Encourage permeable paving on low-use pathways
5. Pursue grants for Floodplain Storage and Diversion projects to alleviate flooding in the most flood prone areas when and where feasible

Stakeholders: BCRP, BDW, Citizens, DHCD, DOP, DOT, DPW, NGOs, Private Developers

IN-18: Evaluate and support DPW's stream maintenance program

Increase resiliency and disaster prevention measures to protect stormwater systems from flooding and sea level rise hazards. Utilize both adaptation and mitigation measures to improve natural stream systems.

Implementation Actions:

1. Review and improve status of standing maintenance requirements
2. Ensure adequate funding is in place to support stream maintenance
3. Identify opportunities where stream restoration efforts will offset maintenance costs
4. Identify interdependencies and benefits of stream maintenance with other transportation programs
5. Conduct regular maintenance of streams and stormwater quality facilities: clear streams, prioritize dredging, increase inspection and cleaning of culverts and storm drains

Stakeholders: DOT, DPW, MDE, MDNR MOEM, USACE

IN-19: Support and increase coordination and information sharing across jurisdictions to better enable mitigation of cross-border impacts on the region's watersheds (e.g., understanding flood conditions upstream in the county)

Enhance adaptive capacity of the City by coordinating stormwater management efforts with surrounding jurisdictions to reduce flooding and improve water quality.

Implementation Actions:

1. Partner with local counties to evaluate major tributaries in all watersheds to determine best management practices for capturing run-off and slowly releasing it (stormwater quantity management)

Stakeholders: BCRP, County Governments, DOP, DPW, MCC, MDNR, NGOs, Stormwater Utility

Solid Waste

IN-20: Reevaluate and support a comprehensive debris management plan for hazard events

Build resilience and disaster prevention into solid waste and stormwater systems through adaptation and mitigation actions.

Implementation Actions:

1. Expand and integrate existing programs to reduce or intercept debris before it gets into the streams and harbor
2. Investigate, develop and promote solid waste management actions for disposing of waste debris removal before a hazard event

Stakeholders: DPW, MOEM, NGOs, R&P

IN-21: Encourage the integration of climate change and natural hazards into private and State planning documents, systems, operations, and maintenance

Increase overall resiliency and disaster prevention efforts in private and statewide planning documents, systems, operations, and maintenance. Consider transportation systems, emergency response actions, and air quality measures.

Implementation Actions:

1. Incorporate consideration of hazards and climate adaptation efforts into all plans, systems, operations, and maintenance
2. Ensure Red Line planning incorporates adaptation strategies
3. Ensure hazard scenarios, utilized in vulnerability assessments, are at a minimum 25% greater in intensity and impact than historical record events to date
4. Develop guidelines for hospital, health care facilities and other institutional entities (e.g. Universities)
5. Partner with regional air quality institutions to integrate air quality measures and messaging into City climate change policy efforts

Stakeholders: BCHD, DHMH (Office of Health Care Quality), DOT, Health Care Community, Hospitals, MEMA, MTA, OEM, SHA

IN-22: Develop City policy which requires new city government capital improvement projects to incorporate hazard mitigation principles

Enhance Baltimore's adaptive capacity through policy improvements that cost-effectively incorporate mitigation actions into ongoing construction and physical maintenance projects.

Implementation Actions:

1. Discourage new public projects in hazard-prone areas such as floodplains or the coastal high hazard areas
2. Utilize hazard mitigation design requirements that exceed minimum standards for critical facilities
3. Use comprehensive infrastructure assessments to identify infrastructure in need of replacement and prioritize funding for those projects

Stakeholders: BCHD, BCRP, DGS, DOP, DOT, DPW, Energy Office, MOEM

Buildings (B)

City Codes and Design Guidelines

B-1: Develop and implement hazard protections for critical facilities including hospitals, fire stations, police stations, hazardous material storage sites, etc.

Prevent structural damage from all natural hazards to critical facilities through adaptation and mitigation actions. Strengthen existing building codes and land use regulations, focusing on efforts to enhance the resiliency of energy systems and reduce vulnerability from flooding.

Implementation Actions:

1. Conduct educational outreach for city-owned, residential, commercial, and industrial buildings about proper storage and disposal of hazardous materials and heating oil
2. Require hazardous materials stored in city-owned, residential, commercial, and industrial buildings within the floodplain to be elevated a minimum of 3 feet above the freeboard
3. Require new critical facilities to be designed with redundant operating systems
4. Require pre-wiring for generators at all facilities designated critical to agency operations and hazard response
5. Develop stricter flood regulations for critical facilities
6. Coordinate delivery of fuel and/or access to fuel for critical facility emergency generators.

Stakeholders: BGE, DGS, DOP, Hospitals, Material Storage Sites

B-2: Enhance City building codes that regulate building within a floodplain or near the waterfront

It is essential to identify ways to facilitate the voluntary construction of new, more resilient building stock and to encourage voluntary retrofits of existing vulnerable buildings over time. Build the City's resilience to flooding and sea level rise hazards through enhanced building codes and regulations in floodprone areas.

Implementation Actions:

1. Design new projects to be resilient to a mid-century sea level rise projection and adaptable to longer term impacts
2. Incorporate climate change and coastal hazard considerations into building codes by increasing freeboard requirements to 2 feet as buildings are redeveloped and renovated
3. Continue to regulate to the existing tidal floodplain delineation as adopted on February 2, 2012
4. Incorporate outfall elevation regulations
5. Develop and share construction Best Practices for development within floodplains
6. Train all code enforcement and building inspectors about floodproofing techniques and the local floodplain ordinance
7. Encourage green roof installations to include vegetative and reflective technologies for all new commercial, industrial, multifamily, and city-owned development

Stakeholders: Baltimore County, BDW, BDC, DHCD, DOP, DPW, MDE, Utilities

B-3: Strengthen City zoning, floodplain and construction codes to integrate anticipated changes in climate

Increase the resilience of Baltimore's buildings and properties to all hazards by addressing land use and stormwater and floodwater management systems. City codes and standards must continue to develop and incorporate climate risks to both protect existing buildings and strengthen new and substantially improved buildings. Utilize both adaptation and mitigation actions to improve building codes and regulations to increase the resiliency of Baltimore's building stock.

Implementation Actions:

1. Review zoning code and strengthen language (where necessary) in order to better protect citizens and increase resiliency in buildings
2. Review and amend existing building and floodplain regulations to require more flood-resistant new and existing structures when located in the floodplain
3. Utilize open space category in zoning code to protect sensitive areas (stormwater sites, steep slopes, floodways, etc.)
4. Review and increase Flood Protection Elevation (Base Flood Elevation + Freeboard) standards to the highest available State, Federal or local elevation level
5. Evaluate and update stormwater management regulations to avoid increases in downstream flooding
6. Adopt design requirements that include wet and dry floodproofing techniques
7. Review and consider adoption of the International Green Construction code

Stakeholders: BDW, City Government, Community Groups, DHCD, DGS, DPW, NAHB, NGOs, MDE, Private developers, Private land owners

B-4: Update a list of floodprone and repetitive loss buildings to consider for acquisition

Where properties suffer from repetitive losses due to flooding, it is important to consider ways to increase their resiliency through physical improvements, or purchase and remove them from the floodplain by demolishing them. Acquisition of floodprone properties requires collaboration between many City agencies, residents and property owners in the area, which is often difficult; it is also an expensive option. The City can focus its efforts on updating the list of floodprone and repetitive loss properties, which will help prioritize and guide mitigation funding and future acquisitions.

Implementation Actions:

1. Continue to acquire property (including repetitive loss properties) in the Special Flood Hazard Areas, where feasible and appropriate
2. Prioritize Hazard Mitigation Assistance funding for mitigation of repetitive loss properties and severe repetitive loss properties
3. Develop a creative financing program for flood resiliency in industrial buildings
4. Pursue grants to acquire flood prone properties when and where feasible

Stakeholders: DHCD, DOP, MEMA, MDE, Office of Real Estate

B-5: Improve wind resiliency of new and existing structures

Scientific projections suggest an overall increase in the frequency of the most intense storm events that are accompanied by wind hazards. Current Building Code requirements should take into consideration this projected increase. Recognizing that older buildings that predate modern standards are particularly vulnerable, efforts should address new structures and renovations to existing structures. The City will review existing building codes and identify where wind-resistance specifications must be made for both façade elements and rooftop structures and equipment.

Implementation Actions:

1. Review local building codes to determine if revisions are needed to improve the structures' ability to withstand greater wind velocities and storm impacts
2. Retrofit emergency shelter windows to withstand winds associated with coastal storm events

Stakeholders: Commercial Building Owners, DCHD, DGS, DOP, MDE, MOEM, Private Developers

B-6: Evaluate various seismic design enhancements using prototypical Baltimore City building types

In 2011, Baltimore experienced a magnitude 5.8 earthquake, originating in Virginia. Due to this event, steps should be taken to increase Baltimore's resiliency to earthquakes and other seismic events.

Implementation Actions:

1. Determine engineering effectiveness and cost benefit of various earthquake mitigation measures using computer modeling

Stakeholders: DCHD, MOEM, USGS

B-7: Retrofit existing buildings in the designated Flood Area to increase resiliency

It is critical to improve flood damage prevention measures by increasing structural resiliency through mitigation actions such as retrofits and upgrades. To accomplish this, engineering alternatives will be studied where assets cannot be moved, and measures will be developed that identify how to best increase structural resiliency within the designated Special Flood Hazard Areas (SFHAs).

Implementation Actions:

1. Target and encourage flood resiliency retrofits for buildings in the designated SFHAs
2. Prioritize retrofitting and increasing resiliency of Public Housing units in the designated SFHA and other high-risk areas
3. Educate building owners within the floodplain to ensure that all electrical, mechanical, and key building systems are above the base flood elevation and meet existing codes
4. Pursue grants to elevate flood prone properties when and where feasible
5. Pursue grants for dry flood proofing of Commercial and Historic structures in the most flood prone areas when and where feasible

Stakeholders: BDC, DHCD, DPW, Federal and State Partners, MCC, MON, NGOs, OEM

B-8: Improve resource conservation practices in all City owned buildings

Increase resiliency of City Government buildings by increasing efficiency of internal energy systems, and increased measures for energy conservation. Energy use reduction is important for regional energy supply protection during extreme heat events and other high energy demand situations.

Implementation Actions:

1. Install energy-efficient and low-water-use equipment during renovations in all City-owned buildings
2. Support energy efficiency and weatherization as part of Baltimore City schools ten-year plan
3. Update Baltimore green building standards by offering multiple compliance paths for new and substantially renovated construction

Stakeholders: BCPSS, DCHD, DGS, DOP

B-9: Conduct educational outreach to increase resource conservation practices in private buildings

Increase hazard mitigation awareness through resource conservation educational materials and programs for the general public and businesses. Include information about utilities, water use, energy savings programs, hazardous materials, and electricity demand.

Implementation Actions:

1. Conduct educational outreach and provide information about savings related to reduced water use
2. Educate and provide resources and information about utility rebate programs
3. Provide energy efficiency education to include information on conserving electrical power. Emphasize reductions during summer peak demand hours (S)

Stakeholders: BCPSS, BGE, BOS, DPW, Exelon, MON, NGOs, OEM

B-10: Use Hazus-MH computer modeling to determine losses generated by coastal storms

Protect the health, wellness, and safety of Baltimore residents by evaluating mitigation practices as the results speak to potential losses generated by coastal storms and extreme wind, flood and earthquake events through the use of computer modeling technology. Determine possible mitigation measures and identify adaptation responses.

Implementation Actions:

1. Utilize engineering studies and cost-benefit analyses to identify additional mitigation needs and actions
2. Evaluate various building design enhancements to reduce losses generated by earthquakes, floods, and storm surge

Stakeholders: DOP, FEMA, MEMA, MOEM, NOAA

Natural Systems (NS)

Urban Parks and Forest

NS-1: Utilize green corridors and parks to help protect surrounding communities from the impacts of hazard events

Leverage natural features to protect the health, wellness, and safety of Baltimore residents. Regard natural elements such as stream corridors and trees for their capacity to mitigate the impacts of hazard events. This strategy is primarily focused on mitigation actions but recognizes that increased natural capacity can positively influence climate adaptation efforts.

Implementation Actions:

1. Evaluate green corridors and parks for possible improvements for floodplain management
2. Increase the resiliency of park facilities and buildings

Stakeholders: BCRP, Community Groups, DPW, NGOs

NS-2: Increase and enhance the resilience and health of Baltimore's urban forest

Baltimore's urban forests and trees offer countless environmental benefits but are vulnerable to climate change-related impacts and hazards, including storm surge, wind, and changes in average temperatures. Increasing Baltimore's tree canopy will improve stormwater management, increase air quality and reduce impacts from the urban heat island.

Implementation Actions:

1. Anticipate the impacts of future changes in temperature and weather on the urban forest by developing a comprehensive list of plant and tree species known to have a broad range of environmental tolerances
2. Establish and routinely update a comprehensive tree inventory to anticipate insect and forest structural impacts of climate change
3. Establish a comprehensive maintenance program that includes pruning for sound structure and the removal of hazardous limbs and trees. First focus on areas where vulnerable infrastructure is nearby such as energy supply and roads
4. Continually adjust and modify planting details and specifications to assure the health and longevity of trees
5. Increase the urban tree canopy and target areas with urban heat island impacts

Stakeholders: BCRP, BGE, Community Groups, DOP, DOT, DPW, MDNR, NGOs

NS-3: Create an interconnected network of green spaces to support biodiversity and watershed-based water quality management

It is important to enhance Baltimore's adaptive capacity through the establishment of an interconnected system of green spaces and natural features that increase biodiversity and reduce stormwater runoff. Actions focus on using vacant properties to create new green spaces and linking these to existing parks, stream valleys, and public lands.

Implementation Actions:

1. Utilize the Baltimore Green Network Plan to increase green spaces in areas where there is available vacant land to reduce the heat island effect and provide other benefits
2. Convert vacant land and row houses into meaningful and connected open space
3. Complete a habitat analysis and plan for the City
4. Create a strategic plan that identifies areas of focus for tree planting, stormwater management, and forest preservation
5. Certify Baltimore as a Community Wildlife Habitat through the National Wildlife Foundation (NWF)

Stakeholders: BCRP, BDC, Community Groups, DHCD, DOP, DPW, Federal Agencies, MDNR, NGOs, State Agencies

NS-4: Expand, protect and restore riparian areas in the city

Baltimore will pursue cost-effective methods for using stream valleys and associated natural features to protect adjacent land and communities from the impacts of flooding hazards. Utilize adaptation and mitigation actions to address the capacity of riparian buffers.

Implementation Actions:

1. Evaluate current regulations regarding stream buffers and floodplains and modify them (if appropriate) to assure they adequately protect perennial stream corridors
2. Evaluate potential for completion of Maidens Choice stream restoration project (Army Corps of Engineers, Baltimore District identified project).

Stakeholders: BCRP, DOP, DPW

NS-5: Preserve and create new coastal buffer efforts and support creating more wetlands and soft shoreline along coastal areas

Enhance ecological buffers along coastal areas to increase floodwater management and resiliency to flooding and sea level rise. Protect the health, safety, and welfare of Baltimore's residents with both adaptation and mitigation efforts.

Implementation Actions:

1. Integrate natural buffer requirements, such as wetlands and soft shorelines, into new development or redevelopment
2. Complete stream restoration projects in Baltimore City and County stream valleys that lead into the coastal wetlands so as to increase habitat and reduce sedimentation (L)
3. Identify and evaluate areas in the Critical Area buffer to prioritize ecological buffer restoration efforts

Stakeholders: BCRP, BDC, DOP, DPW, NGOs, State Agencies, Waterfront Partnership

Water Supply and Management

NS-6: Require the City's drought management plan to account for changes in climate

Enhance the adaptive capacity of the City's water supply with increased drought preparedness.

Implementation Actions:

1. Map drought risks and water availability via climate change scenarios
2. Update drought management plans to recognize changing conditions

Stakeholders: BCHD, DOP, DPW, Water Utility

NS-7: Integrate climate change and natural hazards planning into small watershed action plans (SWAPs)

The City will integrate climate change and hazard mitigation into SWAPs to protect water quality and quantity. Increase the adaptive capacity of the City's stormwater and floodwater management system.

Implementation Actions:

1. Review existing watershed management plans and identify future actions to address climate impacts

Stakeholders: DOP, DPW, NGO's

NS-8: Conduct detailed ongoing analysis of climate information, trends in storm events and hydrology to support policy changes responding to climate change

Use detailed analysis of accurate data to support flood policies to protect the health, safety, and welfare or Baltimore's residents from changes in sea level rise. This strategy is primarily concerned with adaptation measures Baltimore must use to update all City planning and emergency preparedness efforts.

Implementation Actions:

1. Expand the use of climate information (e.g. seasonal forecasts) in water resources planning and management
2. Research and actively monitor trends in storm events, stream flow and other conditions affecting hydrology and water
3. Update flood maps to reflect changing risk associated with climate change
4. Continuously improve and enhance flood vulnerability data
5. Pursue grants and technical assistance to conduct hydrology and hydraulic studies on flood prone areas within the city, to include Maiden's Choice Branch, when and where feasible

Stakeholders: FEMA, MDE, MDNR, MEMA, NGOs, State Agencies, Waterfront Partnership

Public Services (PS)

Emergency Preparedness and Response

PS-1: Strengthen emergency preparedness coordination between local government, NGOs, and private entities by updates to the City Emergency Operations Plan (EOP) and related Emergency Support Functions (ESF)

Increase Baltimore's adaptive capacity by coordinating communication and interaction between various entities using both adaptation and mitigation actions to address all natural hazards.

Implementation Actions:

1. Identify and develop a common database and communication technology that all city government agencies and departments should utilize for hazard information, preparedness and response
2. Ensure consistency and integration with existing and future response plans within and between agencies
3. Coordinate outreach efforts of the Mayor's Office of Emergency Management, Mayor's Office of Neighborhood and Constituent Services and Baltimore City Health Department to leverage messages related to all-hazards emergency preparedness, response and recovery
4. Continue to identify and improve coordination with key partners. Develop strong working relationships with local experts to provide technical assistance to refine and improve City government emergency preparation
5. Review and improve specific response plans contained in the EOP and related ESFs that relate to extreme weather events (snow, heat, flood, wind), electrical outages, and other hazard events
6. Ensure equipment purchases and communication systems are compatible across agencies and jurisdictions
7. Meet with Baltimore City animal rescue and care shelters to further develop their internal plans for animals' health and safety during and after a hazard event
8. Ensure all animal rescue and care shelters located within the floodplain are provided the support to apply for and obtain funds to relocate
9. Facilitate the sharing of hospital-based best practices and resources with Baltimore City hospitals that foster community resilience to climate change

Stakeholders: BARCS, BCHD, City Agencies, County Governments, DOP, Humane Society, MOEM, PSC BCFD, BCPD, Community Groups, DHMH, MOIT, MON

PS-2: Develop a Hazard Awareness Program

Increase hazard awareness with the creation of an ongoing outreach program. Consider both adaptation and mitigation actions to increase Baltimore preparedness for all hazard events.

Implementation Actions:

1. Create a standardized early warning system for members of the public and educate them on actions they should take when an alarm sounds
2. Evaluate and improve community health center strategies for communicating with patients during an emergency

3. Hold climate-specific seminars, in partnership with MHA, for hospital emergency and sustainability managers

Stakeholders: BCHD, DHMH, DOP, MEMA, MOEM, MOIT

PS-3: Designate community leaders and organizations that can assist and provide support during hazard events

Leverage community resources and empower individuals to increase efforts to protect Baltimore residents from all natural hazards. This strategy is concerned with measures for climate adaptation and emergency preparedness.

Implementation Actions:

1. Prior to a hazard event, identify lead contacts serving vulnerable populations and coordinate actions to maximize safety and information sharing
2. Develop a community group coordination plan and implementation guide
3. Identify and evaluate plans already in place and work to improve utilization of community-based leaders to assist in preparedness and response
4. Develop training and guidance documents for Resiliency Hub Leaders that detail the scope of services (include checklists and instructions for opening, running, and closing)
5. Increase number of Resiliency Hubs
6. Initiate community resiliency planning, outreach, and support

Stakeholders: BCFD, BCHD, BCPD, Community Groups, DOP, HABC, Hospitals, MOEM, MON

PS-4: Integrate climate change and natural hazards planning into all City and community plans

The City encourages interagency and cross-jurisdictional partnerships to ensure that resiliency is a factor. Likewise, Baltimore advocates for similar changes in the planning and evaluation of major projects and plans. It is important to embed resiliency and disaster prevention within all City and community plans to address all natural hazards and incorporate climate adaptation measures into City policy.

Implementation Actions:

1. Develop guidelines to include proactive resilience planning into plan development processes
2. Partner with Maryland Department of Health and Mental Hygiene or other pertinent entity to develop institutional checklist and materials for health care - specific resilience plans

Stakeholders: BCHD, DHMH, DOP, MOEM, State and Federal Agencies

Health

PS-6: Anticipate and address potential disease outbreaks caused by extreme weather events and changing climatic conditions

Increase adaptive capacity and prepare for potential disease outbreaks as a result of extreme weather events. This strategy is concerned with adaptation measures and emergency preparedness.

Implementation Actions:

1. Support studies of heat- and flood-related vector-borne diseases in the Baltimore region based on changing temperature and moisture
2. Evaluate existing programs that detect disease outbreaks to determine their flexibility to respond to new conditions

Stakeholders: BCHD, CDC, DHMH, MDE, State Agencies

PS-7: Protect Baltimore residents from the effects of hazard events and plan for more frequent hazard instances

Protect the health and safety of Baltimore's residents by preparing for more frequent hazard instances related to extreme heat. This action addresses both adaptation and mitigation measures and is concerned with emergency preparedness.

Implementation Actions:

1. Re-evaluate and update existing heat alerts, advisories, and updates to healthcare and emergency service providers
2. Ensure that residents and visitors have access and transportation to cooling centers during extreme heat events
3. Communicate with city agencies at the start of the Heat Season on how to protect city staff working outside
4. Include information about Code Red in the event permitting process, and incorporate language that allows BCHD to cancel outdoor events
5. Work with regional, State and local partners to improve air quality and reduce respiratory illnesses
6. Create and implement programs to manage combined health impacts of heat and air pollution
7. When and where feasible pursue grants to complete any project eligible under FEMAs Hazard Mitigation Unified Guidance and its addendum that will contribute to the reduction of hazardous conditions in the city

Stakeholders: BCHD, BCRP, City agencies with outdoor workers, DHMH, Licenses and Permitting, MDE, MOEM, MTA

Education and Outreach

PS-8: Conduct climate, resiliency, and emergency planning education and outreach

Increase hazard awareness related to all natural hazards through education and outreach. Consider emergency preparedness enhancements through hazard response education and risk communication. Use both adaptation and mitigation actions.

Implementation Actions:

1. Incorporate environmental health and climate change into curriculum at schools, universities and health care facilities
2. Create curriculum for hospitals to teach communities about climate change as part of hospital community benefits programs
3. Utilize existing preparedness messaging to include information on universal precautions to insect-borne and other infectious diseases

Stakeholders: BCHD, DNR, DOP, DPW, DHMH, MH2E, MOEM, MOIT, MON, Hospitals

PS-9: Improve awareness and education about the importance of flood insurance and preparation for Baltimore citizens

Insurance plays a significant role in providing citizens and businesses with financial protection against impacts from natural hazards. In order for insurance to be most effective, consumers must be aware of their risks and must clearly understand the coverage provided by their insurance policies, incorporating what the policies may include or exclude.

Additionally, both insurance providers and policyholders should be aware of the extensive efforts that Baltimore is taking to minimize damage from flooding hazards through the efforts outlined in this report. Increasing the overall awareness and understanding of flood insurance, risks associated with flooding, and the City's efforts to address and mitigate flooding impacts will foster a more robust insurance market that serves to benefit all participants.

Implementation Actions:

1. Create an educational program centered on flood hazards, coastal construction practices and evacuation procedures
2. Encourage owners of properties to purchase flood insurance, and improve policyholder awareness at time of sale or renewal
3. Identify programs and grants that assist citizens in purchasing flood insurance and making floodproofing changes
4. Develop an annual newsletter to inform and remind owners of property in the floodplain about flood insurance and floodproofing activities they should undertake
5. Require a flood disclosure form and distribution of floodplain awareness educational information as part of lease agreements for commercial/residential properties, and ensure distribution as tenants change

Stakeholders: Community Groups, DHCD, DHMH, DOP, FEMA, MEMA, MOEM, MON, NFIP, NGOs, MOEM

Food Systems

PS-10: Increase Baltimore's Food Security

To grow the capacity of the food system to withstand direct and indirect risks associated with climate change and natural hazards, Baltimore will work with local and regional partners to study the local food system for potential vulnerabilities and produce a long-term plan for protecting the resiliency of the regional food system. In collaboration with partners, the City will identify what our current food system looks like, where our food comes from, and our food needs. This will lead to identifying vulnerabilities and utilization of scenario modeling to increase food system resiliency.

This process will involve data collection and analysis, proactive planning, and transportation system considerations, all of which are necessary to increase the adaptive capacity of the Baltimore food system.

Implementation Actions:

1. Incorporate Baltimore's food policy initiative into planning efforts and double the size and number of food producing community gardens by 2025
2. Increase food distribution infrastructure and local food aggregation to link regional and local food producers to local distributors
3. Develop a food security plan for Baltimore
4. Increase land under cultivation for commercial urban agriculture
5. Increase the amount of land permanently secured for food production, from community gardens, market gardens, to commercial urban agriculture
6. Implement the Plan for Food Access During Incidents and Disasters
7. Increase food system resilience over the long-term

Stakeholders: BOS, DOP, MDA, Urban Farms and Community Gardens, Johns Hopkins, Farm Alliance of Baltimore, CGRN, Parks and People Foundation, University of Maryland Extension, Home and Garden Information Center, Food Policy Advisory Committee (Food PAC)

Chapter 6

Plan Implementation, Maintenance & Revision

Summary of Changes

- Updated monitoring, evaluation, and implementation plans, including community engagement aspects; new table on available funding sources
- Documentation of 2018 DP3 Plan adoption

Regulatory Checklist

A5. Is there discussion on how the communities will continue public participation in the plan maintenance process? 44 CFR 201.6(c)(4)(iii)

A6. Is there a description of the method and schedule for keeping the plan current (monitoring, evaluating and updating the mitigation plan within a 5-year cycle)? 44 CFR 201.6(c)(4)(i)

E1. Does the plan include documentation that the plan has been formally adopted by the governing body of the jurisdiction requesting approval? 44 CR 201.6(c)(5)

Plan Adoption

Baltimore's 2018 DP3 Plan was presented and adopted by Sustainability Commission on October 24, 2018. On __, 2018, the Baltimore City Planning Commission formally adopted the plan. This plan was also presented to the Federal Emergency Management Agency (FEMA) and the Maryland Emergency Management Agency (MEMA) for approval. This plan is intended to act as a guide for making hazard mitigation and climate adaptation management decisions and will allow city agencies to integrate the strategies and actions into ongoing and new projects and assist in guiding policy decisions.

Implementation Guidance

The 2018 DP3 Plan is the product of a collaborative effort including City agencies and stakeholders from all sectors, and collaboration on moving the plan forward is a vital priority in order to achieve success. Baltimore is committed to reaching the goals of the 2018 DP3 Plan and completing, to the maximum degree possible, the strategies and actions presented in Chapter 5 swiftly and efficiently.

The 2018 DP3 Plan is a living document; as Baltimore grows and develops, or as conditions change and new information becomes available, some adjustments to the plan may need to be made. The implementation framework will guide the processes for monitoring, evaluation, and revisions to ensure that the plan remains both effective and relevant.

Implementation

The Baltimore Office of Sustainability is responsible for general oversight, maintenance, and development of progress reports. Specifically, the City's Climate and Resilience Planner will be the overall lead. However, accomplishing the strategies and actions proposed in this plan will require cooperation from City officials and staff and an ongoing long-term commitment to the plan's vision and goals. It will also require collaboration with FEMA, MEMA, and the other agencies and stakeholders identified throughout the plan. The execution of each strategy and action will lie primarily within the responsibilities of lead agencies that were identified for their capacity for overseeing implementation of individual actions.

The list of strategies included in Chapter 5 includes information on the strategy and action lead agencies, stakeholders, and timeframe, as well as other key details that will guide and manage the implementation of the strategies and actions recommended in this plan. Financial support for the implementation of these strategies had also been considered, and possible sources are suggested for each. Some metrics and performance measures have been identified, but additional indicators will be added as the implementation process begins.

DP3 implementation is an ongoing process, and continued public involvement is critical. As described further in Chapter 7, the Office of Sustainability will be continuing and expanding its community engagement on disaster preparedness. Following the recommendations for sustaining resilience-building efforts will allow the City of Baltimore to involve the public in the maintenance and implementation of the 2018 DP3 Plan, as well as providing input and helping set the direction for future updates to the plan (e.g., developing an equity lens, including man-made hazards, improving food resilience, and addressing the specific needs of historic structures). In addition, a number of strategies and their actions rely heavily on the establishment and use of comprehensive education and

outreach efforts, which contribute to the process for public input and community involvement. These efforts also ensure that residents are provided with adequate information and resources for responding to hazard warnings. The City will continue to engage diverse audiences across Baltimore, and news and information will be shared on the Baltimore Office of Sustainability website and the City's natural hazards site.

DP3 Monitoring and Evaluation, Maintenance and Revision

In order to evaluate the successes and limits of DP3, there must be a process for monitoring the implementation of strategies and actions. Monitoring is best conducted through an organized and routine process that will measure and assess the progress of strategy implementation, evaluating the effectiveness of those recommendations. The Baltimore Office of Sustainability, in collaboration with the Commission on Sustainability and Mayor's Office of Emergency Management, will be in charge of maintenance, monitoring, and reporting for the 2018 DP3 Plan. If necessary, these monitoring bodies may reconvene the DP3 Advisory Committee or its subcommittees to propose, consider, and adopt revisions as formal amendments to the plan. Again, the City's Climate and Resilience Planner will be the lead for these efforts.

On an annual basis, the City will include a review of the DP3 as part of its required Sustainability Report, following a similar format as for past reports. As part of that review, the Climate and Resiliency Planner will examine the implementation efforts and report on progress. Each lead agency will be asked to contribute to the report and include any areas where progress is insufficient. As part of this annual reporting, the strategy and action list will be maintained and revised as needed. The widely publicized annual Sustainability Town Hall meetings will be used as a vehicle for public input into the plan maintenance process, and a review of the DP3 will be on the agenda at these meetings.

The plan monitoring and refinement strategy will include a post-disaster component to identify a framework for reviewing the plan after a future major hazard event. This component will facilitate revisions, as needed, based on new experiences or circumstances. This process will require continued coordination with Baltimore's Mayor's Office of Emergency Management (MOEM) and the Baltimore City Health Department (BCHD). Should this process indicate a need for any revisions, they will be incorporated into the routine plan update noted above. Additionally, following a hazard event, this plan should also be reviewed to assess its continued applicability or any need for revisions.

In compliance with FEMA requirements, the plan will also be updated at least every 5 years and presented to FEMA for approval. Comments and recommendations offered by lead agencies in charge of implementation, DP3 Advisory committee members, City and State Hazard Mitigation Officers, and public comment will be considered and incorporated into plan updates. For each major FEMA update, the climate science will be reviewed and strategies updated to reflect new concerns or vulnerabilities. The public will also be given an opportunity to provide feedback about implementation to date and updates to the plan.

As a result of the ongoing community engagement and the annual review and evaluation, it is possible that the City of Baltimore will decide to conduct a formal update of the DP3 before the 2023 regulatory deadline. In the next 2 years, the City will have new FEMA-developed floodplain maps, as well as completing a study of ways to mitigate flooding hazards for historic buildings. Work to develop an equity lens and to improve food resilience will have progressed, and there will have been more community input on how to incorporate man-made hazards. Furthermore, efforts on community

resiliency plans are expected to highlight additional strategies that could be taken to assist some of our most vulnerable populations.

Funding Sources

A number of financing options are available for the development, operation, and maintenance of hazard mitigation and climate adaptation measures. Identification of these potential funding resources is an essential element to achieving the City's resilience goals. Table 53 contains information on the funding sources currently available.

The following is a list of Federal and State grants that may assist in implementing local All Hazard Mitigation Plans. This information is subject to change at any time; contact the Federal or State agency for current grant status. (Last updated: March 2018)

Table 53: Federal and State Assistance/ Funding Sources

Program Name	Address and Telephone Contact Information	Eligible Activities	Federal, State and Local Cost Share Requirements	Other Program Characteristics	App Due Date
Federal Emergency Management Agency, Hazard Mitigation Grant Program (HMGP)	Maryland Emergency Management Agency, 5401 Rue Saint Lo Drive Reisterstown, MD 21136	All Hazards Mitigation Planning. Acquisition, relocation, elevation and floodproofing of floodprone insured properties, flood mitigation planning, wind retrofit, stormwater improvements, education and awareness	Federal - 75% State - 25%	Local government must be in compliance with the National Flood Insurance Program to be eligible. Projects must be cost effective, environmentally sound and solve a problem. Repetitive loss properties are a high priority	After a Presidential Disaster Declaration
Federal Emergency Management Agency, Pre-Disaster Mitigation Grant Program (PDM)	Maryland Emergency Management Agency 5401 Rue Saint Lo Drive Reisterstown, MD 21136	Funding these plans and projects reduces overall risks to the population and structures, while also reducing reliance on funding from actual disaster declarations	Federal - 75% Non-Federal - 25%	PDM grants are to be awarded on a competitive basis and without reference to State allocations, quotas, or other formula-based allocation of funds	Annual Spring/Summer

Program Name	Address and Telephone Contact Information	Eligible Activities	Federal, State and Local Cost Share Requirements	Other Program Characteristics	App Due Date
Federal Emergency Management Agency, Flood Mitigation Assistance Program (FMA)	Maryland Emergency Management Agency, 5401 Rue Saint Lo Drive Reisterstown, MD 21136	Assist States and communities to implement measures that reduce or eliminate the long-term risk of flood damage to buildings, manufactured homes, and other structures insured under the National Flood Insurance Program.	RL: Federal - 90% Non-Federal - 10% SRL: Federal - 100% Non-Federal - 0%	Available once a Flood Mitigation Plan has been developed and approved by FEMA	Annual Spring/Summer
National Flood Insurance Program (NFIP)	Maryland Emergency Management Agency, 5401 Rue Saint Lo Drive Reisterstown, MD 21136	Provides financial protection by enabling persons to purchase insurance against floods, mudslide or flood-related erosion.	Varies	Includes federally backed insurance against flooding, available to individuals and businesses that participate in the NFIP	Anytime
NFIP Increased Cost of Compliance	Maryland Emergency Management Agency, 5401 Rue Saint Lo Drive Reisterstown, MD 21136	ICC coverage provides payment to help cover the cost of mitigation activities that will reduce the risk of future flood damage to a building. If a flood insurance policyholder's structure suffers a flood loss and is declared to be substantially or repetitively damaged, ICC will pay up to 30,000 to bring the building into compliance with State or community floodplain management laws or ordinances. Usually this means elevating or relocating the building so that it is above the base flood elevation (BFE).	Varies	Once the local jurisdiction determines the building is substantially or repetitively damaged, the policyholder can contact insurance agent to file an ICC claim.	Anytime

Program Name	Address and Telephone Contact Information	Eligible Activities	Federal, State and Local Cost Share Requirements	Other Program Characteristics	App Due Date
U.S. Economic Development Administration, Economic Adjustment Program	U.S. Department of Commerce Economic Development Administration Curtis Center, 601 Walnut Street, Ste 140, South Philadelphia, PA 19106-3323 215-597-4603	Improvements and reconstruction of public facilities after a disaster or industry closing. Research studies designed to facilitate economic development.	Federal - 50%-70% Local - 30%-50%	Documenting economic distress, job impact and proposing a project that is consistent with a Comprehensive Economic Development Strategy are important funding selection criteria	Anytime
U.S. Economic Development Administration, Public Works and Development Facilities	U.S. Department of Commerce Economic Development Administration Curtis Center, 601 Walnut Street, Ste 140, South Philadelphia, PA 19106-3323 215-597-4603	Water and sewer, Industrial access roads, rail spurs, port improvements technological and related infrastructure	Federal - 50%-70% Local - 30%-50%	Documenting economic distress, job impact and projects that are consistent with a Comprehensive Economic Development Strategy are important funding selection criteria	Quarterly Basis
Small Business Administration (SBA) Pre-disaster Mitigation Loan Program	James Rivera, Office of Disaster Assistance, Small Business Administration, 409 3rd Street, SW, STE 6050 Washington, DC 20416; 202-205-6734	Activities done for the purpose of protecting real and personal property against disaster-related damage	No information	The mitigation measures must protect property or contents from damage that may be caused by future disasters and must conform to the priorities and goals of the State or local government's mitigation plan	No Info

Program Name	Address and Telephone Contact Information	Eligible Activities	Federal, State and Local Cost Share Requirements	Other Program Characteristics	App Due Date
Community Development Block Grants / States Program	U.S. Department of Housing and Urban Development, Office of Block Grant Assistance, 451 7th Street SW, Washington, DC 20410-7000; 202-708-1112	Used for long-term recovery needs, such as rehabilitation of residential and commercial buildings; homeownership assistance, including down-payment assistance and interest rate subsidies; building new replacement housing; code enforcement; acquiring, construction, or reconstructing public facilities	No information	Citizen participation procedures must be followed. At least 70 percent of funds must be used for activities that principally benefit persons of low and moderate income. Formula grants to States for non-entitlement communities	After a Presidential Disaster Declaration
Fire Suppression Assistance Program	Infrastructure Division, Response and Recovery Directorate, FEMA, 500 C Street SW, Washington DC 20024; 202-646-2500	Provides real-time assistance for the suppression of any fire on public (non-Federal) or privately owned forest or grassland that threatens to become a major disaster	Federal - 70% Local - 30%	The State must first meet annual floor cost (percent of average fiscal year fire costs) on a single declared fire. After the State's out-of-pocket expenses exceed twice the average fiscal year costs, funds are made available for 100 percent of all costs for each declared fire	Funds from President's Disaster Relief Fund for use in a designated emergency or major disaster area.
Historic Preservation: Repair and Restoration of Disaster-Damaged Historic Properties	Infrastructure Division, Response and Recovery Directorate, FEMA, 500 C Street SW., Washington DC 20024; 202-646-4621.	To evaluate the effects of repairs to, restoration of, or mitigation hazards to disaster-damaged historic structures working in concert with the requirements of the Stafford Act.	Federal - 75% Local - 25%	Eligible to State and local governments, and any political subdivision of a State. Also eligible are private non-profit organizations that operate educational, utility, emergency, or medical facilities	After a Presidential Disaster Declaration

Program Name	Address and Telephone Contact Information	Eligible Activities	Federal, State and Local Cost Share Requirements	Other Program Characteristics	App Due Date
Transportation: Emergency Relief Program	Federal Transit Authority, FHWA, DOT, 1200 New Jersey Avenue Washington, DC 20590; 202-366-4043	Provides aid for the repair of Federal-aid roads and roads on Federal lands	Federal - 100%	Application is submitted by the State Department of Transportation for damages to Federal-aid highway routes, and by the applicable Federal agency for damages to roads on Federal lands	After serious damage to Federal-aid roads or roads on Federal lands caused by a natural disaster or by catastrophic failure
Animals: Emergency Haying and Grazing	Emergency and Non-insured Assistance Programs, FSA, USDA, 1400 Independence Ave, SW, Washington, DC 20013; 202-720-4053	To help livestock producers in approved counties when the growth and yield of hay and pasture have been substantially reduced because of a widespread natural disaster	No information	Assistance is provided by the Secretary of Agriculture to harvest hay or graze cropland or other commercial use of forage devoted to the Conservation Reserve Program (CRP) in response to a drought or other similar emergency	Any time
Emergency Watershed Protection Program	Natural Resources Conservation Service 1400 Independence Avenue, SW Washington, DC 20250	Implementing emergency recovery measures for runoff retardation and erosion prevention to relieve imminent hazards to life and property created by a natural disaster that causes a sudden impairment of a watershed	Federal - 75% Local - 25%	It cannot fund operation and maintenance work or repair private or public transportation facilities or utilities. The work cannot adversely affect downstream water rights, and funds cannot be used to install measures not essential to the reduction of hazards.	TBD
Watershed Protection and Flood Prevention Program	Natural Resources Conservation Service 1400 Independence Avenue, SW Washington, DC 20250	To provide technical and financial assistance in carrying out works of improvement to protect, develop, and utilize the land and water resources in watersheds	Varies due to project type	Watershed area must not exceed 250,000 acres. Capacity of a single structure is limited to 25,000 acre-feet of total capacity and 12,500 acre-feet of floodwater detention capacity.	TBD

Program Name	Address and Telephone Contact Information	Eligible Activities	Federal, State and Local Cost Share Requirements	Other Program Characteristics	App Due Date
Watershed Surveys and Planning	Natural Resources Conservation Service 1400 Independence Avenue, SW Washington, DC 20250	To provide planning assistance to Federal, State, and local agencies for the development of coordinated water and related programs in watersheds and river basins. Emphasis is on flood damage reduction, erosion control, water conservation, preservation of wetlands and water quality improvements	No information	These watershed plans form the basis for installing needed works of improvement and include estimated benefits and costs, cost-sharing, operation and maintenance arrangements, and other information necessary to justify the need for Federal assistance in carrying out the plan.	Any time
Emergency Advance Measures for Flood Prevention (Public Law 84-99 (Section 5 of the Flood Control Act of 1941))	USACE, Baltimore District Emergency Management 2 Hopkins Plaza, Baltimore, MD 21202 410-962-2013	Assistance may be provided in order to prevent or reduce damages when there is an imminent threat of unusual flooding. Technical Assistance may be provided when there is a significant potential that an imminent threat of unusual flooding will develop	No information	Advance Measures projects are temporary projects that provide measures necessary to prevent or reduce impacts of floods that (1) pose a significant threat to life and/or improved property, and (2) are beyond the technical capability of Tribe/State/local interests to perform in a timely manner. Advance Measures projects must be engineering- feasible and capable of being constructed in time to meet the anticipated threat	Governor of State must request assistance

Program Name	Address and Telephone Contact Information	Eligible Activities	Federal, State and Local Cost Share Requirements	Other Program Characteristics	App Due Date
Continuing Authorities Program (CAP) Section 14 - Emergency Streambank and Shoreline Protection	USACE, Baltimore District Emergency Management 2 Hopkins Plaza, Baltimore, MD 21202 410-962-2013	Authorizes the construction of emergency streambank protection measures to prevent damage to highways, bridge approaches, municipal water supply systems, sewage disposal plants, and other essential public works facilities endangered by floods or storms due to bank erosion.	Feasibility: 100%/0% Fed/Local for initial $100,000; 50%/50% remaining cost; Implementation: 65%/35% Fed/Local; Federal Project Limit: $5M	Churches, hospitals, schools, and other non-profit service facilities may also be protected under this program. This authority does not apply to privately-owned property or structures.	Anytime
Continuing Authorities Program (CAP) Section 205 - Flood Damage Reduction	USACE, Baltimore District Emergency Management 2 Hopkins Plaza, Baltimore, MD 21202 410-962-2013	Authorizes the construction of small flood control projects that have not already been specifically authorized by Congress	Feasibility: 100%/0% Fed/Local for initial $100,000; 50%/50% remaining cost; Implementation: 65%/35% Fed/Local; Federal Project Limit: $10M	There are two general categories of projects: structural and nonstructural. Structural projects may include levees, floodwalls, diversion channels, pumping plants, and bridge modifications. Nonstructural projects may include flood proofing, the relocation of structures, and flood warning systems	Anytime

Program Name	Address and Telephone Contact Information	Eligible Activities	Federal, State and Local Cost Share Requirements	Other Program Characteristics	App Due Date
Continuing Authorities Program (CAP) Section 103- Hurricane and Storm Damage Reduction (Beach Erosion)	USACE, Baltimore District Emergency Management 2 Hopkins Plaza, Baltimore, MD 21202 410-962-2013	Development and construction small beach erosion control projects. A potential project must provide benefits other than for the purposes of recreation, such as beach stabilization to reduce flooding or to provide protection to public facilities	Feasibility: 100%/0% Fed/Local for initial $100,000; 50%/50% remaining cost; Implementation: 65%/35% Fed/Local; Federal Project Limit: $10M	Protection of privately owned shorelines which offer no benefits to the public are not eligible for Federal cost sharing	Anytime
USACE Rehabilitation and Inspection Program (RIP) & Inspection of Completed Works (ICW) Program)	USACE, Baltimore District Emergency Management 2 Hopkins Plaza, Baltimore, MD 21202 410-962-2013	Provides for inspection of flood control projects, rehabilitation of damaged flood control projects, and the rehabilitation of federally authorized and constructed hurricane or shore protection projects	100% Federal for projects built by USACE and properly maintained; 80%/20% Fed/Sponsor for projects rehabbed by USACE	Projects initially constructed by the Corps, including hurricane and shore protection projects, and turned over to the local sponsor for maintenance are inspected under authority of the Inspection of Completed Works (ICW) program	After flood or storm event
USACE General Investigation (GI)	USACE, Baltimore District Emergency Management 2 Hopkins Plaza, Baltimore, MD 21202 410-962-2013	Congress can authorize USACE to study, design and construct major flood risk management projects	Feasibility: 50%/50%Fed/Local; Implementation 65%/35%	Generally large scale projects that cost more than $10 million	Anytime

Program Name	Address and Telephone Contact Information	Eligible Activities	Federal, State and Local Cost Share Requirements	Other Program Characteristics	App Due Date
USACE Flood Plain Management Services Program (FPMS)	USACE, Baltimore District Emergency Management 2 Hopkins Plaza, Baltimore, MD 21202 410-962-2013	The program allows USACE to compile and disseminate information on floods and flood damages, including identification of areas subject to inundation by floods, and general criteria for guidance in the use of floodplain areas.	Upon request, program services are provided to the State, regional, and local governments, Native American Tribes, and other non-federal public agencies without charge. Per Section 202 of WRDA 1999, USACE may accept funds voluntarily contributed by sponsor with the purpose of expanding the scope of services.	USACE can provide engineering advice to local interests in planning to reduce flood hazard.	Anytime
Hazardous Materials: State Access to the Oil Spill Liability Trust Fund	Director, USCG National Pollution Funds Center U.S. Coast Guard Stop 7605 2703 Martin Luther King Jr. Avenue, SE Washington, DC 20593-7605 202-795-6000	To encourage greater State participation in response to actual or threatened discharges of oil	No information	Eligible to States and U.S. Trust Territories and possessions	Anytime

Program Name	Address and Telephone Contact Information	Eligible Activities	Federal, State and Local Cost Share Requirements	Other Program Characteristics	App Due Date
Emergency Management Assistance (EMA)	Maryland Emergency Management Agency, 5401 Rue Saint Lo Drive, Reisterstown, MD 21401	Funds may be used for salaries, travel expenses, and other administrative costs essential to the day-to-day operations of State and local emergency management agencies. Program also includes management processes that ensure coordinated planning, accountability for progress, and trained qualified staffing.	Federal - 50%	EMA-funded activities may include specific mitigation management efforts not otherwise eligible for Federal funding. Management Assistance program funds may not be used for construction, repairs, equipment, materials or physical operations required for damage mitigation projects for public or private buildings, roads, bridges, or other facilities.	Anytime
Assistant to Firefighters Grant	Source: U.S. Fire Administration CFDA Number: 97.044	Vehicles, safety equipment, protective equipment, etc.	Federal grant funds match dependent upon population served by fire departments and nonaffiliated EMS organizations	Provides assistance to local fire department to protect citizens and firefighters against the effects of fire and fire-related incidents	Annually in September projects are due
Maryland Program Open Space	Department of Natural Resources 580 Taylor Ave. Annapolis, MD 21401 410-260-8445	Provides financial and technical assistance to local subdivisions for the planning, acquisition, and/or development of recreation land or open space areas	A local governing body may use up to $25,000 annually from its 100% (acquisition) money to fund planning projects that update the Local Land Preservation and Recreation Plans.	Acquires outdoor recreation and open space areas for public use. Administers funds made available to local communities for open and recreational space by the Outdoor Recreation Land Loan of 1969 and from the Land and Water Conservation Fund of the National Park Service, U.S. Department of the Interior	July 1st
Maryland Recreational Trails Program	Maryland Scenic Byways /Recreational Trails Program* Office of Planning &	Maintenance and restoration of existing recreational trail;	Administered by the State Highway Administration (SHA), this	Projects must meet State and Federal environmental regulatory requirements (NEPA, MEPA, Section 106,	July 1st

Program Name	Address and Telephone Contact Information	Eligible Activities	Federal, State and Local Cost Share Requirements	Other Program Characteristics	App Due Date
	Preliminary Engineering State Highway Administration 707 N Calvert Street Baltimore, MD 21201 (p) 410.545.8637 (f) 410.209-5012 tmaxwell@sha.state.md.us	Development and rehabilitation of trailside facilities and trail linkages; Purchase and lease of trail construction equipment; Construction of new trails; Acquisition of easements or property for recreational trails or recreational trail corridors; and Implementation of interpretive/ educational programs to promote intrinsic qualities, safety, and environmental protection, as those objectives relate to the use of recreational trails.	program matches federal funds with local funds or in-kind contributions to implement trail projects. Projects can be sponsored by a county or municipal government, a private non-profit agency, a community group or an individual (non-governmental agencies must secure an appropriate government agency as a co-sponsor). Federal funds administered by the SHA are available for up to 80% of the project cost, matched by at least 20% funding from the project sponsor. Matching funds must be committed and documented in the local jurisdiction's budget.	Section 4(f)). SHA will provide assistance to the project sponsor to acquire these approvals.	

Program Name	Address and Telephone Contact Information	Eligible Activities	Federal, State and Local Cost Share Requirements	Other Program Characteristics	App Due Date
CoastSmart Communities Grant (CCG) Program	Maryland Department of Natural Resources Chesapeake and Coastal Service (p) 410.260.8718 (f) 410.260.8739 sasha.land@maryland.gov	Municipalities and counties in the coastal zone are eligible to apply for and receive funds: Anne Arundel, Baltimore, Calvert, Caroline, Cecil, Charles, Dorchester, Harford, Kent, Prince George's, Queen Anne's, St. Mary's, Somerset, Talbot, Wicomico, and Worcester counties and Baltimore City. Funding for a 1-year project that contributes to understanding, planning for, or implementing planning and outreach measures to address coastal hazard issues.	Up to $75,000 annually	Track A can fund flood vulnerability and risk assessments, updates to planning documents (e.g. hazard mitigation plans, zoning ordinances, building codes, floodplain ordinances, comprehensive plans), education and outreach campaigns and materials, applications to FEMA's Community Rating System in concert with other task outcomes, support for adopting an updated plan and integrating the plan into day-to-day existing planning processes that reduce overall flood risk due to tidal events or stormwater and rain events.	TBD

Program Name	Address and Telephone Contact Information	Eligible Activities	Federal, State and Local Cost Share Requirements	Other Program Characteristics	App Due Date
Green Infrastructure Resiliency Grant Program	Maryland Department of Natural Resources Chesapeake and Coastal Service (p) 410.260.8799 (f) 410.260.8739 (e) megan.granato@maryland.gov	Municipalities and counties within the Maryland portion of the Chesapeake Bay watershed are eligible to apply for and receive funds. Please note that projects proposed in Cecil, Garrett and Worcester counties must be located within the portions of those counties that are within the watershed in order to be eligible. Funding for 1 year for Phase 1 and Phase 2 projects and up to 2 years for Phase 3 projects that will assess stormwater management needs associated with localized flooding and design or construct targeted green infrastructure practices to address those needs.	Up to $100,000 per project	Track B can fund watershed assessments that focus on determining local flood risks and how green infrastructure can be used to address those risks, site or watershed-level green infrastructure implementation plans, and green infrastructure project designs. This track can also fund construction of green infrastructure projects. To apply for construction funding, all applicable permit pre-application meetings must be complete.	TBD

Program Name	Address and Telephone Contact Information	Eligible Activities	Federal, State and Local Cost Share Requirements	Other Program Characteristics	App Due Date
Maryland Community Parks and Playgrounds Program	Department of Natural Resources 580 Taylor Ave. Annapolis, MD 21401 410-260-8445	1) development of new parks 2) rehabilitation of existing parks 3) expansion or improvement of existing parks 4) purchase and installation of playground equipment 5) development of environmentally oriented parks and recreation projects 6) development of new trails or extension of existing trails 7) creation of access points to water recreation resources 8) acquisition of land to create new parks	The source of funds for this program is primarily State General Obligation Bonds, which may be authorized on an annual basis. The program provides funding to incorporated municipalities and Baltimore City. Grants may be for up to 100% of the project cost and are selected on a competitive basis. Each applicant will be limited to one Grant Proposal List submission package, which may contain several prioritized projects, per award cycle.	The Department of Natural Resources works to provide opportunities for Marylanders, especially our children, to experience nature. The Department has developed a website that provides information about Nature Play Spaces. Nature Play Spaces are one of the many types of public recreation projects eligible for consideration for Community Parks and Playgrounds grant funding. While land acquisition costs may be considered for project funding, the highest priority will be placed on capital costs associated with park development and improvement.	TBD

Chapter 7

Moving Forward

Summary of Changes

- This is an entirely new chapter meant to detail future visions for the plan and identify where there is room for improvement
- Discussion of the 2018 public outreach and plan development process
- Includes high-level recommendations for moving forward

Regulatory Checklist

A5. Is there discussion on how the communities will continue public participation in the plan maintenance process? 44 CFR 201.6(c)(4)(iii)

A6. Is there a description of the method and schedule for keeping the plan current (monitoring, evaluating and updating the mitigation plan within a 5-year cycle)? 44 CFR 201.6(c)(4)(i)

E1. Does the plan include documentation that the plan has been formally adopted by the governing body of the jurisdiction requesting approval? 44 CR 201.6(c)(5)

Introduction

The research and public engagement conducted in support of this plan helped identify recommendations for meaningful public participation in the implementation and update of the plan. Moving forward, planners have identified seven high-level recommendations designed to foster continued equitable engagement and strengthen community resilience. This chapter summarizes these recommendations as well as concurrent efforts underway in the Office of Sustainability.

Recommendations for Sustaining Resilience-Building Efforts

Community Resilience Recommendations

Recommendation 1: Continue planning efforts centered on increasing community resilience, including ongoing formalization and expansion of Resiliency Hubs

The City has made a concerted effort to make community resilience a pillar of the City's preparedness vision and planning. This is evident in initiatives like the establishment of Resiliency Hubs and the development of a community resilience framework though the Coastal Zone Management (CZM) grant.

Collected feedback from the public validated the mandate for these efforts. Many members expressed a desire for stronger ties between their communities, community associations, and City agencies in the public survey and in targeted outreach described in Chapter 1 and Appendix 1-4. Several faith-based organizations expressed a desire to learn more about the process and requirements for becoming a Resiliency Hub (see Glossary) as well.

Baltimore is a diverse city, a characteristic evidenced by its sheer number of neighborhoods. Community-based organizations, like those that choose to become Resiliency Hubs, are often best positioned to help residents be prepared and informed. Many neighborhoods have organizations with trusted networks that are able to access vulnerable populations during disasters, but those organizations are often under-prepared and under-resourced to educate and support residents in times of crisis. Equipping neighborhood and community organizations with resources, training, and technical assistance—through Resiliency Hubs and other initiatives—stands to best address and account for the unique needs and concerns of Baltimore neighborhoods.

Continued formalization of the role of Resiliency Hubs is important and sought after. Community leaders indicated they do not have a clear understanding of the scope or parameters of the work Resiliency Hubs are meant to accomplish. Additionally, Hub leaders are often uncertain about the specifics of how they are to support their community. Amplification of the existence and resources of Hubs is a recommended area of focus. Responses in both the public risk survey and the targeted outreach indicated the Resiliency Hubs are not well known, but there is a growing interest in their role and potential to serve neighborhood needs.

Recommendation 2: Use community resilience initiatives to address varying regional concerns

Analysis of the public survey data disaggregated by region underscored the need for continued community resilience planning initiatives (see Appendix 1-4.) Levels of concern for specific hazards, as well as overall levels of concern, varied by region. For example, overall levels of reported concern

for natural hazards in Southeast and Central Baltimore was lower than overall levels of concern in Northwest and West Baltimore, while concern for specific hazards in all regions varied. Vulnerability to specific hazards varies by region as well, as identified in Chapter 4.

Renewed focus and resources for community resilience planning, such as the Community Resilience Plan for the Sandtown-Winchester Area developed through the CZM grant, stands to equip city agencies and community-based organizations alike with the knowledge and resources needed to develop plans that adequately address the concerns and vulnerabilities of geographic areas. Preparedness and response planning anchored in community resilience is best suited for identifying vulnerable populations, addressing their needs, and generating plans tailored to specific community needs.

Recommendation 3: Broaden public outreach and engagement efforts to include greater representation from all Baltimore neighborhoods and communities in planning efforts

Planners recognize and appreciate that the community members and organizations engaged in this update do not fully reflect the diversity of Baltimore. Complete engagement will always be a moving target, but strategies to involve the public sooner and more consistently can broaden reach and receptivity.

The sheer complexity of Baltimore—a city with over 200 neighborhoods—makes collecting a representative sample of the city challenging. Experts and community members alike may differ in beliefs about what constitutes a representative sample. There has been consensus that continuous attention should be given to key groups, including:

- Communities in economic distress, including low-income, socioeconomically disadvantaged communities;
- Displaced, homeless, and otherwise housing-insecure citizens (with consideration for the growing LGBTQ+ segment);
- Retired and elderly citizens;
- Those living in areas affected by structural discrimination (i.e. historically redlined neighborhoods), and
- All people living within the intersection of two or more of these communities.

Additional methods of engagement are necessary to connect City planners with the neighborhoods and communities not yet reached. In addition to conducting targeted interviews and spreading a public survey, additional methods to employ include:

- Convening population-specific and general interest focus groups that foster discussions on disaster-related concerns and forward-facing solutions;
- Organizing large-scale community meetings open to residents around the city, supplemented by specialized community meetings open to members of a target community; and
- Hosting interactive booths at small community farmer's markets, festivals, and public events intentionally chosen to represent neighborhoods around the city, especially those that have not previously been able to be involved in this process.

Recommendation 4: Introduce solutions-oriented public engagement practices designed to solicit community-driven solutions

Public engagement for this plan intentionally focused on collecting perspectives and concerns regarding specific hazards, rather than requesting proposed solutions. As a first step, planners sought to learn more about community members' attitudes and experiences with the hazards addressed in this plan.

An appropriate next step will be to introduce new questions and mechanisms designed to seek input on solutions to perceived challenges. A more concerted effort to solicit public input on solutions to hazards should aid in identifying sustainable solutions and stay true to the City's commitment to equity in planning. Future plans stand to benefit from soliciting concerns and experience with hazards and proposed solutions concurrently.

Recommendation 5: Determine a strategy for incorporating information on vulnerable populations collected during the development of this plan

A Coastal Zone Management (CZM) grant awarded in 2016 allowed the Office of Sustainability to complete an initial mapping of vulnerable populations. Public engagement completed in support of this plan collected public perspectives on vulnerable populations.

Public perception of, and concern for, vulnerable populations frequently aligned with the maps developed through the CZM grant. Two particular groups that warrant near-term attention include seniors and the socially isolated.

Figure 33 depicts a map developed under the CZM grant that overlays senior populations with factors contributing to heat vulnerability. Senior populations can be vulnerable to heat-related hazards due to physical conditions and isolation. In this analysis, the factors utilized are populations over 65 and vehicle access from the Census American Community Survey, and concentration of heat islands as a measure developed through Landsat ETM thermal measurement. In addition, distance from Code Red Cooling Center was utilized to indicate locations where a local cooling center is less likely to be accessed. The map highlights only a few areas of the City that have the highest concentration of these factors. Conducting community resiliency planning in the Rosemont neighborhoods south of North Avenue and just east of Leakin Park, for example, should take into account the need for outreach and support for seniors in heat events.

Figure 32: Seniors and Heat Vulnerability

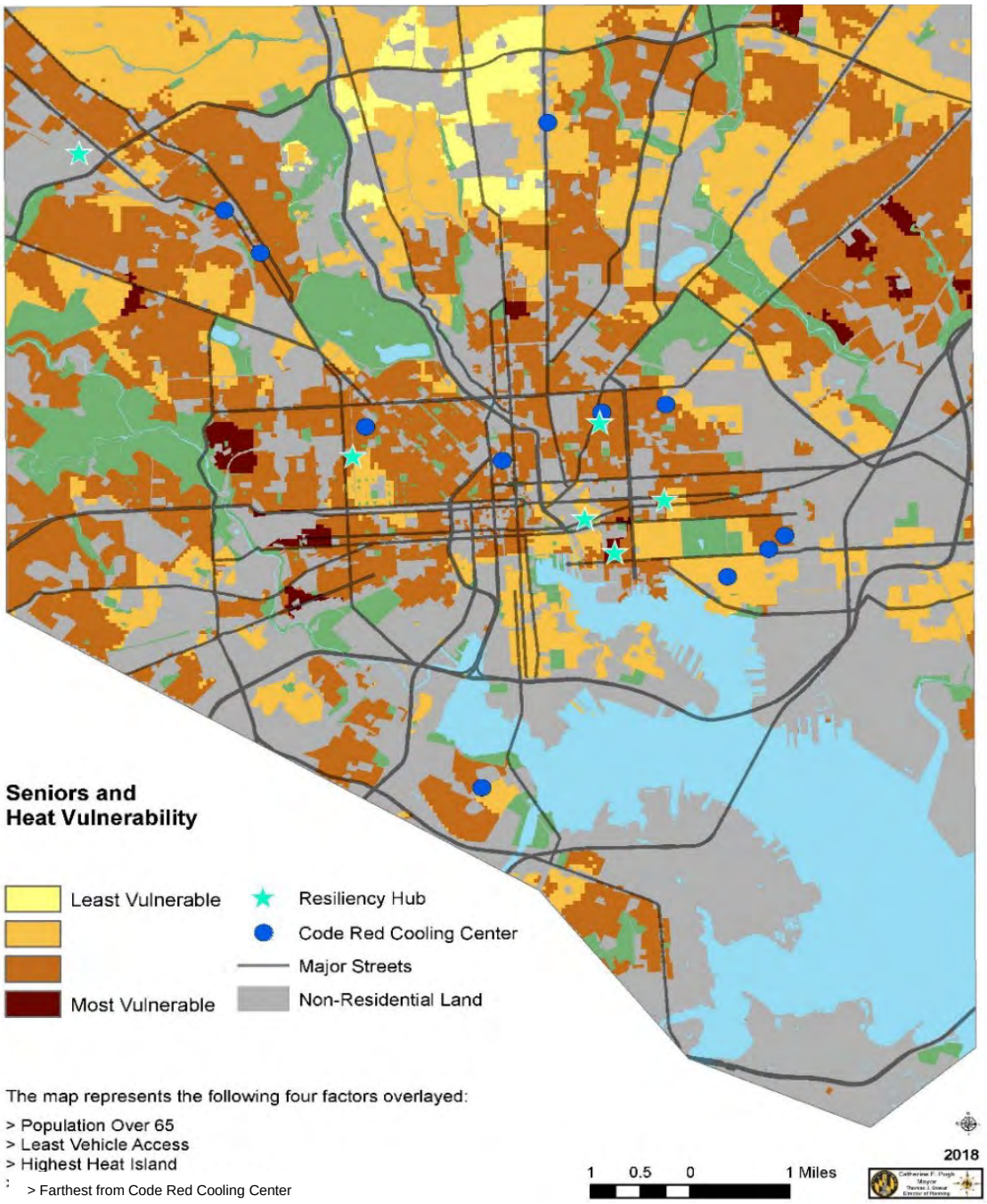
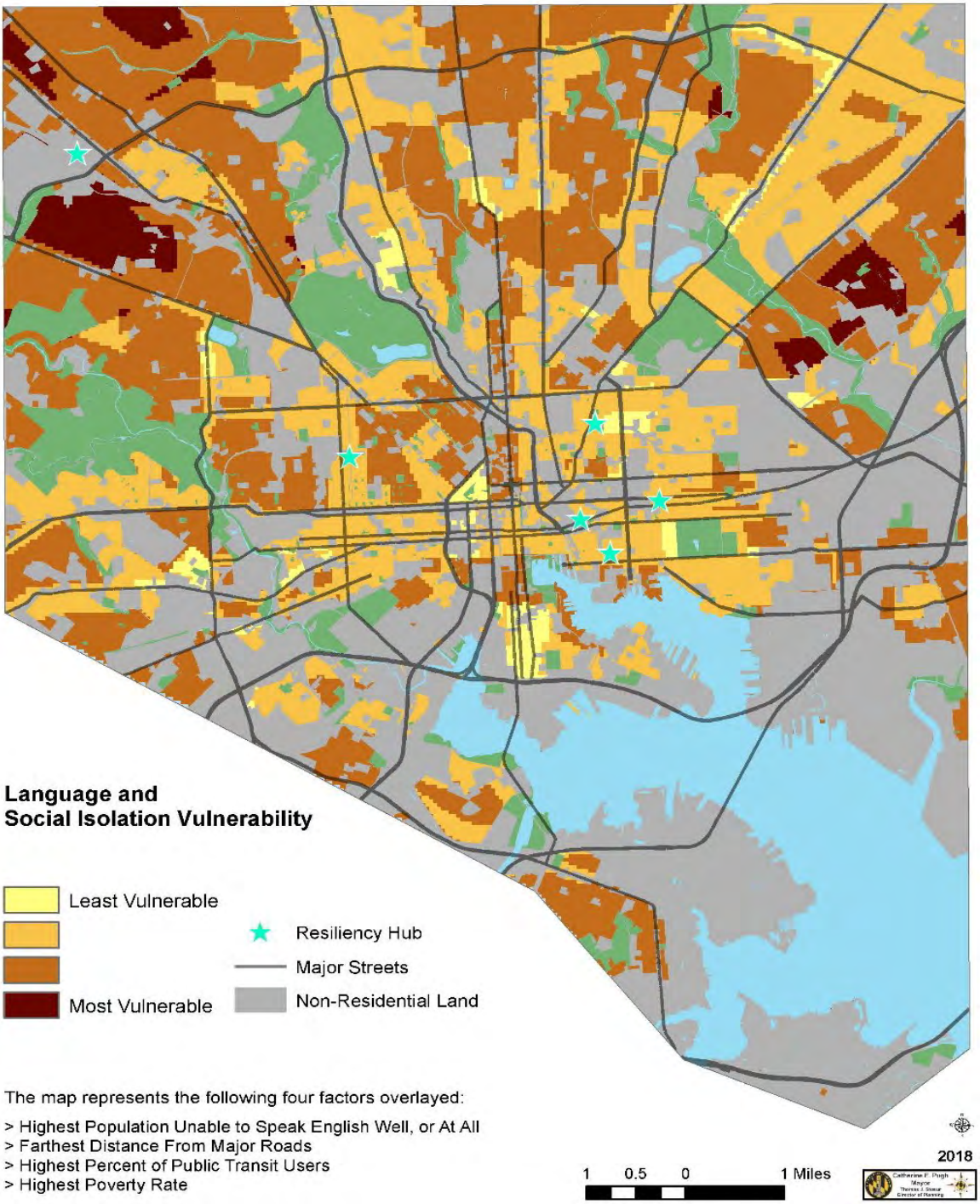


Figure 34 is a map developed under the CZM grant that depicts populations who have limited English proficiency, use public transit, have a high poverty rate, and are removed from major roads and arteries. While the data do not provide insight into "social isolation," the most vulnerable areas in the northeast area of the City correspond to areas known to have high refugee resettlement populations. The demographics of this local population have implications about mobility and language services that should be taken into account in resiliency planning. This notion was underscored in public outreach,

with citizens expressing concern for this populations' ability to know or learn evacuation routes, for example.

Figure 33: Language and Social Vulnerability



Recommendation 6: Use public feedback to identify vulnerable populations and specify vulnerable populations to the greatest extent possible

The public risk perspectives survey allowed the public to share their thoughts on vulnerable populations and groups in the city. Respondents were given the chance to share their thoughts on how their neighborhoods and other communities are potentially vulnerable to disasters. Valuable insight was gained by this process, as members of the community were able to lend genuine perspectives as members or leaders of these communities.

Several key groups were identified in the process, and these serve to represent important target populations for equitable planning and community resilience efforts. Homelessness presents unique challenges that were apparent to an overwhelming majority of survey respondents and backed by anecdotal evidence recorded during several interviews. A map of homeless population density overlaid with hazard and other relevant information, similar to Figure 7-2, is an important first step.

As the City continues to prioritize and implement equitable engagement strategies and incorporate an equity lens in planning efforts, specifying vulnerable populations to the greatest extent possible will assist in achieving truly equitable plans. Examples of these populations include emerging vulnerable populations (e.g. LGBTQ homeless) and overlooked or unobvious populations (e.g. those not living near tree canopies).

Recommendation 7: Develop criteria and a strategy for integrating man-made hazards into the next DP3 with input from the public at the outset

The integration of man-made hazards has been identified as a new component for future DP3 updates. The public survey disseminated for this plan included a set of questions asking the public their concern for, and experience with, man-made hazards, in order to collect baseline data on man-made hazards.

Markedly varied responses to these questions suggest that, while the integration of man-made hazards into the DP3 is a worthwhile and timely endeavor, it will require careful scoping. Trends in the survey data suggest Baltimoreans have a diverse understanding of the threats posed by man-made hazards, as well as what constitutes a man-made hazard. For example, many respondents described very specific events when conveying concern regarding man-made events, citing surges in synthetic drug use, concerns around lead poisoning, and specific infrastructure concerns, for example, as well as general events such as "crime" and "shootings."

Variation in definitions and understand of man-made hazards is perhaps most evident in data collected related to active shooter threats. Survey responses suggest that a subset of respondents conflated gun violence of any kind with active shooter events. This is an important consideration, as the definition of an active shooter in the emergency management field is considerably narrower (referring to a shooting occurring in a contained environment as a form of terrorism).

The integration of man-made hazards into the DP3 will benefit from including public perspectives on the best approach(es) for accomplishing this from the beginning.

Food Resilience

Food as Critical Infrastructure

Baltimore views food resilience as an integral part of hazard mitigation planning. Many natural and non-natural hazards threaten food security, especially in urban areas where growing populations place extra demands on the food supply. Ensuring stable food security before, during, and after disasters requires resilient food systems that can withstand and recover from disruptions. By considering "food as critical infrastructure," jurisdictions can better incorporate food access priorities into response and recovery, as well as developing a forward-thinking food system resilience framework.

Emergency Management and Response

The April 2015 Baltimore Uprising highlighted the ways a disruption could harm food security in Baltimore and the need to better coordinate City agencies and food suppliers. At least 107 food-selling retail businesses sustained damage to or loss of their inventory or property; a weeklong night-time curfew limited food deliveries to stores; and public schools were closed, leaving many students without their regular food source for breakfast and lunch. Food assistance organizations and individuals donated food to Baltimore communities after the unrest; however, local organizations reported poor communication and coordination, creating confusion and inefficient distribution of donations to residents most in need.

In response, the Mayor's Office and the Baltimore Food Policy Initiative (BFPI) formed an Emergency Food Working Group in December 2015. The Working Group included 13 City agencies, seven emergency food non-profits, three State and Federal agencies, and an academic research institution. The working group drafted a "Plan for Food Access during Incidents and Disasters," which details the City's short-term emergency preparedness protocols related to supporting private and non-profit food entities during emergency events. These activities are intended to prevent an emergency event from increasing food insecurity for already vulnerable populations (particularly children and seniors) with existing resources, but they do not supplant large-scale food distribution or feeding efforts by larger entities such as State or Federal agencies or the American Red Cross.

The plan will be incorporated into the City's Emergency Operations Protocol (EOP) in partnership with the Mayor's Office of Emergency Management (MOEM), which is updating the EOP for 2019. To support the implementation of the plan during times of emergency, the BFPI Food Resilience Planner has access to the Emergency Operations Center, when it is activated, to help coordinate response and disseminate information.

BFPI has provided technical assistance on incorporating similar emergency response and recovery strategies through the lens of food to other nearby jurisdictions, including Baltimore County and Philadelphia, PA. The Food Resilience Planner has presented these ideas at national forums, including the Preparedness Summit, and through the Urban Sustainability Directors Network.

Long-Term Food System Resilience

The Johns Hopkins Center for a Livable Future partnered with the BFPI and the Office of Sustainability to create a broader Baltimore Food System Resilience Advisory Report based on 36 key informant interviews with food system stakeholders, literature reviews, and GIS mapping. That report included an assessment of the Baltimore City food system's vulnerability to 14 natural and non-natural

hazards, the extent of stakeholder preparedness for food supply disruptions, and identified opportunities for enhancing long-term food system resilience. The report presented policy recommendations for Baltimore and a framework for conceptualizing food system vulnerabilities.

These recommendations and considerations can be used as a framework to guide future planning and work to increase resilience and preparedness in the food system. Considerations include the following populations and key challenges:

Populations: Those who may be most at risk of losing access to safe and nutritious food during and after a crisis include people with low incomes, residents of food deserts, children, older adults, people with disabilities, people experiencing homelessness, and people with special dietary needs

Key Challenges:

- High food insecurity and poverty mean that many residents will not be able to store emergency food supplies or easily restock after a disaster.
- The City's mid-Atlantic location makes its food system particularly susceptible to flooding and snowstorms that disrupt transportation routes.
- Grocery stores rely on computer systems and electricity to operate and to accept payment and nutrition assistance benefits. This puts economic access to food at a higher risk to power outages and cyber-attacks.
- Public schools play a key role in food security, providing 60,000 students with free lunch every day. School closures leave many students without a key food source.
- Public transit lacks reliability and redundancy, and snow or flooding can close routes.
- Many neighborhoods are underserved by supermarkets, and one-third of the City's residents do not own cars. When public transit is impeded, so too is food access.
- The Baltimore food system's connection to the global market makes it vulnerable to global agricultural challenges. Urban agriculture is not sufficient to feed the City's population.
- Many food warehouses are located along the I-95 corridor, which is subject to bottlenecks that can disrupt food deliveries to Baltimore.
- A national truck driver shortage and high staff turnover in the food industry weaken resilience in the food labor supply.
- Many small businesses and non-profits lack resources to adequately prepare for emergencies.

The recommended strategies and actions to improve food system resilience cover the span of food system activities and include:

Economic Access

- Support economic development programs in food-insecure neighborhoods.
- Improve uptake of existing food assistance programs (before and after disasters).

Physical Access

- Consider food access in public transit redesign.

- Expand efforts to develop a community food storage plan.

Production

- Incentivize increased agricultural product diversity in urban and regional food production.
- Support local farmers' capacity for emergency preparedness.

Processing/Wholesale

- Evaluate the Baltimore metropolitan region's processing facility capacity.

Distribution

- Expand opportunities for local and regional food aggregation and distribution.
- Assess feasibility of backup food transport methods.

Retail

- Support small business preparedness in the food sector.

Donations/Food Assistance

- Identify and designate critical food facilities in each neighborhood for prioritized access and recovery support.
- Coordinate resources to enhance the preparedness capacity of food assistance organizations.

Labor

- Support safe and equitable labor and hiring practices in the city's food industry to increase food industry worker retention rates.

Food Acceptability

- Ensure that food stored in communities is culturally appropriate, safely used, and anticipates special dietary needs of community members.
- Continue and expand existing initiatives that support access to healthy, nutritious food.

Government

- With community input, incorporate findings into a Baltimore Food System Resilience Plan.
- Connect food resilience planning to broader City resilience planning.

Social Capital

- Support existing programs proven to strengthen social capital, such as community gardens.
- Include community members in development and implementation of the Food System Resilience Plan and local community food storage plans.

Waste

- Encourage the inclusion of waste removal contingency plans in business and food assistance organization preparedness training.

Monitoring

- Develop ongoing and crisis-oriented monitoring to identify food system failures and factors that can lead to them

Integrating Historic and Cultural Considerations

Special Program/Hurricane Sandy Disaster Relief Assistance Grant-NPS/Hazard Mitigation

The Baltimore City Department of Planning, Office of Sustainability, and Commission for Historical and Architectural Preservation have engaged a consultant to develop a hazard mitigation planning strategy for the City's historic resources, and to help determine resource-specific and neighborhood-specific adaptation strategies for the historic neighborhoods and areas most vulnerable to climate hazards. Strong, quickly implemented recommendations based upon careful study will help reduce the detrimental impacts that flooding events have on historic properties. The consultant will put together a guide that identifies existing best practices and innovative planning measures for hazard mitigation for vulnerable historic resources. This process will include research of best practices in other cities and jurisdictions, nationally and internationally; identifying which best practices most closely align with Baltimore's historic building typologies.

Conclusion

The City of Baltimore has adopted a progressive and holistic approach to disaster preparedness and resilience, as evidenced by the community resilience, food resilience, and historic preservation initiatives and efforts described in this chapter. The recommendations outlined here represent important steps for the City to take moving forward, but are not intended to be comprehensive. Planners recognize that resilience is a moving target and requires consistent public engagement and continuous evaluation of preparedness approaches.

Glossary

100-year floodplain- The geographical area with a 1 percent or greater chance of flooding in any given year.

500-year floodplain- The geographical area with a 0.2 percent chance of flooding in any given year.

Adaptive Capacity- The ability of a system to adjust to changes in the environment — including climate variability and extreme shifts in weather — in order to moderate potential damages or cope with the consequences of those changes.

Asset- Any manmade or natural feature that has value, including, but not limited to people; buildings; infrastructure like bridges, roads, and sewer and water systems; lifelines like electricity and communication resources; or environmental, cultural, or recreational features like parks, dunes, wetlands, or landmarks.

Base Flood- A flood that has a 1% probability of being equaled or exceeded in any given year. Also known as the 100-year flood.

Base Flood Elevation (BFE)- Elevation of the base flood in relation to a specified datum, such as the National Geodetic Vertical Datum of 1929. The Base Flood Elevation is used as the standard for the National Flood Insurance Program.

Building- A structure that is walled and roofed, principally above ground, and permanently affixed to a site.

Code Blue Cold Alert- Baltimore City Health Department official declaration of extreme cold conditions.

Code Red Heat Alert- Baltimore City Health Department official declaration of extreme heat conditions.

Community Rating System (CRS)- An NFIP program that provides incentives for NFIP communities to complete activities that reduce flood hazard risk. When the community completes specified activities, the insurance premiums of policyholders in these communities are reduced.

Cooling Center- A building or set of buildings that are open on Code Red Heat Alert days to provide resources and relief for those impacted by extreme heat.

Climate- Describes the long-term trends of atmospheric conditions in particular regions.

Climate Adaptation- A process that intends to reduce long-term risks from hazards associated with climate variability and climate change. More specifically, adaptation refers to changes that are made to better respond to new climate conditions, thereby reducing harm and taking advantage of present opportunities.

Climate Change- Any significant long-term change in global or regional climate patterns attributed largely to the increased levels of atmospheric carbon dioxide produced by the use of fossil fuels.

Climate Normals- The latest three-decade averages of climatological variables including temperature and precipitation.

Climate Projection- Consolidates weather patterns over a period, typically 30 years, to determine expected changes in averages, called "climate normals."

Community Asset- Anything that can be used to improve the quality of community life such as a person, physical structure or space, business or community service.

Critical Facilities- Facilities that are critical to the health and welfare of the population and that are especially important following hazard events. Critical facilities include, but are not limited to, shelters, police and fire stations, and hospitals.

Critical Infrastructure- The assets, systems, and networks, whether physical or virtual, so vital that their incapacitation or destruction would have a debilitating effect on security, national economic security, national public health or safety, or any combination thereof.

Debris- The scattered remains of assets broken or destroyed in a hazard event. Debris caused by a wind or water hazard event can cause additional damage to other assets.

Duration- How long a hazard event lasts.

Earthquake- A sudden motion or trembling that is caused by a release of strain accumulated within or along the edge of earth's tectonic plates.

Erosion- The wearing away of the land surface by detachment and movement of soil and rock fragments, during a flood or storm or over a period of years through the action of wind, water, or other geologic processes.

Exposure- Extent to which an asset experiences an impact.

Extent- The size of an area affected by a hazard or hazard event.

Extreme Cold- When the low temperature experienced by a region is severe enough to cause a substantial threat to the life or health if people are exposed.

Extreme Heat- When the high temperature experienced by a region is severe enough to cause a substantial threat to life or health if people are exposed.

Fault- A fracture in the continuity of a rock formation caused by a shifting or dislodging of the earth's crust, in which adjacent surfaces are differentially displaced parallel to the plane of fracture.

Flash Flood- A flood event occurring with little or no warning where water levels rise at an extremely fast rate.

Flood- A general and temporary condition of partial or complete inundation of normally dry land areas from (1) the overflow of inland or tidal waters, (2) the unusual and rapid accumulation or runoff of surface waters from any source, or (3) mudflows or the sudden collapse of shoreline land.

Flood Depth- Height of the floodwater surface above the ground surface.

Flood Elevation- Elevation of the water surface above an established datum, e.g. National Geodetic Vertical Datum of 1929, North American Vertical Datum of 1988, or Mean Sea Level.

Flood Hazard Area- The area shown to be inundated by a flood of a given magnitude on a map.

Flood Insurance Rate Map (FIRM)- Map of a community, prepared by FEMA that shows both the special flood hazard areas and the risk premium zones applicable to the community.

Floodplain- Any land area, including watercourse, susceptible to partial or complete inundation by water from any source.

Floodway- The channel of a river or other watercourse and the adjacent land areas that must be reserved in order to discharge the 1-percent-annual-chance flood without cumulatively increasing the water surface elevation by more than a designated height.

Frequency- A measure of how often events of a particular magnitude are expected to occur. Frequency describes how often a hazard of a specific magnitude, duration, and/or extent typically occurs, on average. The reliability of this information varies depending on the kind of hazard being considered.

Fujita Scale of Tornado Intensity Rates- tornados with numeric values from F0 to F5 based on tornado wind speed and damage sustained. An F0 indicates light damage such as broken tree limbs or signs, while an F5 indicates incredible damage was sustained.

Geographic Information Systems (GIS)- A computer software application that relates physical features on the earth to a database to be used for mapping and analysis.

Global Warming- The recent ongoing rise in global average temperature near Earth's surface caused mostly by increasing concentrations of greenhouse gases in the atmosphere.

Hazard- A source of potential danger or adverse condition. Hazards in this plan are both natural and technological in origin and include: floods/flash floods, droughts, wind, thunderstorms/lightning, winter storms, tornados, hurricanes, extreme heat, landslides, earthquakes, wildfires/fires, land subsidence, mining hazards, dam failures, hazardous materials, and nuclear accidents. These events are hazards when they have the potential to harm people or property.

Hazard Event- A specific occurrence of a particular type of hazard.

Hazard Identification- The process of identifying hazards that threaten an area.

Hazard Mitigation- Any sustained action taken to reduce or eliminate long-term risks to people and their property from hazards and their effects.

Hazard Profile- A description of the physical characteristics of hazards and a determination of various descriptors including magnitude, duration, frequency, probability, and extent. In most cases, a community can most easily use these descriptors when they are recorded and displayed as maps.

HAZUS- A GIS-based, nationally standardized hazard loss estimation tool developed by FEMA.

Hurricane- An intense tropical cyclone, formed in the atmosphere over warm ocean areas, in which wind speeds reach 74-miles-per-hour or more and blow in a large spiral around a relatively calm center or "eye." Hurricanes develop over the North Atlantic Ocean, northeast Pacific Ocean, or the South Pacific Ocean east of 160° longitude. Hurricane circulation is counter-clockwise in the Northern Hemisphere and clockwise in the Southern Hemisphere.

Hydrology- The science of dealing with the waters of the earth. A flood discharge is developed by a hydrologic study.

Infrastructure- Refers to the public services of a community that have a direct impact on the quality of life. Infrastructure includes communication technology such as phone lines or internet access, vital services such as public water supplies and sewer treatment facilities, and includes an area's transportation system such as airports, heliports; highways, bridges, tunnels, roadbeds, overpasses, railways, rail yards, depots; and waterways, canals, locks, seaports, ferries, harbors, dry-docks, piers and regional dams.

Intensity- A measure of the effects of a hazard event at a particular place.

Impact- The action of one object coming forcibly into contact with another or having a strong effect on someone or something.

Impact Assessment- Identifies the degree to which, and in what manner, hazards will impact people, places, and the economy. The impact assessment identifies what stands to be damaged due to a hazard event, and the cost of such a loss

Landslide- Downward movement of a slope and materials under the force of gravity. Lateral Spreads Develop on gentle slopes and entail the sidelong movement of large masses of soil as an underlying layer liquefies in a seismic event.

Magnitude- A measure of the strength of a hazard event. The magnitude (also referred to as severity) of a given hazard event is usually determined using technical measures specific to the hazard.

Mitigation Plan- A systematic evaluation of the nature and extent of vulnerability to effects of natural hazards typically present in the state and includes a description of actions to minimize future vulnerability to hazards.

National Flood Insurance Program (NFIP)- Federal program created by Congress in 1968 that makes flood insurance available in communities that enact minimum floodplain management regulations in 44 CFR §60.3.

National Weather Service (NWS)- Prepares and issues flood, severe weather, and coastal storm warnings and can provide technical assistance to federal and state entities in preparing weather and flood plans.

National Emergency Management Information System (NEMIS)- An evolving agency-wide system of hardware, software, telecommunications and applications software that provides a new technology base to FEMA and its partners to perform the emergency management mission.

No-notice- A no-notice incident is one that occurs unexpectedly or with minimal warning. Incidents with typically predictable patterns can also become no-notice incidents when their behaviors or patterns differ from what had been predicted or expected. Due to the nature of no-notice events, the ability of emergency responders to react in a timely manner may be challenged

No-regrets Actions- Actions that have negative net costs because they generate direct or indirect benefits that are large enough to offset the costs of implementing the action.

Nor'easter- An extra-tropical cyclone producing gale-force winds and precipitation in the form of heavy snow or rain.

Planning- The act or process of making or carrying out plans; the establishment of goals, policies and procedures for a social or economic unit.

Pre-Disaster Mitigation Program (PDM)- The Pre-Disaster Mitigation (PDM) Program was authorized by §203 of the Robert T. Stafford Disaster Assistance and Emergency Relief Act (Stafford Act), 42 USC, as amended by §102 of the Disaster Mitigation Act of 2000. Funding for the program is provided through the National Pre-Disaster Mitigation Fund to assist states and local governments (to include Indian Tribal governments) in implementing cost-effective hazard mitigation activities that complement a comprehensive mitigation program.

Probability- A statistical measure of the likelihood that a hazard event will occur.

Recurrence Interval- The time between hazard events of similar size in a given location. It is based on the probability that the given event will be equaled or exceeded in any given year.

Repetitive Loss Property- A property that is currently insured for which two or more National Flood Insurance Program losses (occurring more than ten days apart) of at least $1000 each have been paid within any 10- year period since 1978.

Replacement Value- The cost of rebuilding a structure. This is usually expressed in terms of cost per square foot, and reflects the present-day cost of labor and materials to construct a building of a particular size, type and quality. In this plan, replacement values are largely based on insurance estimates.

Resilience (Baltimore City definition)- the ability of our community to anticipate, accommodate, and positively adapt to or thrive amidst changing climate conditions or hazard events and enhance quality of life, reliable systems, economic vitality, and conservation of resources for present and future generations.

Resiliency Hub (Baltimore City definition)- a building or set of buildings and neighboring outdoor space that will open to community members during the daytime, and provide access to resources which may include food, water, ice, cell phone charging stations in the event of an emergency. Other key components include ensuring that members of the surrounding communities are educated about natural and other human-made hazards that potentially threaten their community; engaging residents and businesses on steps they can take to respond before, during and after those events; connecting members of the community to resources to prepare for and withstand the impacts from hazard events; and at certain hubs, increasing energy and water efficiency of surrounding businesses and residences.

Richter Scale- A numerical scale of earthquake magnitude devised by seismologist C.F. Richter in 1935.

Risk- The estimated impact that a hazard would have on people, services, facilities, and structures in a community; the likelihood of a hazard event resulting in an adverse condition that causes injury or damage. Risk is often expressed in relative terms such as a high, moderate, or low likelihood of sustaining damage above a particular threshold due to a specific type of hazard event. It also can be expressed in terms of potential monetary losses associated with the intensity of the hazard.

Risk Assessment- identifies the nature, location, intensity and probability of a threat, and then determines vulnerabilities and exposure to those threats while considering the capacities and resources available for to address or manage threats. A risk assessment is a multi-faceted, 'stepped' process. It includes three stages: (1) Hazard identification, (2) vulnerability assessment, and (3) impacts assessment.

Riverine- Of or produced by a river.

Scale- A proportion used in determining a dimensional relationship; the ratio of the distance between two points on a map and the actual distance between the two points on the earth's surface.

Sensitivity- Degree to which an asset is impaired by an impact.

Stafford Act- The Robert T. Stafford Disaster Relief and Emergency Assistance Act, PL 100-107 was signed into law November 23, 1988 and amended the Disaster Relief Act of 1974, PL 93-288. The Stafford Act is the statutory authority for most federal disaster response activities, especially as they pertain to FEMA and its programs.

State Hazard Mitigation Officer (SHMO)- The representative of state government who is the primary point of contact with FEMA, other state and federal agencies, and local units of government in the planning and implementation of pre- and post- disaster mitigation activities.

Structure- Something constructed. (See also Building)

Sustainability (Baltimore City definition)- Improving the quality of human life while balancing the need for environmental protection, societal progress, and economic growth so as to maintain the balance between meeting the needs of people today without diminishing the ecosystems upon which future generations rely.

Topographic- Characterizes maps that show natural features and indicate the physical shape of the land using contour lines. These maps may also include manmade features.

Tornado- A violently rotating column of air extending ground-ward.

Tropical Cyclone- A cyclonic, low-pressure system over tropical or sub-tropical waters.

Tropical Storm- A tropical cyclone with maximum sustained winds greater than 39 mph and less than 74 mph.

Tsunami- Great sea wave produced by submarine earth movement or volcanic eruption.

Urban Heat Island- A metropolitan area that is significantly warmer than its surrounding rural areas due to human activities.

Urban Karst- Urban land with sinkholes, springs, and streams that sink into subsurface caverns. These sinkholes may develop progressively as subtle, bowl-shaped depressions, or they may collapse suddenly into steeply sided, water-filled craters.

Vulnerability- Describes how exposed or susceptible to damage an asset is. Vulnerability depends on an asset's construction, contents, and the economic value of its functions. Like indirect damages, the vulnerability of one element of the community is often related to the vulnerability of another. For example, many businesses depend on uninterrupted electrical power – if an electric substation is flooded, it will affect not only the substation itself, but a number of businesses as well. Often, indirect effects can be much more widespread and damaging than direct ones.

Vulnerability Assessment- A process that further develops the risk assessment by examining current exposure (measure(s) of defense), sensitivity (degree to which something is affected), and adaptive capacity (ability to recover). This assessment determines the extent of injury and damage that may result from a hazard event of given intensity in a given area.

Weather - Refers to what changes we experience on a day-to-day basis or over a short period of time. Weather may describe current temperature, humidity, precipitation, wind, or other similar conditions; and a weather forecast may predict conditions in the near future.

Endnotes

[1] Previously, All-Hazard Mitigation Plans had been completed in 2006 and 2011, without addressing climate adaptation.

[2] Congress of the United States Congressional Budget Office, "Potential Cost Savings from the Pre-Disaster Mitigation Program", September 2007, https://www.cbo.gov/sites/default/files/110th-congress-2007-2008/reports/09-28-disaster.pdf

[3] More information on climate change and the City's efforts to mitigate the impacts of climate change can be found in the 2012 Baltimore Climate Action Plan (https://www.baltimoresustainability.org/plans/climate-action-plan/)

[4] See Annual Reports at https://www.baltimoresustainability.org/about/achievements-2/ and https://www.baltimoresustainability.org/plans/disaster-preparedness-plan/

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