Baltimore Office of Sustainability
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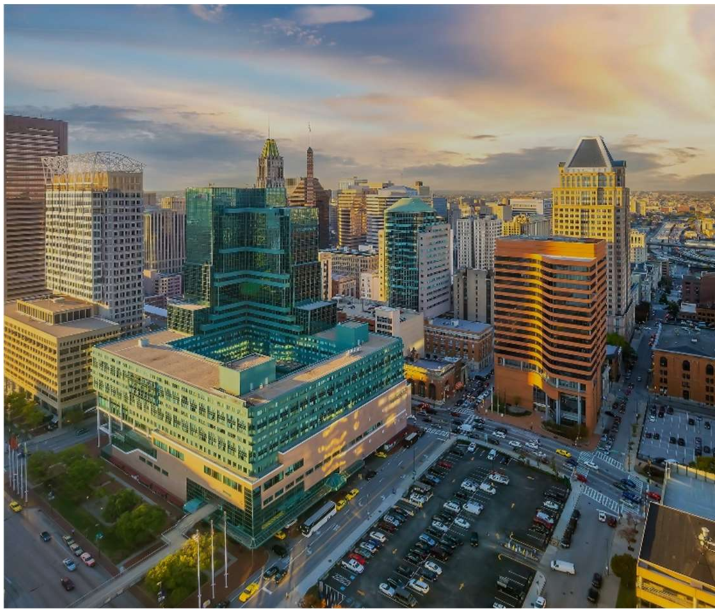
CITY of BALTIMORE DEPARTMENT of PLANNING

CITY OF BALTIMORE

Brandon M. Scott
Mayor

2023 Baltimore City Disaster Preparedness and Planning Project (DP3)



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U.S. Department of Homeland Security
Federal Emergency Management Agency
Region 3

One Independence Mall
615 Chestnut Street, 6th floor
Philadelphia, PA 19106-4404

December 15, 2023

Caitlin Whiteleather
State Hazard Mitigation Officer
Maryland Department of Emergency Management
5401 Rue Saint Lo Drive
Reisterstown, Maryland 21136

Dear Caitlin Whiteleather:

FEMA has reviewed the Baltimore City Hazard Mitigation Plan (HMP), based on standards in Title 44 of the Code of Federal Regulations, Part 201. The items reviewed address the planning process, hazard identification and risk assessment, mitigation strategies, and plan maintenance. The plan received a "satisfactory" rating on all required criteria. It is Approvable Pending Adoption (APA) as of November 30, 2023.

Prior to final approval, each jurisdiction that took part in the Baltimore City HMP must send FEMA a resolution of adoption. Also note, each plan participant must adopt within **one year** of the APA date. Plan participants that adopt the plan after one year must validate that their information in the plan remains current. If it is not, they must make the necessary updates before submitting the adoption resolution to FEMA.

I commend you for your continued commitment to reducing future disaster losses. If you have questions, please contact me at (215) 931-5532.

Sincerely,

Sarah Wolfe, Branch Chief
Floodplain Management and Insurance Branch
FEMA Region 3

Enclosure

cc: Jesse Delph, Hazard Mitigation Specialist, MDEM
Marcia Barben, Hazard Mitigation Project Officer, MDEM
Aliyah Russell, Mitigation Project Officer, MDEM
Ava Richardson, Director, Baltimore Office of Sustainability
Valerie Rupp, Climate and Resilience Program Manager, Baltimore Office of Sustainability
Aubrey Germ, Climate and Resilience Planner, Baltimore Office of Sustainability

PLANNING COMMISSION
Sean Davis, Chairman

Adoption Resolution
2023 Disaster Preparedness and Planning Project

Brandon M. Scott
Mayor

Chris Ryer
Director

Baltimore City, Maryland

A RESOLUTION OF THE CITY OF BALTIMORE ADOPTING THE 2023 DISASTER PREPAREDNESS AND PLANNING PROJECT.

WHEREAS Baltimore City recognizes the threat that natural hazards pose to people and property within Baltimore; and

WHEREAS the Baltimore City has prepared a multi-hazard mitigation plan, hereby known as the 2023 Disaster Preparedness and Planning Project (2023 DP3) in accordance with the Disaster Mitigation Act of 2000; and

WHEREAS the 2023 DP3 identifies mitigation goals and actions to reduce or eliminate long-term risk to people and property in Baltimore from the impacts of future hazards and disasters; and

WHEREAS adoption by Baltimore City demonstrates their commitment to hazard mitigation and achieving the goals outlined in the 2023 DP3.

NOW THEREFORE, BE IT RESOLVED BY BALTIMORE CITY, MARYLAND THAT:

Section 1. In accordance with The Charter of Baltimore City, the Baltimore City Planning Commission adopts the 2023 DP3. This plan, approved by the community, may be edited or amended after submission for review, but will not require the community to re-adopt any further iterations. This only applies to this specific plan and does not absolve the community from updating the plan in 5 years.

ADOPTED by a vote of 8 in favor and 0 against, and 0 abstaining, this 30th day of November, 2023.

By: ________________________________

Sean Davis, Chairman, Baltimore City Planning Commission

BALTIMORE COMMISSION ON
SUSTAINABILITY *People ♦ Planet ♦ Prosperity*

November 17, 2023

Sean Davis, Chairman
Baltimore Planning Commission
Baltimore City Department of Planning
417 East Fayette Street, 8th Floor
Baltimore, MD 21202

Dear Chairman Davis and members of the Planning Commission,

In the coming years, climate hazards and extreme weather events, which are already impacting the City on a regular basis, are projected to increase in intensity and magnitude due to climate change. The Sustainability Commission believes that it is critical for cities, including Baltimore, to become more resilient to these hazards by strengthening buildings, utilities, and emergency preparedness, as well as proactively and intentionally improving social systems and resident safety nets.

Baltimore is highly vulnerable to coastal storms, flooding, heavy precipitation, extreme heat, high winds, and winter storms. Combined with a projected rise in sea level, these hazards will reach more areas of our city than in the past and have disproportionate impacts on our most vulnerable community members. Beyond property and economic damage, climate hazards also threaten Baltimore's city-wide utilities and transportation systems. These climate hazards have the potential to cause the most strain for low-income residents who face greater challenges to preparedness and recovery after a disruption. Therefore, it is essential that the city has a plan in place that identifies how to proactively build resilience to future impacts.

Baltimore's Disaster Preparedness and Planning Project (DP3) is Baltimore’s FEMA-sanctioned Hazard Mitigation Plan. It was first produced in 2013, laying out a single, city-wide approach to adapting to climate change and preparing for natural hazards. The 2023 DP3 update addresses changes that have taken place since the plan was last updated five years ago in 2018 and includes new strategies and actions to help Baltimore continue moving forward with hazard mitigation and community preparedness. The 2023 DP3 includes input from a Hazard Mitigation Advisory Committee, an Equity Subcommittee, and hundreds of community members and stakeholders. It also comprises new hazard risk and vulnerability analyses and incorporates priority human-caused hazards for the first time. The 2023 DP3 also aligns with the Community Preparedness Chapter of the City's 2019 Sustainability Plan and serves as a necessary complement to the city's 2023 Climate Action Plan.

The Baltimore Commission on Sustainability will vote to approve the 2023 Disaster Preparedness and Planning Project on November 29th and fully supports its adoption by the City Planning Commission.

Sincerely,

Mia Blom
Co-chair, Commission on Sustainability

Baltimore City
Office of Emergency Management
501 N. Calvert St, 3rd Floor
Baltimore, Maryland 21202
(410) 396-6188

Brandon M. Scott
Mayor
City of Baltimore

Joey Henderson
Emergency Manager
Office of Emergency Management

November 15, 2023

Sean Davis, Chairman
Planning Commission
Baltimore City Department of Planning
417 East Fayette Street, 8th Floor
Baltimore, MD 21202

Dear Chairman Davis and members of the Planning Commission,

On behalf of the Baltimore City Office of Emergency Management (OEM), I would like to submit this letter of support for the City's 2023 All Hazard Mitigation Plan/Disaster Preparedness and Planning Project (2023 DP3). At its core, the DP3 is a risk-reduction and climate adaptation plan. It outlines pressing climate and hazard threats that Baltimore faces and identifies strategies that are essential to proactively mitigating their impacts on the city, our infrastructure, and our most vulnerable communities.

OEM considers itself an essential partner in hazard mitigation planning in Baltimore. OEM was involved with the 2023 DP3 Update from the very beginning and remained involved throughout the 1-year planning process. As part of the 2023 DP3 Core Planning Team (CPT) and Hazard Mitigation Advisory Committee (HMAC), OEM engaged with partners across the city to hear directly from stakeholders about their lived experiences and hazard-risk realities in Baltimore. We are confident that between the in-depth stakeholder engagement process and the data-driven vulnerability and risk assessments, the 2023 DP3 is reflective of Baltimore's vulnerability to hazards and identifies important mitigation solutions. With a focus on equity and the addition of priority human-caused hazards to complement the traditional climate-hazard framing of the plan, this iteration of the DP3 is particularly strong.

OEM would like to underscore the importance of the DP3 being adopted by the City of Baltimore. By approving the updated plan, the Planning Commission can ensure that the city is eligible to apply for Federal Emergency Management Agency (FEMA) mitigation grants, which can be used to proactively protect our most vulnerable areas. I whole heartedly believe we have produced a high-quality plan update that will serve the city well for many years to come. I encourage the Planning Commission to review the document in detail, as I believe you will see an excellent document focused on the mitigation needs of our diverse city.

Sincerely,

Joey Henderson
Director
Office of Emergency Management

Section 1. Introduction

The Disaster Preparedness and Planning Project (DP3) details Baltimore City's strategy to locally address existing and future hazards and serves as the official hazard mitigation plan (HMP). The plan serves to identify the vulnerabilities to Baltimore City's population, natural and built environments, and economy. This 2023 DP3 update builds upon the successes of the 2013 DP3 and the 2018 DP3. Baltimore continues to comprehensively assess its vulnerabilities to hazard impacts and climate change while identifying solutions to combat this risk. Baltimore City understands the importance and need to ensure the mitigation plan and risk assessment remain current in order to cultivate a more resilient Baltimore, now and into the future.

1.1 Hazard Mitigation Planning Overview

Hazard mitigation planning is the process of identifying disaster risks and vulnerabilities and subsequently developing measures and strategies that will reduce or eliminate the loss of life and/or property damage that can result from hazard events.

Key Terms

- Hazard Mitigation—Any substantial action that reduces or eliminates long-term risk to people and property from future disasters.
- Vulnerability—Describes how exposed or susceptible to damage an asset is hazard impacts. Vulnerability depends on an asset's construction, contents, and the economic value of its functions.
- Natural Hazard—Environmental phenomena that have the potential to impact societies and the human environment (FEMA n.d.).
- Human-caused Hazard—The result of human intent, error, or as a result of failed systems.

Hazard mitigation measures may be large infrastructure projects implemented to reduce roadway flooding, or they may include measures at the individual level, such as installing a rain barrel to collect graywater and reduce flooding.

Baltimore City will continue to implement hazard mitigation planning into its framework as long as natural and human-caused hazards continue to affect its communities. Mitigation and climate adaptation measures will be assessed and implemented to address Baltimore City's vulnerabilities, which evolve throughout the years as seen in previous plans. This 2023 DP3 update fulfills the federal requirements to regularly update formal plans and serves as a critical resource for all people who work, live, and play in Baltimore City to be aware of the risk they face regarding natural and human-caused hazards. This 2023 DP3 update prioritized expanding community engagement efforts, integrating human-caused hazards such as cyber terrorism and hazardous materials, and having a greater focus on equity.

1.1.1 Scope and Vision of the Plan

With the goal to become more resilient, the 2023 DP3 updates the strategies Baltimore City will implement to adapt to the impacts caused by frequent and intense extreme weather events and human-caused hazards. This specific hazard mitigation approach has many benefits, including but not limited to:

- **Protection for people and property** – Baltimore will protect and improve essential and critical infrastructure. Natural systems will be enhanced, resulting in green infrastructure advancements.
- **Cost savings** – Pre-emptive actions offer cost savings for Baltimore. For every dollar spent on mitigation projects, losses from future disasters can be reduced by at least $6 (FEMA 2019).
- **Proactive Action** – Baltimore will not wait for a crisis to occur. Baltimore City will proactively implement the strategies detailed in this plan to reduce future hazard impacts and promote a resilient and sustainable future for the community.

The planning process for the 2023 DP3 update included updating profiles and historic occurrences of hazard events; evaluating Baltimore City's risk and vulnerability for each hazard; and estimating hazard-specific loss in terms of economic damage. To learn more about how the risk assessment was conducted refer to Section 3 (Risk Assessment). An overview of the planning process and major milestones is shown in Figure 1-1. Baltimore City has already experienced climate-related impacts; therefore, this plan update aims to identify opportunities to strengthen preparation and adaptation efforts in the face of new climate conditions. Baltimore City's environmental, social, and economic spheres are projected to be impacted by heat waves, sea level rise, and flooding. The solutions built into this plan update will reduce Baltimore City's risks associated with these hazards and increase resiliency.

Figure 1-1. 2023 DP3 Update Process Overview

Through the planning process, City representatives, stakeholders, and community members identified the vision and goals described below to guide the development of the plan and the solutions to combat impacts from hazards.

VISION

Baltimore is a resilient city whose daily activities reflect a commitment shared by all people who work, live, and play in the City to reduce or eliminate impacts from current and future hazards, especially those exacerbated by climate change.

GOALS

- Goal 1: Ensure the equitable protection of the health, safety, and welfare of all people who work, live, and play in the City, with specific consideration for the barriers and challenges that may result in disproportionate hazard impacts to socially vulnerable populations and underserved communities.
- Goal 2: Strengthen the resilience of critical government and community facilities, services, and systems to reduce or prevent impacts from natural and human-caused hazard events.
- Goal 3: Enhance the integration of resilience, disaster prevention, and planning into all City programs, policies, and operations.
- Goal 4: Enhance the City of Baltimore's adaptive capacity and build institutional structures that can proactively cope with dynamic future conditions.
- 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) classification.

Scenes from the 2023 Sustainability Open House

Role of Climate Change and Climate Adaptation

Hazard mitigation and climate adaptation are complementary efforts with the same goal of reducing the long-term risk for people and increasing the safety of communities. Climate change increases the frequency, duration, and intensity of natural hazards. Many communities across the U.S. today are already experiencing the impacts caused by climate change. Hazard mitigation encompasses all natural hazards, while climate adaptations focus on current and projected impacts of climate change.

Key Terms

- Climate Change—The long-term shift in global climate patterns as a result of changes in the atmosphere from greenhouse gas emissions (GHG). A changing climate is a force multiplier, increasing the number of storms, floods, fires, and extreme temperatures that threaten the well-being of people across the nation (FEMA and the Changing Climate, 2023).
- Climate Adaptation—Actions taken at the individual, local, regional, and national levels to reduce risks from today's changed climate conditions and prepare for impacts from changes projected for the future (U.S. Global Change Research Program, 2018).
- Climate Mitigation—Includes activities to reduce and stabilize the levels of heat-trapping greenhouse gases in the atmosphere. (IPCC 2018).
- Climate Maladaptation—When actions taken to help communities adapt to climate change have unexpected consequences resulting in increased vulnerability (IPCC, 2022).

Baltimore is a coastal city located along the Chesapeake Bay. Over the last century, average rainfall for the State of Maryland has increased by 5 percent, and the average temperature has risen 2° F (EPA 2016). Maryland has also experienced increases in sea levels at a rate of approximately 1 inch every 7 years, which will be consistent over time, given conditions remain the same (UMD n.d.). This may seem like small numbers today, but over time, these changes to Maryland's climate will cause drastic impacts and changes to the communities and environment. Rising sea levels and increased precipitation are a real threat to Baltimore City's social, economic, and natural environment.

It is important for Baltimore City to incorporate climate change projections and adaptation measures into the 2023 DP3 update to ensure the long-term safety, health, and well-being of the community. Incorporating climate change adaptations is another form of hazard mitigation that allows Baltimore City to adapt to anticipated impacts from climate change and reduce the risk of current and future events. It is increasingly important to ensure these adaptations are analyzed and assessed to limit the possibility of maladaptation. Maladaptation refers to actions intended to reduce the impacts of climate change that actually create more risk and vulnerability (IPCC 2022). For example, building a dam to manage flood waters in lowlands may increase the vulnerability of those living above the dam by increasing their susceptibility to riverine flooding. Baltimore City is aware of maladaptation and evaluates all adaptation practices recommended in the 2023 DP3 update to prevent this from occurring.

The role and impact climate change has on natural hazard events in Baltimore City was assessed, and current projections were included to influence best planning practices. Climate change is expected to exacerbate many of these natural hazard impacts resulting in intense and unpredictable events. Regardless of the reduction of greenhouse gas emissions (GHG), climate change impacts will continue to prevail for Baltimore City and its people.

High tide inundation at the Inner Harbor on April 13, 2020

Source: Baltimore City Office of Sustainability 2020

Hazard mitigation encompasses all natural hazards, including short-term and episodic events that may or may not be connected to climate change. Climate adaptation is focused on reducing risks to and mitigating climate change impacts.

As natural disasters increase in frequency and intensity, the need for supporting hazard mitigation and climate adaptation plans is greater than ever. A community implements a form of hazard mitigation by adapting to the expected impacts of climate change. An HMP that addresses climate change in the risk assessment and includes adaptation actions in the mitigation strategy can reduce the community's risk to current and future events (FEMA 2022).

Role of Social Vulnerability

Hazards affect all individuals in the impact area, but those with heightened social vulnerability or in underserved communities are impacted at a disproportionately higher rate than others. The whole community must be equipped with the resources and knowledge to prepare for, respond to, and recover from hazardous events.

The Federal Emergency Management Agency (FEMA) defines social vulnerability as "the potential for loss within an individual or social group." The degree to which a community has certain social factors and characteristics (i.e., poverty, crowded households, disabled residents, elderly populations, etc.) can drastically affect their ability to respond to and prepare for impacts. Social vulnerability considers the social, economic, and demographic characteristics that "influence an individual's or group's ability to prepare, respond, cope, or recover from an event" (FEMA 2023).

Key Terms

- Social Vulnerability—Is the susceptibility of social groups to the adverse impacts of natural hazards, including disproportionate death, injury, loss, or disruption of livelihood (FEMA n.d.).
- Underserved Community—Groups that have limited or no access to resources or that are otherwise disenfranchised. These groups may include people who are socioeconomically disadvantaged; people with limited English proficiency; people who are geographically isolated, etc. (FEMA n.d.).
- Equity—The consistent and systematic fair, just, and impartial treatment of all individuals, including individuals who belong to underserved communities (FEMA 2022).

For the 2023 DP3 update, Baltimore City's social vulnerability was measured with a Social Vulnerability Index (SVI) calculated with data from the Center for Disease Control/Agency for Toxic Substance and Disease Registry (CDC/ATSDR). The SVI score represents a national percentile ranking of social vulnerability for a county or census tract compared to all others at the same level. A higher SVI score indicates greater vulnerability to hazard impacts.

Baltimore City has a high SVI score; therefore, it is essential that Baltimore City continues to incorporate social vulnerability into its planning processes. According to the 2020 SVI CDC/ATSDR data, Baltimore City has a 0.931 SVI score overall, with 1 being the highest level of social vulnerability. In comparison, Baltimore County has an SVI score of 0.696 and Howard County has an SVI score of 0.174 (CDC/ATSDR 2020). The 2023 DP3 update considers many of the socioeconomic variables that affect Baltimore City's high SVI score to promote a more resilient future for all of Baltimore's communities. Additional information on socially vulnerable populations and underserved communities within Baltimore City can be found in Section 2 (City Profile).

Role of Nature-based Solutions

Hazard mitigation activities are inclusive of gray infrastructure, such as pipes and seawalls, and nature-based solutions (also referred to as green infrastructure). Nature-based solutions are long-term sustainable planning, design, environmental management, and engineering practices that weave natural features or processes into the built environment to build more resilient communities (FEMA 2023). Utilizing nature-based solutions to reduce the risk posed by hazards can achieve multiple benefits and contribute to climate mitigation. In addition to providing hazard mitigation benefits, nature-based solutions also contribute to the following:

- **Ecosystem Services** – these projects can aid in improving filtering stormwater runoff, reducing air temperatures, and preserving open space
- **Economic Benefits** – green stormwater infrastructure creates new job opportunities
- **Social Benefits** – contributes to additional opportunities for recreational and open spaces
- **Cost Savings** – nature-based solutions are generally a more cost-effective alternative when compared to traditional gray infrastructure (FEMA 2023).

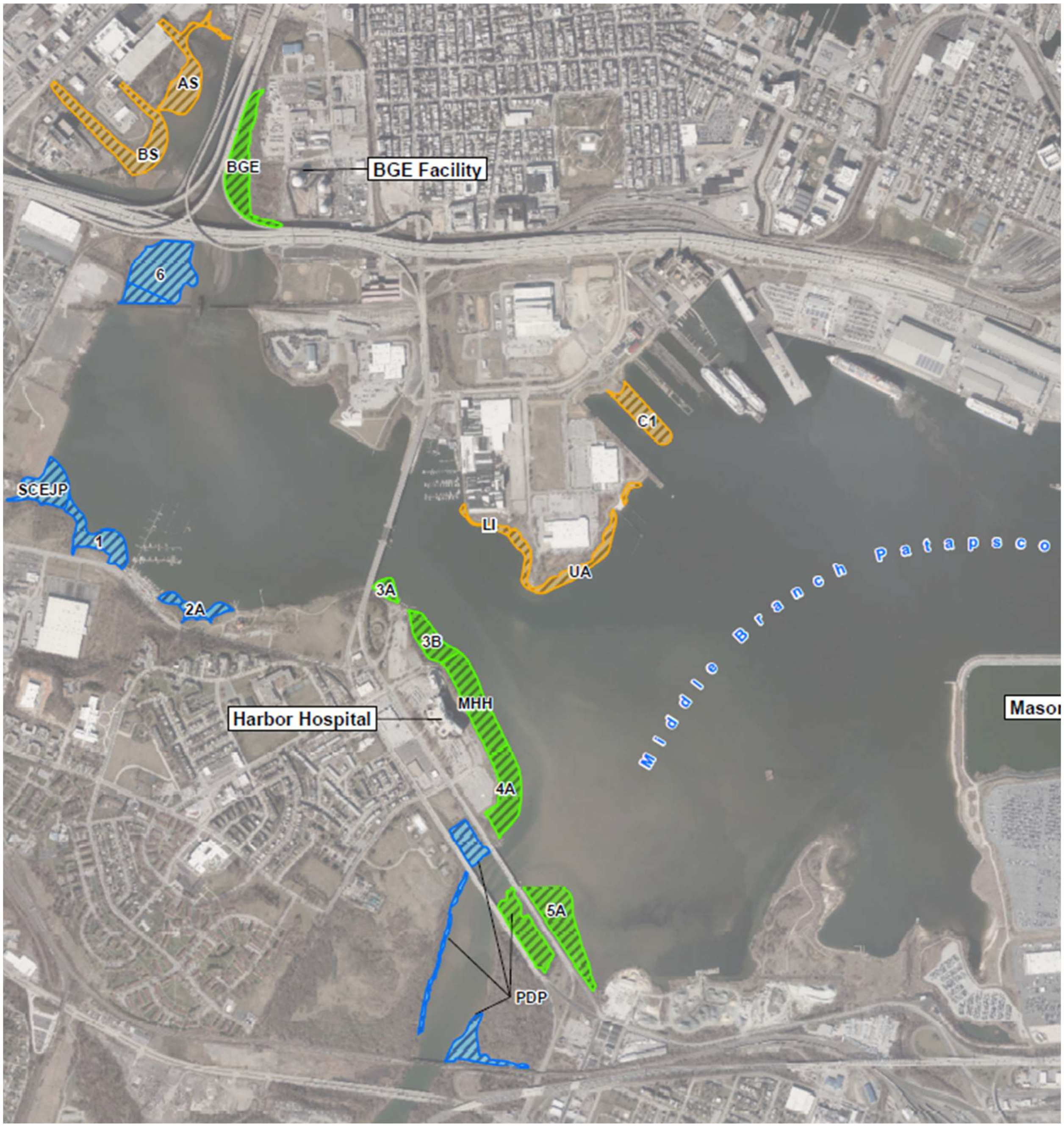
Baltimore Green Space outdoor education event

Communities can suffer significantly from natural hazards if they are under-invested in, under-targeted for, or excluded from community investment in nature-based solutions. Frontline communities are "neighborhoods or populations of people who are directly affected by climate change [and other natural hazards] and inequity in society at higher rates than people who have more power in society. They are on the frontlines of the problem" (NAACP 2018). These communities are at greater risk as structural and institutional inequities often create additional barriers that prevent these populations from being adequately prepared to withstand and recover from a disaster or emergency.

Within Baltimore City there are several examples of nature-based solutions being implemented to provide communities with multiple benefits. One example is the current Middle Branch Resiliency Initiative (MBRI) to restore approximately 3,000 acres of wetlands within the

Middle Branch of the Patapsco River. The initiative aims to improve air and water quality, enhance access to open spaces, and improve aquatic habitat. The effort consists of reestablishing natural habitats and creating new nature-based infrastructure, including vegetated berms, living shorelines, restored aquatic habitats, and natural stormwater management facilities. Figure 1-2 depicts the current and future locations of MBRI projects.

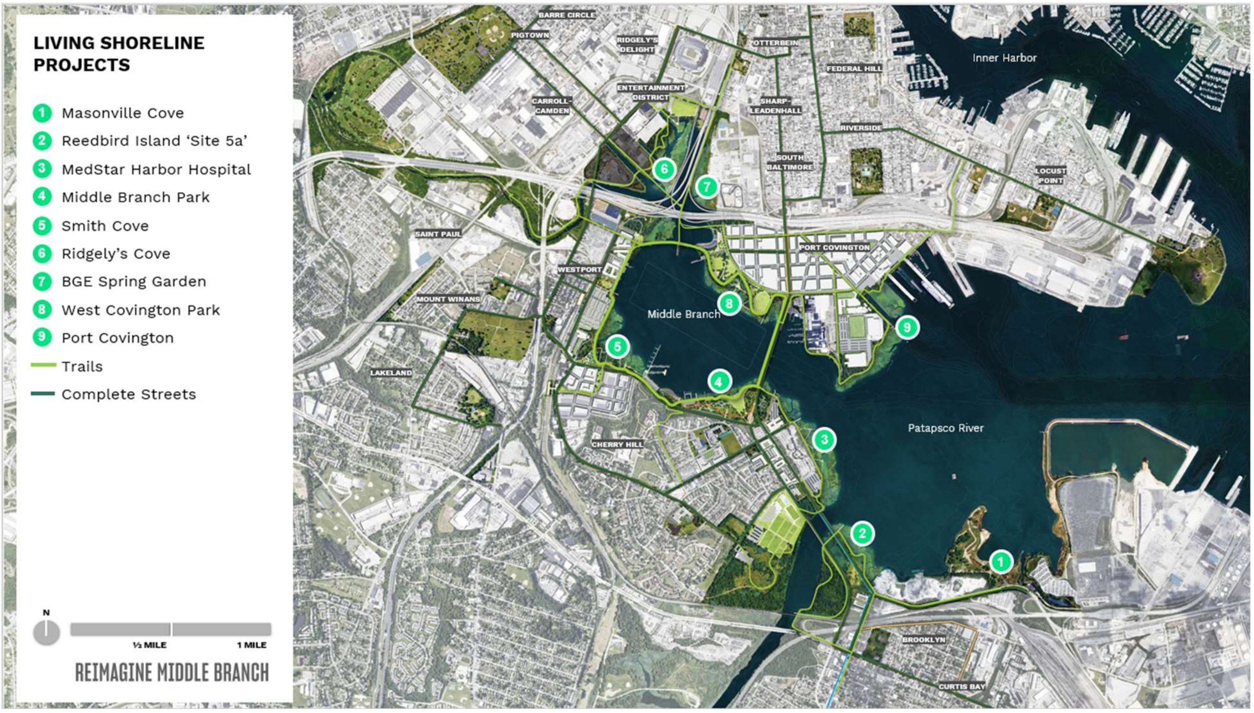
Figure 1-2. Identified MBRI Project Sites



Source: GreenVest 2023
Note: Sites identified in green are underway. Sites identified in blue and orange are for future MBRI projects.

The first stage of the MBRI is now underway, with $53 million in fully funded projects now being implemented. Approximately $32 million of funding for the project was awarded through FEMA's Building Resilient Infrastructure and Communities (BRIC) program, which supports mitigation focused programs annually. These efforts are detailed in the Reimagine Middle Branch Plan, a comprehensive, basin-wide implementation effort to build community resiliency through nature-based solutions. Potential restoration opportunities are depicted in Figure 1-3.

Figure 1-3. Potential Restoration Opportunities in the Reimagine Middle Branch Plan



Source: City of Baltimore 2023

Hazard mitigation projects that prioritize nature-based solutions are key for promoting resilient communities and advancing climate adaptation goals. FEMA is increasingly recognizing the importance of nature-based solutions to reduce hazard risk and has produced guidance and other resources to assist communities with planning and implementing nature-based solutions.

Changes from 2018 DP3

The 2018 DP3 identified opportunities to continue to strengthen subsequent versions of the plan in Chapter 7: Moving Forward. Those opportunities included the following:

- Center planning efforts on increasing community resilience, including ongoing formalization and expansion of Resiliency Hubs.
- Use community resilience initiatives to address varying regional concerns.
- Broaden public outreach and engagement efforts to include greater representation from all Baltimore neighborhoods and communities in planning efforts.
- Introduce solutions-oriented public engagement practices designed to solicit community-driven solutions.

- Determine a strategy for incorporating information on vulnerable populations collected during the development of this plan.
- Use public feedback to identify vulnerable populations and specify vulnerable populations to the greatest extent possible.
- Develop criteria and a strategy for integrating human-caused hazards into the next DP3 with input from the public at the outset.
- Integrate food resilience into mitigation and preparedness efforts.
- Integrate Historic and Cultural Resources Hazard Mitigation Strategy.

Through this 2023 DP3 update and the planning process, these opportunities were evaluated and incorporated into the update. The update process prioritized expanding the representation of stakeholders and community members engaged in the development of the 2023 DP3 update, including establishing a Social Equity Subcommittee to provide guidance on community concerns and needs.

1.1.2 Authorities and Responsibilities

The Baltimore Office of Sustainability (BoS) within the Baltimore Department of Planning (DOP) is responsible for developing the DP3. BoS coordinates with the Office of Emergency Management (OEM), the agency responsible for overseeing planning, implementation, and maintenance of mitigation efforts for Baltimore City. BoS also serves as the official point of contact for Baltimore City's DP3.

Authority for this plan originates from the following federal sources:

- Robert T. Stafford Disaster Relief and Emergency Assistance Act (Stafford Act), as amended
- Code of Federal Regulations (CFR), Title 44, Part 201 Mitigation Planning
- Disaster Mitigation Act (DMA) of 2000, Public Law 106-390, as amended

The Stafford Act of 1988 amended the Disaster Relief Act of 1974 (Public Law 93-288). The Stafford Act constitutes the statutory authority for most federal disaster response activities.

The DMA is the current federal regulation addressing hazard mitigation planning. It amended the Stafford Act to require the preparation of HMPs by state and local governments, emphasizing planning for disasters before they occur.

FEMA Requirements and Guidance

The 2023 DP3 update aims to advance previous and ongoing mitigation efforts proposed in the 2018 DP3 by calculating changes in risk to reassess mitigation strategies and priorities (44 CFR § 201.6(d)(3)). The 2023 DP3 update will also be integrated into other community planning initiatives to promote cohesive planning practices recommended by FEMA.

FEMA requires local mitigation plans include the following elements (FEMA 2023):

- **Planning Process:** Describes how the plan was developed, who is involved, and what data was used to build the plan.
- **Hazard Identification/Risk Assessment:** Identifies the hazards that can affect jurisdictions participating in the mitigation plan, including high hazard potential dams required for the High Hazard Potential Dams Grant Program.

- **Mitigation Strategy:** Serves as the long-term blueprint for reducing the potential losses that are identified in the risk assessment.
- **Plan Maintenance:** Documents the process of plan development, which allows for efficiency for future updates to the plan.
- **Plan Update:** Reflects how current conditions have changed since the last plan and effectively represents the jurisdiction's overall strategy for reducing risks from natural and human-caused hazards.
- **Plan Adoption:** Legitimizes the plan and authorizes the responsible agencies to perform their responsibilities.

In addition to the above elements, the FEMA *Local Planning Policy Guide*, effective April 2023, emphasizes the importance of incorporating climate change impacts and equity considerations into hazard mitigation planning.

Eligibility for Funding

The requirement for a local HMP is continued as a condition for disaster assistance. Local jurisdictions must have an approved standard HMP meeting the requirements in 44 CFR 201.6 as a condition of receiving the Stafford Act assistance and FEMA mitigation grants listed in Table 1-1.

Table 1-1. Non-Emergency Stafford Act Assistance Programs

Program	Description
Building Resilient Infrastructure and Communities (BRIC)	Pre-disaster funding for proactive mitigation and community resilience projects and plans
Hazard Mitigation Grant Program (HMGP)	Post-disaster funding for mitigation and community resilience projects and plans
HMGP-Post-Fire	Assistance to help communities implement hazard mitigation measures after wildfire disasters
Flood Mitigation Assistance (FMA)	Pre-disaster funding for flood hazard mitigation and community resilience activities that benefit properties insured under the National Flood Insurance Program (NFIP)
Rehabilitation of High Hazard Potential Dams	Technical, planning, design, and construction assistance in the form of grants for rehabilitation of eligible high hazard potential dams
Safeguarding Tomorrow Revolving Loan Fund Program	Capitalization grants passed through to states in order for states to establish revolving loan funds that provide hazard mitigation assistance for local governments to reduce risk from natural hazards and disasters

1.2 Planning Process

FEMA Planning Policy Element A1: 44 CFR 201.6(c)(1): The plan must include a description of the process used to develop the plan, including how the plan was prepared, the schedule or timeframe, specific milestones and activities, the agencies and stakeholder involved, and if the mitigation process was integrated to the maximum extent possible with other state planning efforts.

The planning process serves as the foundation for developing an effective plan to reduce risk and vulnerability posed by hazards across Baltimore City. The 2023 DP3 update process continues the work achieved during the implementation of the 2013 and 2018 DP3s.

BoS received a BRIC grant, supplemented with City funds, to support the development of the 2023 DP3 update. BoS procured technical services from Tetra Tech, Inc., to provide support for facilitating the planning process, conducting the risk and vulnerability assessment, coordinating stakeholders, and drafting the plan.

The 2023 DP3 update process officially kicked off on February 10, 2023. The Core Planning Team (CPT) was convened to discuss the priorities for the 2023 DP3 update. Over the course of the next nine months, City representatives, stakeholders, and community members engaged regularly to inform the development of the plan, ensuring community needs and concerns were addressed. The initial draft of the plan was reviewed by stakeholders, the public, and the State from August 11 to September 11, 2023, and the plan was submitted to FEMA for formal review on October 2, 2023. The Baltimore City Planning Commission formally adopted the plan on November 20, 2023, and the plan was formally approved by FEMA on XXX.

The 2023 planning process prioritized expanded stakeholder and community engagement. The planning process utilized a variety of outreach and engagement methods to integrate stakeholders into the process. This included hosting in-person and virtual meetings, deploying surveys, developing a website, and regular communication through email. These engagement efforts served to facilitate obtaining stakeholder input on identifying the hazards of concern, assessing risk and vulnerability, updating capabilities, providing status updates on the 2018 mitigation actions, updating and developing goals and objectives, and developing the mitigation strategy. Regular communication and engagement with the stakeholders permitted continuity throughout the process and kept the project on schedule.

Figure 1-4 shows FEMA's core steps for developing an HMP; the 2023 DP3 update process followed these steps. During each of these steps, meetings were held to provide opportunities for stakeholders and community members to provide input and shape the development of the plan.

Figure 1-4. Local Hazard Mitigation Planning Cycle

The following process was used to develop the 2023 DP3 update in alignment with FEMA's core steps:

- **Organize Resources:** Identify committee members, and stakeholders and convene throughout the planning process.
- **Identification:** Profile current and future natural hazards present in Baltimore City.
- **Inventory:** Identify all critical assets in Baltimore City, such as hospitals, schools, emergency response shelters, etc.
- **Modeling:** Identify risks to Baltimore City from impacts by natural hazards to predict climate change impacts.
- **Vulnerability Analysis:** Identify critical facilities and assets throughout Baltimore City to highlight Baltimore City's exposure, sensitivity, and adaptive capacities.
- **Actions and Recommendations:** Identify recommended actions to address existing natural hazards and predicted climate change impacts.
- **Implementation Plan:** Develop an implementation plan with recommendations for stakeholder involvement and funding strategies.
- **Adopt and Implement:** Formally adopt the plan and implement the strategies identified.

1.2.1 Organizing the Resources

FEMA Planning Policy Element A2: 44 CFR 201.6(b)(2): The plan must document opportunities for neighboring communities, local, and regional agencies involved in hazard mitigation activities, and agencies that have authority to regulate development as well as businesses, academia, and other private and non-profit interest to be involved in the planning process.

FEMA Planning Policy Element A3: 44 CFR 201.6(b)(1): The plan must document how the public was involved in the planning process during the drafting state and prior to plan approval.

Core Planning Team (CPT)

The CPT is an advisory team that was responsible for the key decisions during the planning process. The CPT was responsible for maintaining the schedule and timeline, reviewing deliverables/plan drafts, informing the development of the outreach and plan content, and assisting in identifying solutions for obstacles that may arise during the planning process. Table 1-2 lists the members of the CPT, titles, respective organizations, and their sector/area of expertise.

Table 1-2. CPT Members

Name	Title	Sector/Area of Expertise
Baltimore City Office of Sustainability (BoS)		
Bruna Attila	Coastal Resources Planner	Land Use and Development and Natural and Cultural Resources
Joanna Birch	Floodplain Manager	Land Use and Development and Floodplain Management
Aubrey Germ	Climate and Resilience Planner	Land Use and Development, Natural and Cultural Resources, Climate Change, and Sustainability
Quentin Klein-Alfano	Climate Outreach Intern	Land Use and Development, Natural and Cultural Resources, Climate Change, and Sustainability
Ava Richardson	Director	Land Use and Development, Natural and Cultural Resources, Climate Change, and Sustainability
Valerie Rupp	Climate and Resilience Program Manager	Land Use and Development, Natural and Cultural Resources, Climate Change, and Sustainability
Department of Planning (DOP)		
Nicholas O'Gara	GIS Analyst	Land Use and Development and GIS
Jamie Williams	City Planner Supervisor	Land Use and Development and GIS
Office of Emergency Management (OEM)		
Michelle Smith	Preparedness Section Chief	Emergency Management
Elise Whiteford	Planning Section Chief	Emergency Management
Department of Public Works (DPW)		
Kimberly Grove	Chief, Office of Compliance & Research	Infrastructure

Hazard Mitigation Advisory Committee

The Hazard Mitigation Advisory Committee (HMAC) is an advisory team that provided oversight during the planning process. Their role was to advise the CPT on the community needs and concerns to ensure community representation and inclusion during the planning process. The HMAC aimed to include agencies and organizations that lead and support implementation of the mitigation strategy. Table 1-3 lists the members of the HMAC, titles, respective organizations, and their sector/area of expertise.

The CPT reviewed and expanded the HMAC to include representation from additional sectors and community lifelines. During the CPT kickoff meeting on February 24, 2023, and a subsequent meeting on March 10, 2023, the CPT reviewed previous members of the 2018 HMAC. The CPT was provided a list of recommended representatives to include on the 2023 HMAC based on expertise from the consultant and BoS. Those recommendations included:

- Aging Services
- Baltimore City Department of Housing and Community Development
- Baltimore City Information and Technology
- Baltimore City Law Department
- Baltimore City Recreation and Parks
- Baltimore City Youth Commission
- Baltimore Development Corporation
- Baltimore Sheriff's Office
- Baltimore Urban Area Security Initiative (UASI) Recovery Committee
- BMORE Beautiful
- Environmental Control Board
- Housing Authority of Baltimore City
- Johns Hopkins University
- Mayor's Office of Correspondence and Constituent Services
- Mayor's Office of Infrastructure Development
- Say YES!

CPT members participated in an interactive brainstorming session to identify additional representatives to invite to participate on the HMAC.

CPT HMAC membership brainstorming activity

Table 1-3. HMAC Members

Name	Title	Sector/Area of Expertise
Baltimore City Health Department (BCHD)		
Kim Eshleman	Director, Office of Public Health Preparedness and Response (OPHPR)	Health and Social Services
Alice Huang	Acting Assistant Commissioner, Community Services	Health and Social Services, Equity, and Community Advocacy
Kay Webster	Deputy Director, OPHPR	Health and Social Services and Emergency Management
Baltimore City Recreation and Parks (BCRP)		
Dan Coy	Chief of Forestry	Natural and Cultural Resources
Kendra Moore	Recreation Manager South District	Natural and Cultural Resources
DPW		
Yolanda Cason	Operations Manager I, Solid Waste	Infrastructure
Toya Sykes-Coates	Chief of Solid Waste Administration	Infrastructure
Kimberly Grove	Chief, Office of Compliance and Research	Infrastructure
Yvonne Moore-Jackson	Bureau Head, Solid Waste	Infrastructure
Yosef Kebede	Bureau Head, Water and Wastewater	Infrastructure
Antoine Smith	Emergency Response and Preparedness	Infrastructure and Emergency Management
Theresa Wilson	Operations Officer III	Infrastructure
Baltimore Gas and Electric (BGE)		
Danielle Gooden	Governmental and External Affairs Manager	Private Sector, Infrastructure, and Energy
Matt Piechocki	Senior Emergency Preparedness Administrator	Private Sector, Infrastructure, Energy, and Emergency Management
BoS		
Bruna Attila	Coastal Resources Planner	Land Use and Development and Natural and Cultural Resources
Joanna Birch	Floodplain Manager	Land Use and Development and Floodplain Management
Aubrey Germ	Climate and Resilience Planner	Land Use and Development, Natural and Cultural Resources, Climate Change, and Sustainability
Amy Gilder-Busatti	Sustainability Manager	Land Use and Development, Natural and Cultural Resources, Climate Change, and Sustainability
Ava Richardson	Director	Land Use and Development, Natural and Cultural Resources, Climate Change, and Sustainability
Valerie Rupp	Climate and Resilience Program Manager	Land Use and Development, Natural and Cultural Resources, Climate Change, and Sustainability
Department of General Services (DGS)		
Marwan Alkarajat	Chief, Capital Projects and Energy Division	Infrastructure and Energy

Name	Title	Sector/Area of Expertise
Herman Guadalupe	Engineer Supervisor	Infrastructure
Christopher Hepler	Construction Project Supervisor II	Infrastructure
Julia Kalloz	Energy Division Chief	Infrastructure and Energy
DOP		
Lindsay Adams	Food Resilience Planner	Equity and Food Resilience
Nicholas O'Gara	GIS Analyst	Land Use and Development and GIS
Kyle Leggs	City Planning Supervisor	Land Use and Development
Stacy Montgomery	Historic Preservation Planner Supervisor, Commission for Historical and Architectural Preservation (CHAP)	Land Use and Development and Historic Preservation
Lauren Schiszik	Historic Preservation Planner, CHAP	Land Use and Development and Historic Preservation
Jamie Williams	City Planner Supervisor	Land Use and Development and GIS
DOT		
Tavon Braxton	Deputy Director of Operations	Infrastructure and Transportation
William Ethridge	City Planner II	Infrastructure and Transportation
Environmental Control Board (ECB)		
Natasha Neale	Community Program Liaison	Environmental Hazards
Brandi Welsh	Community Program Liaison	Environmental Hazards
Maryland Department of Emergency Management (MDEM)		
Bridget Cantwell	Hazard Mitigation Planner	Emergency Management
Aliyah Russell	Project Officer	Emergency Management
Mayor's Office		
Angela McCauley	Emergency Services Manager (Homeless Services)	Equity and Community Advocacy
Anthony Scott	Associate Director of Project Management	Economic Development
Candisse Bennett-Parker	Director (Correspondence and Constituent Services	Equity and Community Advocacy
Graham Young	Project Manager (Infrastructure Development)	Infrastructure
Justin Elszasz	Chief Data Officer	Cyber
Masuma Islam Lonczak	Deputy Director (Immigrant Affairs)	Equity and Community Advocacy
OEM		
Michelle Smith	Preparedness Section Chief	Emergency Management
Elise Whiteford	Planning Section Chief	Emergency Management
Waterfront Partnership of Baltimore		
Allison Blood	Healthy Harbor Program Manager	Non-profit, Economic Development, Land Use and Development, Housing, Infrastructure, Natural and Cultural Resources, Equity, and Community Advocacy

Name	Title	Sector/Area of Expertise
Baltimore City Department of Housing and Community Development (DHCD)		
Eric Booker	Deputy Commissioner, Housing Code Enforcement and Emergency Operations	Housing
Baltimore City Sheriff's Office		
Chaya Deitsch	Director of Emergency Management	Safety and Security
Department of Homeland Security (DHS) Cybersecurity and Infrastructure Security Agency (CISA)		
Al Frenette	Protective Security Advisor	Emergency Management, Infrastructure, and Cyber
Maryland Insurance Administration		
Joy Hatchette	Associate Commissioner for Consumer Education and Advocacy	Emergency Management and Community Advocacy
Maryland Zoo		
Jess Henson	Senior Director Risk and Safety	Non-profit, Natural and Cultural Resources, and Emergency Management
Maryland Port Administration (MPA)		
Cindy Hudson	Environmental Manager	Infrastructure and Economic Development
Baltimore Police Department (BPD)		
Tom Jugan	Detective	Safety and Security
Baltimore City Information and Technology (BCIT)		
Kevin Kearney	Chief Information Security Officer	Cyber
FEMA Region 3		
Joshua Norris	Hazard Mitigation Planner	Emergency Management
InfoSec / BCIT		
Ron Rego	Cybersecurity Engineer	Cyber
South Baltimore Gateway Partnership		
Brad Rogers	Executive Director	Non-profit, Economic Development, Land Use and Development, Housing, Infrastructure, Natural and Cultural Resources, Equity, and Community Advocacy
Baltimore City Fire Department (BCFD)		
Kevin Ryan	HazMat Tech	Emergency Management
Baltimore Development Corporation (BDC)		
Larysa Salamacha	Managing Director	Quasigovernmental, Economic Development and Land Use and Development
Baltimore Metropolitan Council		
Eileen Singleton	Principal Transportation Engineer	Infrastructure
Johns Hopkins University		
Benjamin Zaitchik	Earth and Planetary Sciences Professor	Academia and Climate Change

HMAC Social Equity Subcommittee

The HMAC Social Equity Subcommittee was convened to prioritize the representation of socially vulnerable populations within Baltimore City. These stakeholders included representatives from community organizations and Resiliency Hub leaders (see Table 1-4). The 2023 DP3 update includes outreach and engagement recommendations to increase the representation of all Baltimore neighborhoods and communities.

Table 1-4. Social Equity Subcommittee Members

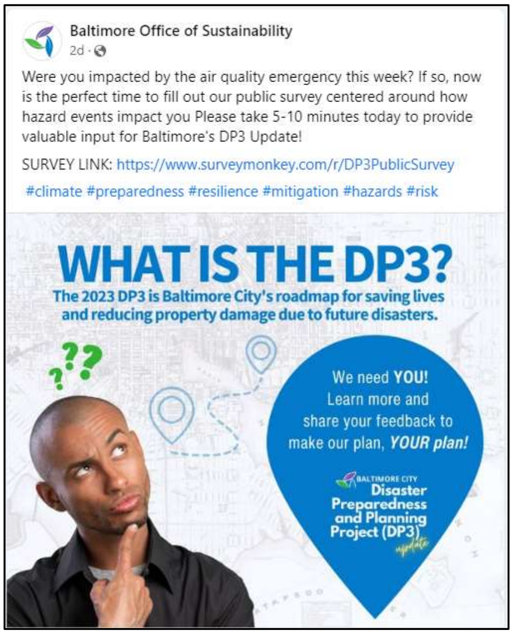
Name
Alexandra Grayson
Bonnie Sorak
Cameron Snell
Daniella Hutcherson
Jacques Benter
Jeenly Louis
Lynette Hodge
Naadiya Hutchinson
Ritzy Chirinos
Sharon Hayes
Tiffany Page-Cooper
Tim Barrows

1.2.2 Community Engagement Strategy and Methodology

Baltimore City is dedicated to integrating equitable policies into its planning efforts and tools. In order to effectively include equitable lenses into the 2023 DP3 update, it was essential to include broader outreach activities that encompass all of the Baltimore communities and organizations.

The goals for the 2023 DP3 update engagement included:

- Inform stakeholders and community members about risks associated with natural and human-caused hazards.
- Foster a collaborative process to develop a mitigation strategy to reduce identified risks.
- Demonstrate how mitigation solutions support co-benefits that improve quality of life both now and in the future.
- Design community-informed mitigation solutions that align with other community and City priorities (or identify mitigation solutions that are community-informed).
- Develop a better sense of the demographics of individuals actively engaged and participating in the planning process.
- Increase engagement with diverse neighborhoods and communities.



Example of social media postings spreading awareness of the planning process

More information, including tools such as StoryMap and the Engagement Toolkit, can be found in Appendix A: Engagement Strategy. Meeting documentation is available in Appendix B: Meeting Documentation.

At the initiation of the planning process, a series of surveys was deployed to the following targeted groups: stakeholders (including City agencies, private sector, and non-governmental organizations), general public, and neighboring jurisdictions (including Anne Arundel, Baltimore, and Howard Counties). Outreach to spread awareness about the surveys was conducted through meetings, emails, and in-person at several community-oriented facilities. In total, 192 responses were received: 157 public, 31 stakeholders, and 4 neighboring jurisdictions. The locations listed below were identified as focus areas to distribute in-person surveys to reach a wider representation of the community and provided dedicated engagement opportunities for neighborhoods and populations with increased vulnerability:

- Harlem Gardens: A senior center in the Harlem Park neighborhood in West Baltimore
- Bentalou Recreation Center: Located in the Lexington neighborhood in West Baltimore
- Edmondson Commons: A senior center in the Harlem Park neighborhood in West Baltimore
- Harvey Johnson Towers: An apartment complex in the Sandtown Winchester neighborhood in West Baltimore
- Plantation Park Heights: An urban farm in the Park Heights neighborhood in Northwest Baltimore
- MonteVerde Apartments: An apartment complex in the Park Circle neighborhood in Northwest Baltimore
- Oliver Senior Center-Home: A senior center, as well as an additional drop-off in its associated community center, in the Broadway East neighborhood in East Baltimore
- Herring Run Branch of the Enoch Pratt Free Library: In the Belair Edison neighborhood in East Baltimore
- Cherry Hill Branch of the Enoch Pratt Free Library: In the Cherry Hill neighborhood of South Baltimore

Neighboring jurisdictions were surveyed regarding new opportunities and past cross-jurisdictional collaboration and coordination; shared risk and vulnerabilities; and to identify potential mitigation actions. The survey results indicated that while there are some formal agreements, such as mutual aid, in place to support cross-jurisdictional collaboration, there are multiple opportunities to strengthen coordination across jurisdictions related to emergency response, recovery, and mitigation efforts. Additionally, survey results indicated that cross-jurisdictional preparedness measures, such as public education and outreach, is further propelled by efforts from Federal, State, and non-profit organizations.

Additional engagement included:

- Hanging posters for the DP3 public survey at the West Baltimore Marc Station in Midtown Edmondson.
- Tabling at the following events: JFX Farmers Market in Downtown Baltimore, the Cherry Hill Farmers Market in the Cherry Hill neighborhood in South Baltimore, the Onyx Farmers' and Artisans' Market in the Old Goucher neighborhood in Central Baltimore, the Plantation Park Heights Food Giveaway in the Park Heights

neighborhood in Northwest Baltimore during a Morgan State event at the farm and during their Senior Volunteer day, and the Liberty Grace Church of God GROW Center in Ashburton in West Baltimore.

- Presenting at the following meetings: Local Emergency Planning Committee, Waste Working Group of the Sustainability and Resiliency Subcabinet, Extreme Heat Working Group of the Sustainability and Resiliency Subcabinet, and the Frederick Avenue Flood Mitigation community meeting.

1.2.3 Schedule

The planning process was conducted over 9 months, beginning in February 2023 and concluding in November 2023, to ensure the plan was FEMA-approved and locally adopted prior to the December 2023 expiration of the 2018 DP3. The schedule was developed to allow for flexibility to account for unexpected delays that may occur throughout the process. Table 1-5 provides a summary of key planning meetings and milestones.

Table 1-5. Key Planning Meetings and Milestones

Meeting Date	Milestone
February 27, 2023	CPT Kickoff
April 4, 2023	HMAC Kickoff
May 2, 2023	Public Kickoff
May 5 and 19, 2023	CPT 2023 Vision and Goals Review
May 30, 2023	HMAC 2023 Vision and Goals Review
June 12, 2023	HMAC Social Equity Subcommittee Kickoff
June 16, 30, and July 7 and 14, 2023	CPT Review of 2018 DP3 Mitigation Strategy
June 21, 2023	Sustainability Open House
June 27, 2023	HMAC Risk Assessment Review
July 17, 2023	HMAC Social Equity Subcommittee Risk Assessment Review and Mitigation Strategy Development
July 20, 2023	HMAC and Stakeholder Mitigation Strategy Workshop
August 11 – September 11	HMAC, MDEM, and Public Review Period
October 2 – November 10, 2023	FEMA Plan Review
November 20, 2023	City Adoption

1.2.4 Plan Integration and Existing Mitigation and Adaptation Efforts

FEMA Planning Policy Element A4: 44 CFR 201.6(b)(3): The plan must describe the review and incorporation of existing plans, studies, reports, and technical information. Communities participating in the NFIP must incorporate regulatory flood mapping products.

Mitigation plan implementation is most effective when mitigation planning efforts are integrated and coordinated with other city, state, and federal programs and initiatives. The 2023 DP3 update planning process aimed to enhance coordination among sectors, as discussed previously, and integrate the DP3 with other City planning efforts such as the Climate Action Plan and Comprehensive Plan. These plans were updated concurrently with the 2023 DP3 update to provide opportunities for individuals to participate in both planning processes. This coordination allowed for the alignment and integration of cohesive planning processes into these keystone plans for Baltimore City.

During the initiation of the plan development process, a review of existing plans, studies, reports, technical information, and other resources was conducted. The plan development team compiled documents to represent a cross-section of the sectors and disciplines that are engaged in mitigation actions. These documents served to provide an opportunity to align City plans, programs, and policies as well as ensure consistency of goals, priorities, and projects across City departments.

Within Baltimore, there are several plans and initiatives that foster DP3 integration and coordination. These programs and initiatives are summarized below. Table 1-6 highlights integration opportunities during the planning process as well as a sampling of plans that were integrated into the risk assessment.

Table 1-6. Opportunities for Plan Integration

Land Use and Planning	
Our Baltimore, Your Baltimore: Updating Baltimore's Comprehensive Plan	The plan discusses Baltimore City's changing population growth, economic strategies and needs, and improvements to historical and cultural resources. There are several pathways for integration, including but not limited to discussions on vulnerable population and population changes prevalent in Baltimore City; major economic players within Baltimore City; improvements to cultural and historic resources, natural resources, and open spaces; and stronger education and enrollment numbers. The Comprehensive Plan Update also discusses mitigation efforts targeting lead contamination, a human-caused, hazardous material.
Zoning Code Amendments (2022)	Among other key aspects, the amendments address flooding hazards by defining the uses that are permissible in a floodway and requiring all others to have a variance and/or conditional use; identifying Site Plan Review requirements for environmentally sensitive areas; and increasing Baltimore City's environmental quality and green infrastructure. These amendments (2022) can provide discussion on zoning code restrictions in the DP3 and identify the regulatory/policy capabilities for Baltimore City.
Sustainability Plan	Provides guidance on how to protect the environment while advancing Baltimore City's economy. The plan focuses on social equity with five key themes: community, human-made systems, climate and resilience, nature in Baltimore City, and economy. The 2019 Sustainability Plan can provide insight into the racial equity of Baltimore City through climate change and sustainability.
Climate Action Plan	Establishes the guidelines and policies aimed at reducing Baltimore City's greenhouse gas emissions (GHG) by incorporating energy savings, assessing best land use practices, and cleaner transportation networks. The plan, once updated, will work in tandem with the Baltimore Sustainability Plan to focus on integrating equity and resilience by identifying at-risk communities and areas of repetitive and severe repetitive loss, which could aid in securing other funding sources.
Emergency Management	

Emergency Operations Plan (EOP)	Establishes policies and guidelines needed to respond to and recover from major incidents and disasters. The EOP discusses Baltimore City's incident management structure, assigns responsibilities, and is designed to ensure an effective emergency response to protect the life, property, and environment of Baltimore City. The EOP provides insight on the operations in the event of an emergency and can assist in identifying lead agencies for mitigation actions. It also discusses various funding opportunities following a disaster event. Other supporting documents mentioned in the EOP can also be integrated into the DP3.
Infrastructure Planning	
Capital Improvement Budget and Plan	The Planning Commission recommends a new six-year Capital Improvement Plan (CIP) each year. There are eight agencies that participate in the process and preparation of the CIP. The Department of Planning works with these participating City agencies to solicit new project requests, prioritize projects for funding, and prepare the 6-year CIP plan. CIP FY24/29 only addresses one natural hazard, flooding. It identifies locations of frequent flooding, critical infrastructure vulnerabilities, and population vulnerabilities. These items can be integrated into the DP3 as potential mitigation actions. Each item also identifies possible funding courses which can assist in the completion of Baltimore City's financial capabilities.
Natural and Cultural Resources	
Green Network Plan	A collective vision aimed at strengthening communities by creating interconnected networks of greenspaces throughout Baltimore City. The vision for the plan is to connect existing parks, water bodies, and natural areas with paths for walkers, joggers, and bicyclists. This plan also supports the goals and strategies of the Baltimore Sustainability Plan, previously mentioned. This plan in its entirety can be incorporated into the DP3 under the topic of equity and vulnerable population.
Fells Point Flood Mitigation Guidelines	Provides information to property owners and tenants to help with assessing their options to minimize flooding impacts on their historic properties. This guide is specific to the Fells Point Neighborhood area. This guide in its entirety can be incorporated into the DP3 update under the topic of hazard mitigation planning and can be used to secure further funding opportunities. In particular, the section on wet/dry floodproofing can be used to create actions within the DP3.
Housing	
Framework for Community Development	Lays out the framework for strategies in investing in the neighborhoods of Baltimore City. The document mainly focuses on vulnerable or financially disadvantaged communities. The strategies included discussing current and future development, partnerships, funding opportunities, and available programs. This document can be incorporated into the DP3 update under the topic of equity and vulnerable populations. More specifically, the document discusses plans for development and redevelopment in underserving communities by incorporating green spaces and property acquisition strategies.
Consolidated Plan FY21/25 and Annual Action Plan FY21	The Consolidation and Annual Action Plan is a federally required document that is submitted every five years by the Baltimore City DHCD. This plan guides community development efforts in Baltimore City. It serves as the application for funding from four federal formula grant programs, such as Community Development Block Grants (CDBG), Home Investment Partnership (HOME), Housing Opportunities for People with AIDS, and Emergency Solutions Grants. Several sections of this plan can be incorporated into the DP3 update under the topic of equity and vulnerable populations. It refers to potential funding sources and identifies areas in Baltimore City for future community development.

Health and Social Services	
Emergency Preparedness and Response: Baltimore City Health Department	This web-based platform for emergency preparedness and response is managed by the Baltimore City Health Department. It provides information on how to manage natural hazards such as extreme temperatures, bioterrorism, pandemics, and many more. This platform is a great resource for the community to prepare for and respond safely to natural hazards that are outlined in the DP3 update.
Food Access: Baltimore City Health Department	This web-based platform outlines many community-based food access and food justice programs available to the citizens of Baltimore. Those programs include, but are not limited to, virtual supermarket program, healthy stores program, food justice forum, and more. This platform is a great resource for the community to receive information and assistance in maintaining and accessing health equity in Baltimore City.
Baltimore City 2017 Neighborhood Health Profile Report: Baltimore City Health Department	Identifies the demographics, socioeconomics, and built environments of Baltimore City. These Neighborhood Profiles bring together data about significant health outcomes for each of the 55 communities within Baltimore City. These Community Statistical Areas (CSA) are clusters of neighborhoods developed by the Baltimore Planning Department. This report can be incorporated in the DP3 and used to identify vulnerable populations within Baltimore City and surrounding areas. It can assist with establishing future mitigation actions.

1.3 Navigating the Plan

This 2023 DP3 update outlines the strategies and actions that will assist Baltimore City with achieving its resiliency goals. Each section includes a 2023 DP3 Updates section that highlights the changes or additions made to the 2018 DP3.

- **Section 1: Introduction—**This section defines hazard mitigation and climate adaptation and provides a summary of changes made to the 2018 DP3. It includes an overview of the federal requirements for hazard mitigation planning and provides details on the planning process, including project milestones, stakeholder and community engagement, and outreach to socially vulnerable and underserved communities.
- **Section 2: City Profile—**This section includes an overview of Baltimore City's history and governance and descriptions of Baltimore City's physical setting and assets, community composition, land use and development, and cultural and natural resources.
- **Section 3: Risk Assessment—**This section identifies and defines natural and human-caused hazards for Baltimore City and details the methodology used to assess each hazard. The identified hazards are examined in individual sections. Finally, this section addresses why Baltimore City is at risk and where the greatest risks are located.
- **Section 4 – 12: Hazard Profiles—**Each hazard section includes a description of the hazard, location, extent, previous occurrences and losses, and probability of future events. The hazard sections also include climate change projections and impacts to address adaptation needs for Baltimore City. Building upon the hazard identification process, each hazard section includes a risk and vulnerability assessment; potential losses; and estimations of potential injuries, property damage, economic loss, disruption of critical services, and cascading and compounding impacts. The hazard

sections address future changes that may impact vulnerability, such as climate change, land use and development, and changes in the population.

- **Section 13: Capability Assessment—**This section addresses Baltimore City's risk and capability framework. It assesses the tools and resources Baltimore City has in place to reduce and eliminate risk. The capability assessment serves to inform the development of the mitigation strategy.
- **Section 14: Mitigation Strategy—**This section establishes the vision and goals of the 2023 DP3. This section also examines best management practices, focusing on the risks specified in previous sections. This section provides key strategies and actions for the four City sectors (infrastructure, buildings, natural systems, and public services), identifies implementation strategies, and outlines actions based on the information in this 2023 DP3 update. This section also identifies leading agencies, stakeholders, timelines, policy mechanisms, and financing options for each action listed in this plan.
- **Section 15: Plan Implementation and Maintenance—**This section addresses how Baltimore City can ensure the 2023 DP3 remains current. Key topics include annual reviews, stakeholder outreach, public participation, and more.
- **Section 16: Moving Forward—**This section identifies high-level recommendations designed to foster the continuation of equitable engagement and strengthen Baltimore City's community resilience. This section also includes a summary of concurrent efforts underway in the BoS.
- **Glossary—**The glossary includes key terms and definitions.
- **Appendix A: Engagement Strategy—**This appendix contains the engagement strategy developed to guide outreach and engagement throughout the planning process. The appendix details the goals, meetings, and participants involved in the development of the 2023 DP3 update. Additionally, this appendix contains examples of outreach materials, such as social media graphics, messaging, and flyers used throughout the development of the 2023 DP3 update.
- **Appendix B: Meeting Documentation—**This appendix contains documentation of meetings, which includes meeting participants, meeting notes, and presentation materials.
- **Appendix C: Socially Vulnerable Population Exposure to Hazards—**This appendix contains tables with a breakdown of exposure for identified socially vulnerable populations for specific hazards, which have a spatial extent.

Section 2. City Profile

Understanding the history and physical setting of a community informs the potential for risk. Discussion of Baltimore City's history and governance provides details on how the State of Maryland (the State) has approached hazard mitigation and risk reduction. Risk occurs when hazards impact people, a community's assets, such as buildings, the environment, and economy. The following sections provide an overview of Baltimore City's history, government, physical setting, community composition, land use and development, housing, and physical assets. Baltimore City Profile informs the Risk Assessment (Section 3) to assess the economic, structural, and population assets at risk and the concerns that may be present related to the hazards analyzed. Vulnerability, and therefore risk, may be increased or decreased based on land use, governance, and allocation of resources.

2.1 History

Officially founded in 1729, Baltimore is the most populous city in Maryland and home to one of the largest ports on the East Coast of the United States. Baltimore City's history provides insight into how the susceptibility of Baltimore City to hazards has evolved and why present-day vulnerabilities exist. The *History of Baltimore City*, published by DOP, provides a detailed description of the history of Baltimore City.

Early development focused on the inner basin of the Patapsco River (now the Inner Harbor) and was relatively slow, with only 25 buildings constructed by 1752. Development gained momentum when people decided to use the harbor to ship goods to Ireland; roads, houses, warehouses, mills, and wharves were developed along waterways and reached throughout the surrounding areas and into southern Pennsylvania. This signaled the beginning of the industrialization of Baltimore City. Future public works projects would include the straightening of the Jones Falls in 1797. (DOP n.d.)

As Baltimore City continued to grow, development along the waterfront and rivers followed leading to the present-day flooding susceptibility of Baltimore City's waterfront residential, commercial, and industrial areas. In the early 1800s the northern shoreline of the Inner Harbor was extended two blocks south filling open water to create new land (DOP n.d.). This historical pattern of development focused on access and dependency on the waterfront has increased the susceptibility of Baltimore City to sea level rise.

When tracks for the nation's first railroad were laid in 1829, the thriving port city increased both its accessibility to other cities and its attractiveness to migrants and investors. Baltimore's Inner Harbor was once the second leading port-of-entry for migrants to the United States and was considered to be a major manufacturing center. By 1830, Baltimore was the second largest city in the United States.

After a decline in population and manufacturing industries in the 1970s and 1980s, Baltimore shifted to a service sector-oriented economy. While the Port of Baltimore and the waterfront remain a significant economic engine for Baltimore City and the region, Baltimore City's present-day leading industries are financial and professional services, health and bioscience technology, culture and tourism, information and creative services, logistics, and advanced manufacturing. Baltimore's economy has diversified and now supports eight business and industrial parks, two biotechnology parks, and over 20 business incubators and makerspaces. Major businesses include Exelon, Legg Mason, Morgan Stanley, Pandora Americas, and Under Armour. (Maryland Department of Commerce 2023)

While the economic history of Baltimore City provides invaluable insight into how and why hazards impact Baltimore City today, the social history also is important. In the 1930s, racially discriminatory policies and practices in Baltimore City were evident and continue to shape inequities and disparities in communities of color today (Huang and Sehgal 2022). This is most prevalent through the practice of redlining. The term refers to the practice of mortgage lenders drawing red lines around portions of a map to indicate areas or neighborhoods in which they do not want to make loans. In Baltimore City, redlining was done on the basis of prohibiting African Americans from securing loans to purchase property in predominately White neighborhoods that were categorized as “best” and “still desirable.” This practice led to segregation, with most African American neighborhoods being categorized as “hazardous” and mortgage lenders not providing loans in these areas. This would lead to reduced homeownership, property values, and credit scores that continue to impact these communities today. Particularly for Black residents of redlined neighborhoods, redlining compounded barriers and increased the challenge of social and economic well-being. (Huang and Sehgal 2022)

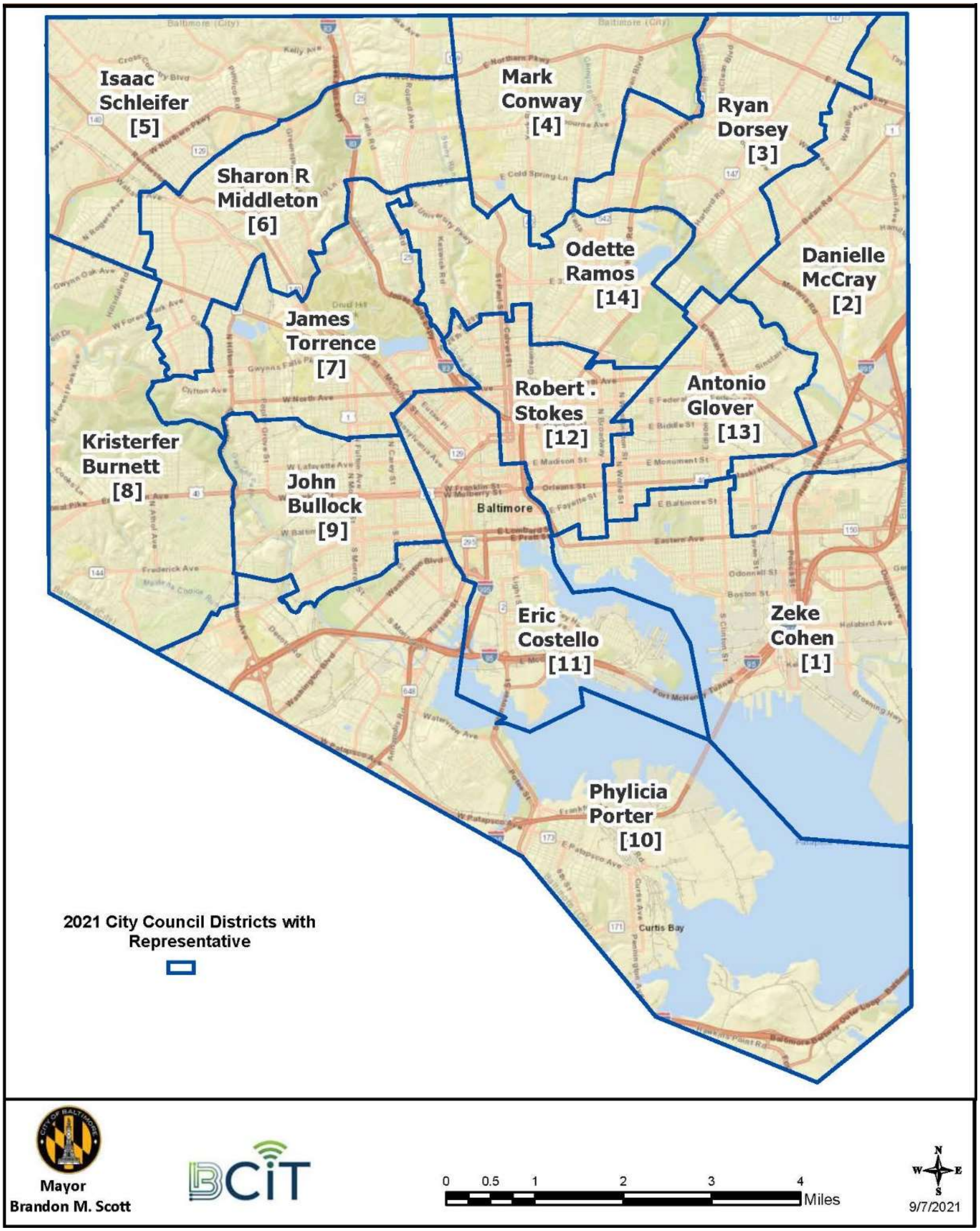
The effects of historic redlining and other discriminatory practices are still seen today. In 2000, there were 31 predominately Black middle class census tracts in Baltimore. By 2017, there were only 16. In these neighborhoods, Baltimore’s legacy of covenants, real estate segregation and federal redlining policies have led to disinvestment rather than gentrification. (DOP 2020)

Vulnerability may be increased or decreased based on land use, governance, and allocation and use of resources. Industrialization has contributed to brownfields, development in hazard-prone areas, and concerns for air and water quality. Historic segregation and discrimination have contributed to inequities in resource distribution, food desserts, and concentrations of failing infrastructure.

2.2 Government

Baltimore was designated as an independent city by the Constitution of Maryland in 1851. Baltimore City’s government structure consists of an elected Mayor and elected members of Baltimore City Council. The Mayor serves as the chief executive, and Baltimore City Council serves as the legislative body. The Mayor is in charge of enforcing City laws and has the power to approve and veto ordinances, resolutions, and bills that are passed by Baltimore City Council. Baltimore City Council is the legislative body that has the authority to enact all ordinances and resolutions. The council members are elected from 14 districts, with the President elected at-large by all of the voters of Baltimore City. The 15 Council members, along with the Mayor, act by ordinance, resolution, or motion (Baltimore City Council n.d.). Figure 2-1 depicts the 14 City Council districts within Baltimore City.

Figure 2-1. City of Baltimore Council Districts



Source: Baltimore City Council 2021

In addition, Baltimore City has numerous commissions and departments that contribute to the governance of Baltimore City with specific regard to hazard mitigation. The Baltimore Office of Sustainability (BoS), within the Department of Planning, oversees the development, implementation, and maintenance of the Disaster Preparedness and Planning Project (DP3). BoS focuses on integrating the principles of environmental integrity, social equity, and economic prosperity into plans, practices, policies, and partnerships in an innovative way. The Baltimore Office of Emergency Management (OEM) is in charge of maintaining the highest possible level of preparedness in order to protect Baltimore City's residents, workers, visitors, and environment. OEM ensures that Baltimore City is prepared for emergencies and is in charge of coordinating emergency response and recovery (OEM 2023). The responsibility for implementing mitigation actions is carried out by multiple departments and commissions throughout Baltimore City; therefore, the need for strong interagency collaboration is required to successfully reduce risk in Baltimore City.

2.3 Physical Setting

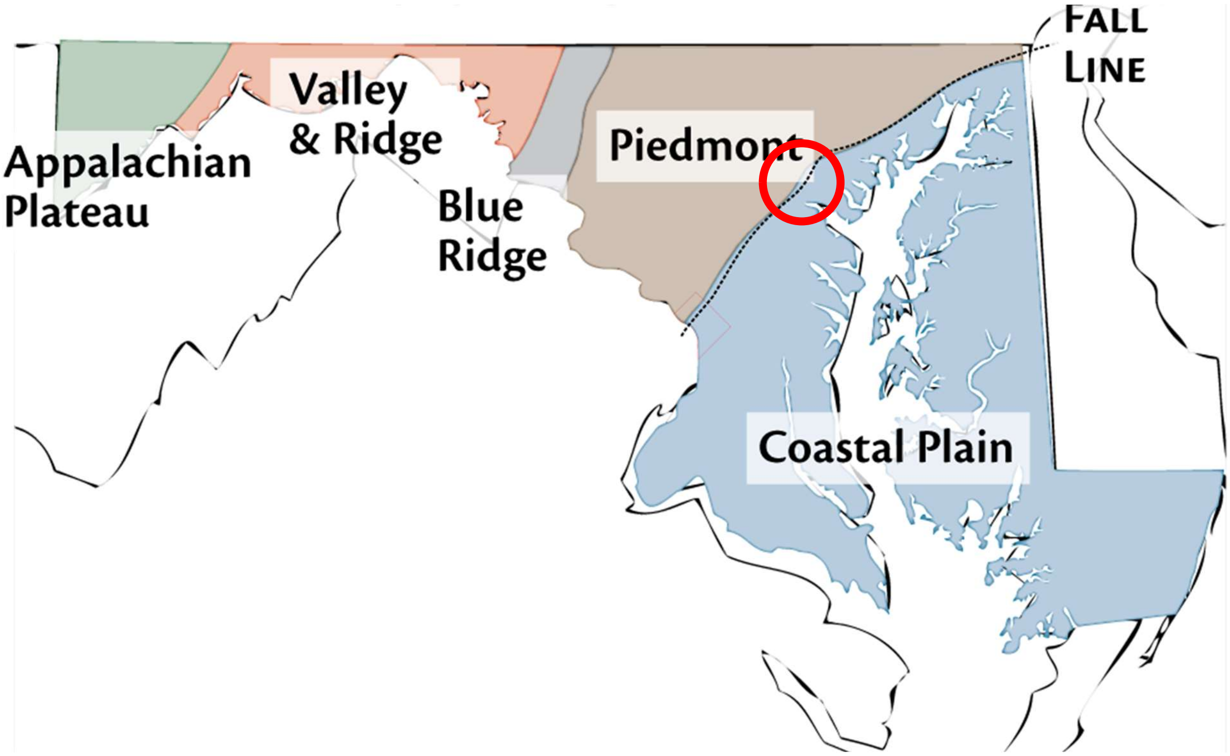
Baltimore City is located in north-central Maryland at the head of the Patapsco River, which is a part of the Chesapeake Bay. Baltimore City is approximately 92.1 square miles (81 square miles of land and 11.1 square miles of water) and is bordered to the north, east, and west by Baltimore County and to the south by Anne Arundel County.

2.3.1 Geography and Topography

Baltimore City is located on the eastern seaboard in the Mid-Atlantic region. Baltimore City's 81 square miles of land comprise the most heavily developed area in Maryland. Baltimore City's elevation ranges from sea level near the Inner Harbor to nearly 480 feet toward the northwestern corner of Baltimore City. The location of Baltimore City is also a crucial stopover habitat for millions of migrating birds that contribute to the biodiversity of Baltimore City.

Baltimore City is a part of two physiographic provinces. The northwestern area of Baltimore City is a part of the Piedmont Plateau Province, and the southeastern area of Baltimore City is a part of the Atlantic Coastal Plain Province. The Piedmont Plateau Province consists of crystalline metamorphic and igneous rocks and is made up of a variety of mineral resources. Building stone, slate, gold, iron ore, and sulfides used to be mined in this area, and there is a moderate supply of ground water available throughout the region. The Atlantic Coastal Plain Province has rocks that are overlapped with gravel, sand, silt, and clay, which tend to be used by the construction industry. This province also has a significant supply of ground water available throughout the region (Maryland Geological Survey 2023). Figure 2-2 shows Maryland's physiographic regions and depicts Baltimore City's location with a red circle.

Figure 2-2. Physiographic Regions of Maryland



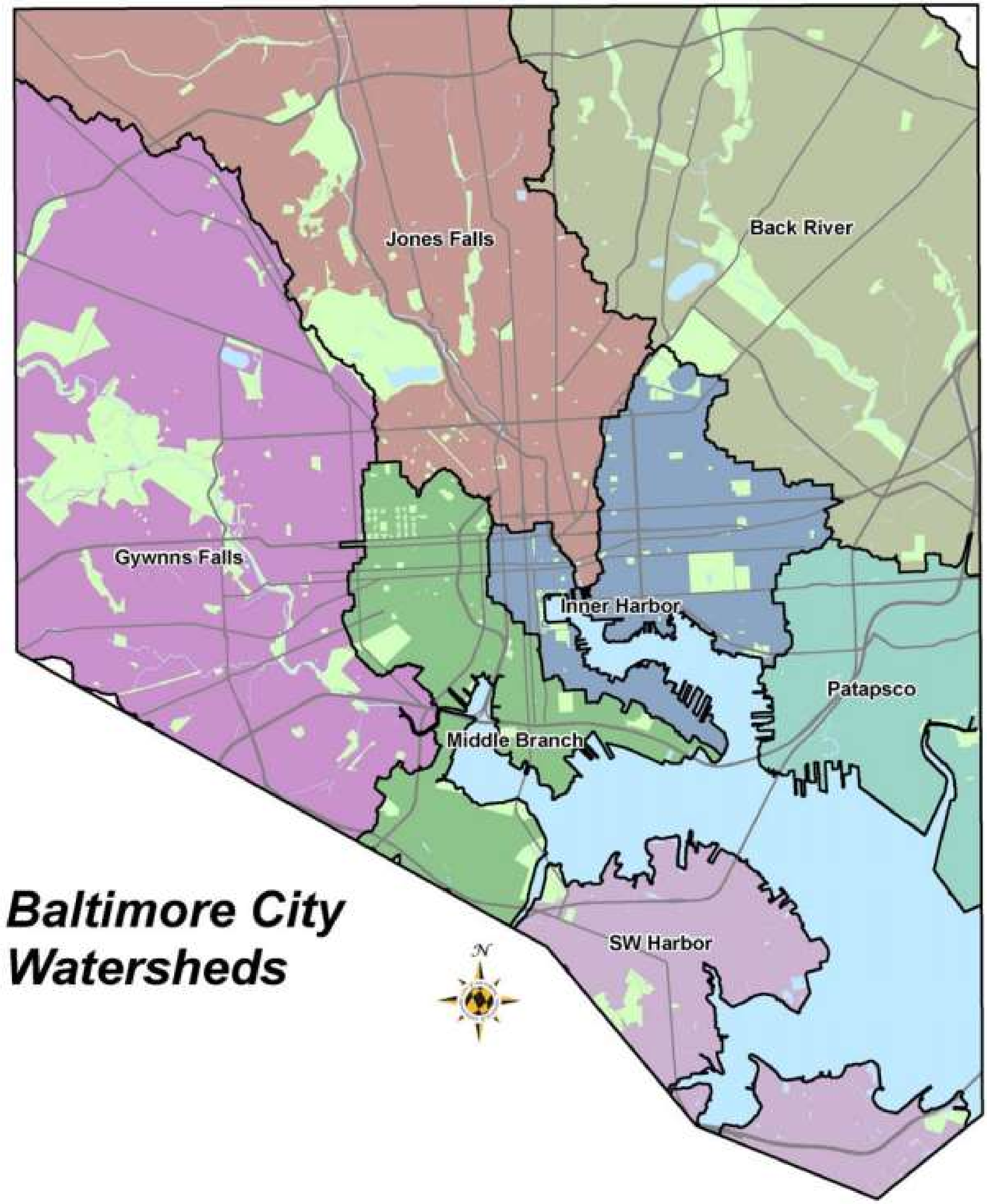
Source: University of Maryland 2008
Note: The red circle shows the approximate location of Baltimore City.

2.3.2 Hydrography and Hydrology

Baltimore City features 60 miles of waterfront within five local watersheds: Baltimore Harbor (includes the Inner Harbor, Middle Branch and SW Harbor), Gwynns Falls, Jones Falls, Back River, and the Lower North Branch of the Patapsco River (Baltimore Public Works n.d.). Situated within the greater Chesapeake Bay Watershed, Baltimore surrounds a natural harbor near the mouth of the Patapsco River. Figure 2-3 depicts the watershed located throughout Baltimore City boundaries.

The Baltimore Harbor watershed is located in the southeastern part of Baltimore City and includes Bear Creek, Old Road Bay, Shallow Creek, and small Chesapeake Bay tributaries. The land is highly developed and built out by residential and commercial waterfront communities. The Gwynns Falls watershed encompasses the western and southwestern parts of Baltimore City and contains 133 miles of streams and drains to the Middle Branch of the Patapsco River; nearly 75 percent of the watershed is classified as urban with a population of over 350,000 (Baltimore County Government 2023). The Jones Falls watershed encompasses the northwestern areas of Baltimore City and is roughly 40 square miles with tributaries that extend through Baltimore City until emerging from a tunnel into the Inner Harbor. Back River Watershed encompasses the northeastern parts of Baltimore City and has 73 miles of streams, including Herring Run, Red House Run, and Stemmers Run. The Lower North Branch of the Patapsco River watershed dips into the southwestern part of Baltimore City, and its tidal area is composed of the Northwest Harbor and Middle Branch, which is crossed by the Baltimore Harbor (Baltimore County Government 2023).

Figure 2-3. Baltimore City Watershed Map

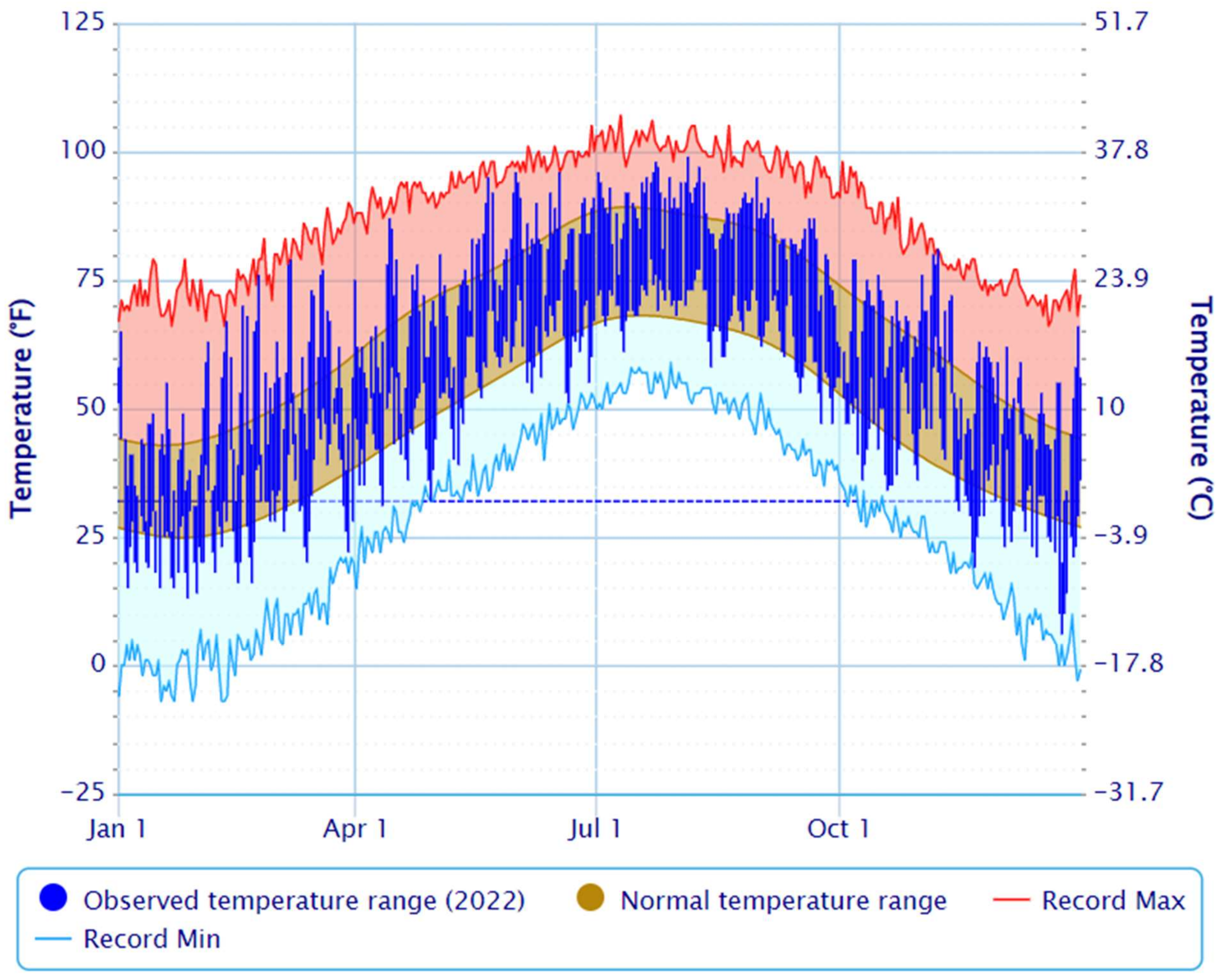


Source: Baltimore City Planning Department 2009

2.3.3 Climate

Baltimore City is located within the northern temperate climate zone, which means Baltimore City experiences changing seasons with moderate winters and summers (NOAA n.d.). Baltimore experiences summers with high humidity and heat exacerbated by the urban island heat effect. The overall average temperature in Baltimore is 56°F. Winter temperatures average 36.5°F, and summer temperatures average 76°F (NOAA 2023). Figure 2-4 details daily temperatures experienced by Baltimore residents in 2022.

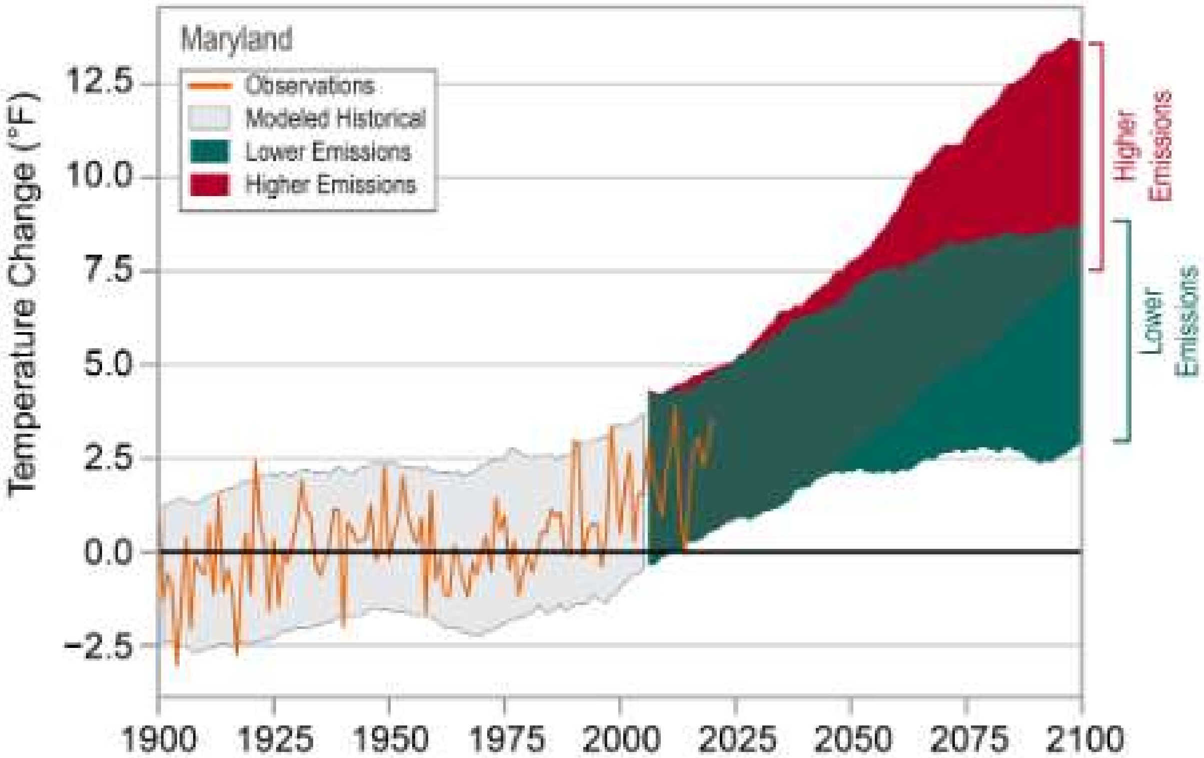
Figure 2-4. Daily Temperature Data for Baltimore (2022)



Source: NOAA 2023

Since the beginning of the 20th century, Maryland's average temperature has risen by approximately 2.5°F and is projected to continue rising (UMD Extension n.d.). 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. Figure 2-5 depicts the observed and projected temperature changes in Baltimore City from preindustrial temperatures.

Figure 2-5. Observed and Projected Temperature Change in Baltimore City

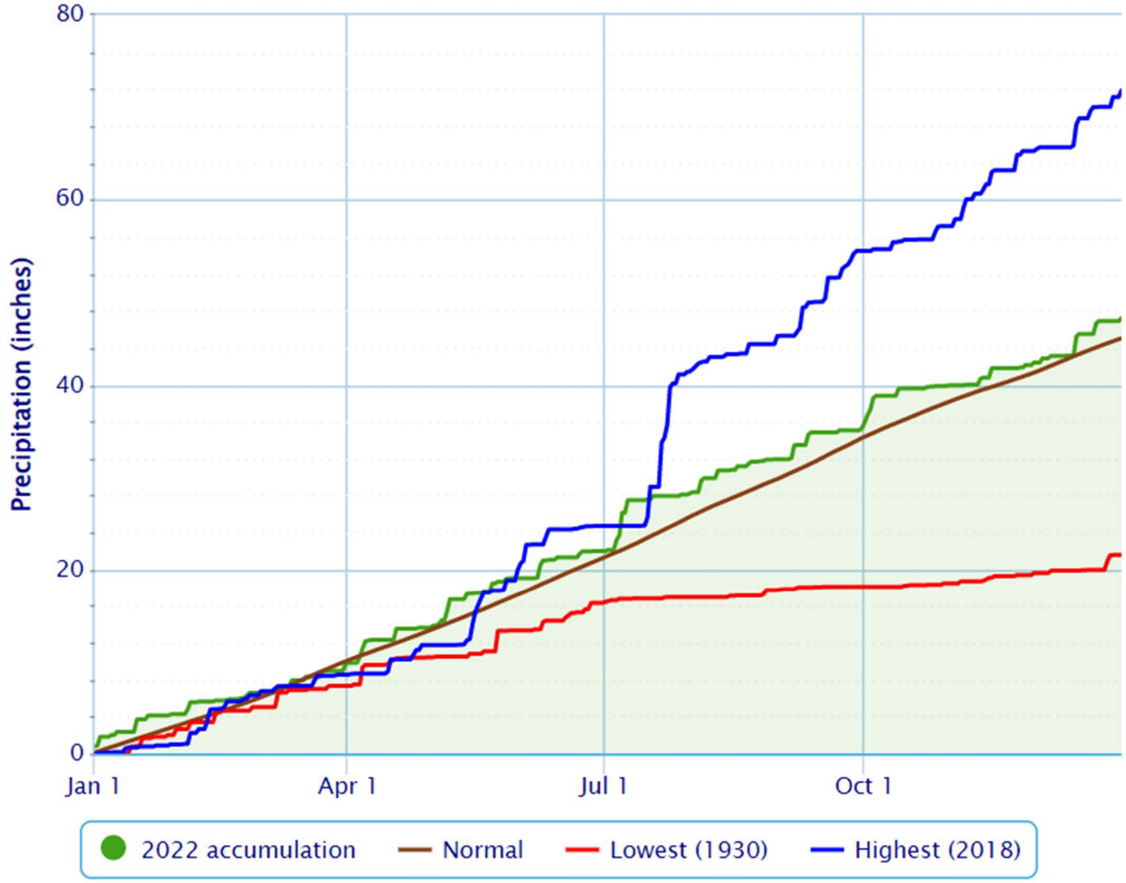


Source: NOAA 2022

Average annual precipitation in Baltimore City is 45 inches, with the highest precipitation in summer, at 12.55 inches (NCEI 2023). This averages to be about 3–4 inches of precipitation per month. In Maryland, annual precipitation is projected to continuously increase due to climate change over this century, accompanied with an increase in frequency and intensity of precipitation events (NCEI 2022). Annual precipitation for 2022 is shown in Figure 2-6 in comparison with Baltimore City's highest and lowest annual precipitation events. Table 2-1 shows the annual precipitation in Baltimore City from 2000 to 2022.

A changing climate is now affecting many of the natural hazards that influence daily life, causing these events to become more extreme over time (NCEI 2022). Simultaneously, new hazards are emerging, which will introduce additional planning challenges for public safety and policymakers, including sea level rise and urban island heat effect. Urban island heat effect makes cities hotter overall due to the lack of environmental amenities, which can range from trees to parks and other vegetation, and the presence of building materials or the lack of impervious surfaces that absorb sunlight. Sea level rise affects all coastal areas and those that are located near major waterways. Impacts associated with climate change may still be reduced or prevented by reducing greenhouse gas (GHG) emissions. Baltimore's *Climate Action Plan* (CAP) is Baltimore 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 climate mitigation initiatives continue to be essential to reducing the emission of greenhouse gases and addressing the warming effects, it will take time for the planet to respond to GHG reductions. Figure 2-7 depicts different sea level rise projections based on current observations.

Figure 2-6. Baltimore Area Accumulated Precipitation for 2022



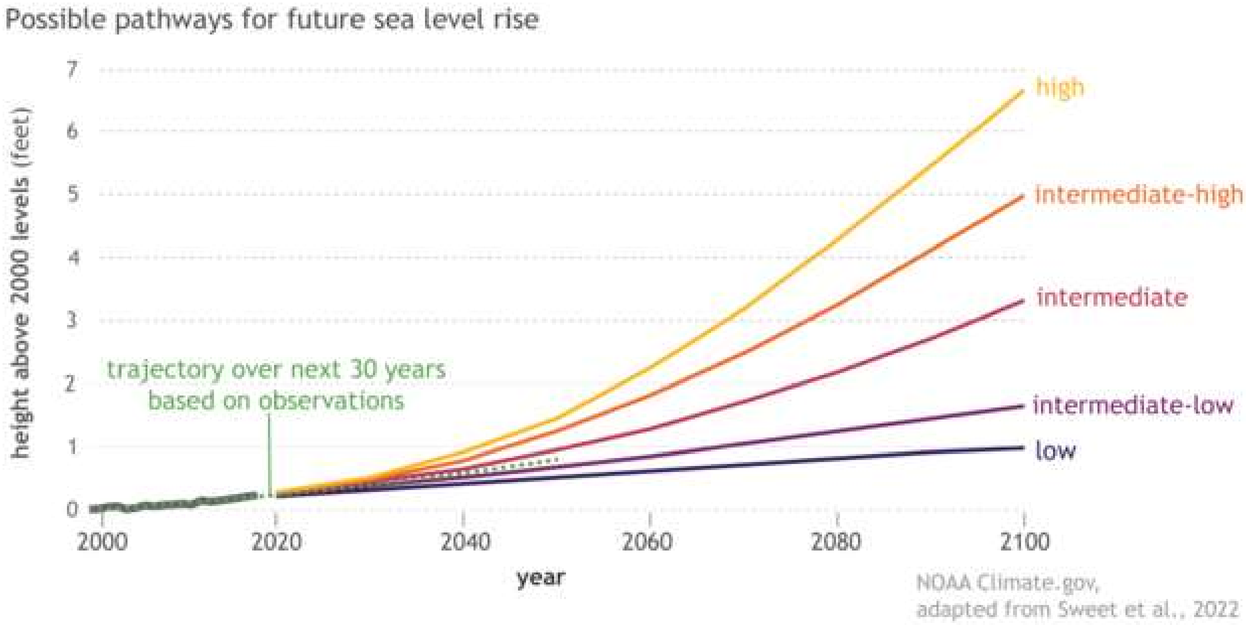
Source: NOAA 2023

Table 2-1. Annual Precipitation in Baltimore City (2000-2022)

Year	Inches of Precipitation	Year	Inches of Precipitation
2000	41.91	2012	37.42
2001	34.57	2013	42.93
2002	39.60	2014	52.58
2003	62.66	2015	51.16
2004	45.67	2016	40.52
2005	49.13	2017	38.28
2006	43.24	2018	71.82
2007	34.97	2019	38.13
2008	44.97	2020	57.38
2009	55.57	2021	40.79
2010	43.47	2022	47.18
2011	56.52		

Source: NOAA 2023

Figure 2-7. Sea Level Rise Projections



Source: NOAA 2022

2.4 Community Composition

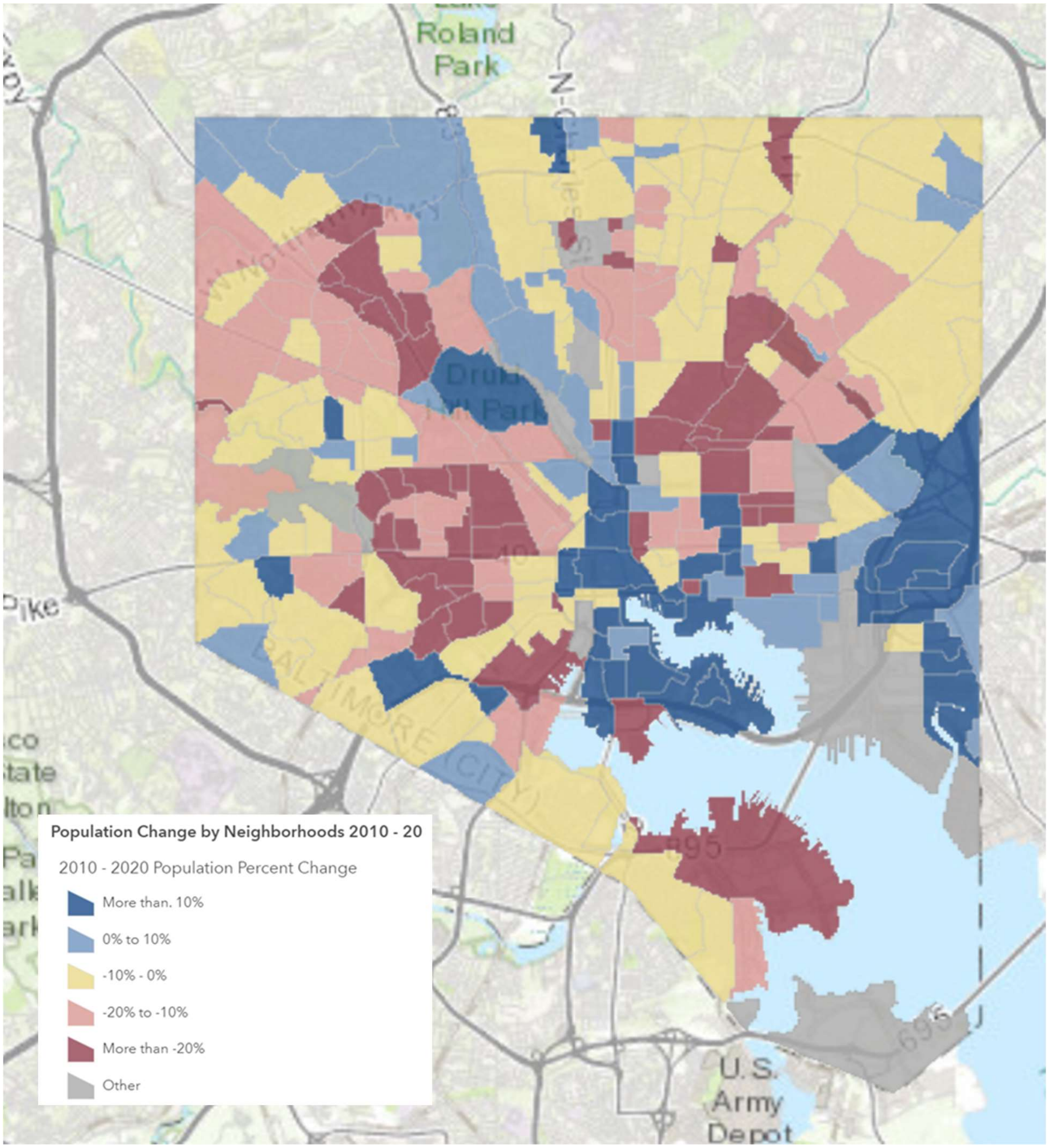
Population trends can provide a basis for making decisions on the type of mitigation approaches to consider and the locations in which these approaches should be applied. This information can also be used to support planning decisions regarding future development in vulnerable areas. Evaluating development trends and population and demographic changes provides insight into how vulnerability may evolve over time.

2.4.1 Population

Baltimore is the most populous city in Maryland (U.S. Census 2022). The 5-year estimates from the American Community Survey (ACS) show Baltimore City's population to be 591,489, a decrease from the 2010 Census population of 620,961 people (ACS 2021). The ACS provides the most current information (conducted monthly and annually) and is based on a sampling whereas the Census is conducted every ten years. City Council District 11 is projected to have the highest population in Baltimore City, with just over 48,000 people within the district. Table 2-2 depicts the population values by district and Census data.

Population trends can provide a basis for making decisions on the type of mitigation approaches to consider and the locations in which these approaches should be applied. This information can also be used to support planning decisions regarding future development in vulnerable areas. Figure 2-8 shows the population percentage change experienced by different areas of Baltimore City.

Figure 2-8. Population Change in Baltimore City from 2010–2020



Source: Baltimore Department of Planning 2022

Table 2-2. Population by City Council Districts

City Council District	2016–2021 ACS 5-Year Estimates	Percent of City Total
1	43,739	7.4%
2	45,252	7.7%
3	42,257	7.1%
4	45,027	7.6%
5	43,601	7.4%
6	41,604	7.0%
7	39,638	6.7%
8	46,396	7.8%
9	35,869	6.1%
10	41,521	7.0%
11	48,022	8.1%
12	37,130	6.3%
13	38,768	6.6%
14	42,665	7.2%
Baltimore City Total	**591,489**	**100.0%**

Source: U.S. Census 2023

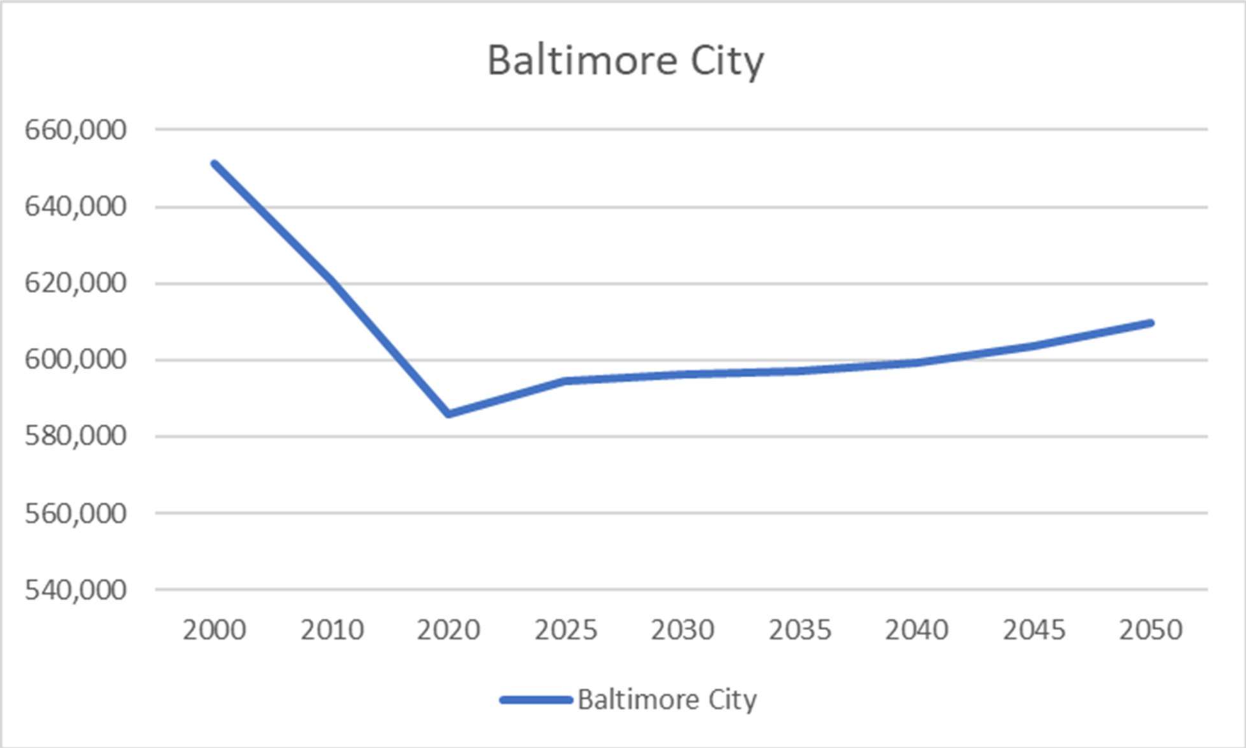
According to the Maryland Department of Planning, Baltimore City is projected to experience a growth in population in the upcoming years despite seeing a decline in population from 2000 to 2020. This trend is expected to follow suit with Baltimore County as well as the Baltimore metropolitan region, as shown in Table 2-3. As a state, Maryland is also expected to see continuous growth from 2020 through 2050. This means that there will be more people at risk from the hazards of concern present in Baltimore City, County, Region, and State. As hazards continue to increase in frequency and intensity due to climate change, these areas will continue to become more vulnerable to natural hazards, making it crucial for these areas to have updated evacuation plans, alert systems, backup power for critical facilities as well as the capacity to protect the increasing population from these hazards. Figure 2-9 shows the trend line of Baltimore City's population growth.

Table 2-3. Baltimore Area Population Projections

Area	2000	2010	2020	2030	2040	2050
Baltimore City	651,154	620,961	585,708	596,390	599,220	609,780
Baltimore County	754,292	805,029	854,535	876,730	909,000	934,520
Baltimore Region	2,512,431	2,662,691	2,794,636	2,940,280	3,056,810	3,150,530
Maryland	5,296,486	5,773,552	6,177,224	6,576,840	6,909,050	7,183,020

Source: Maryland Department of Planning 2022

Figure 2-9. Baltimore City Population Projections



Source: Maryland Department of Planning 2022

Baltimore City's population density is 7,235.8 people per square mile compared to the national average of 93.8 people per square mile (US Census Bureau 2022). High-density areas pose a greater risk because a larger number of people and structures are concentrated in one area. There is the possibility for diseases to spread quicker in these areas, and structural damage is expected during certain hazard events because of the proximity of buildings. It is likely that the magnitude of an emergency or disaster will increase in more populous areas. However, having a higher concentration of people in the same area will provide an opportunity to quickly disseminate information. Additional focus should be provided for evacuating and sheltering larger populations during emergencies and disasters (Population Reference Bureau 2011).

2.4.2 Demographics

Baltimore City is very diverse in terms of characteristics of the population; approximately 8.1 percent of individuals in Baltimore City are estimated to be foreign born (U.S. Census 2023). DOP maintains a dashboard detailing demographics of foreign-born individuals in Baltimore City that may be accessed at the Baltimore City Foreign Born Demographics Dashboard.

In terms of race, Baltimore City has a large Black or African American community, with nearly 61.6 percent of people in Baltimore City being Black or African American. Approximately 5.6 percent of Baltimore City's population is of Hispanic or Latino origin. Table 2-4 provides a breakdown of race and Table 2-5 provides a breakdown of Hispanic or Latino origin.

Table 2-4. Racial Diversity for Baltimore City

Race	2016–2021 ACS 5-Year Estimates	Percent of City Total
White	173,079	29.2
Black or African American	364,879	61.6
American Indian and Alaska Native	1,706	0.3
Asian	14,887	2.5
Native Hawaiian and Other Pacific Islander	131	0.0
Other Race	14,438	2.4
Two or more races	23,091	4.0

Source: U.S. Census 2023

Table 2-5. Hispanic or Latino Origin for Baltimore City

Hispanic or Latino	2016–2021 ACS 5-Year Estimates	Percent of City Total
Not Hispanic or Latino	558,965	94.4
Hispanic or Latino	33,246	5.6

Source: U.S. Census 2023

According to the Census, while there was an overall shrinking population from 2010 to 2020, the age 65 and over population grew from 72,603 people in 2010 to 83,527 people in 2021. In conjunction, the median age went from 34.5 years in 2010 to 35.7 years in 2021. Most of the other demographic categories decreased from 2010 to 2020. This means that the overall population is decreasing, and the general population of Baltimore City is getting older, making the population more vulnerable to hazards due to the known barriers older adults may face such as limited mobility. See Section 2.4.3 for more information on socially vulnerable populations. Table 2-6 breaks down Baltimore City's population demographics.

Table 2-6. Population Demographics for Baltimore City

Demographics	2010	2016–2021 ACS 5-Year Estimates
Male	291,392	278,792
Female	329,146	313,419
Median Age (years)	34.5	35.7
Under 5	40,956	36,468
18 Years and Over	481,538	470,655
65 Years and Over	72,603	83,527

Source: U.S. Census 2023 and 2010

The 2020 Census indicates that median household income in Baltimore City was $54,124, with the per capita income being $34,378. Approximately 115,625 people or 19.6 percent were identified as living below the national poverty level. The Census Bureau identifies households with two adults and two children with an annual household income below $27,479 per year as living in poverty (U.S. Census 2021).

2.4.3 Vulnerable Populations and Underserved Communities

The ability of an individual or community to withstand and quickly recover from hazards and threats is critical to building City-wide community resilience. The same disaster or emergency can impact different populations in different ways. For example, differences in age, income, disabilities, and English proficiency affect people's ability to cope with the effects of disasters. Individuals may also face compounding barriers because they may fall within multiple categories of vulnerability.

Key Terms

- Socially Vulnerable Populations—Populations or groups who have access and functional needs, including but not limited to people without vehicles, people with disabilities, older adults, and people with limited English proficiency (Centers for Disease Control and Prevention n.d.).
- Underserved Communities—Populations and geographic communities sharing characteristics that have been systematically denied a full opportunity to participate in aspects of economic, social, or civic life (U.S. President. Executive Order 13985 2021).
- Underrepresented Communities—Populations or groups lacking historical or current representation in decision-making or aspects of economic, social, or civic life. This includes individuals that may not have been captured by the Census.
- Historically Marginalized Communities—Groups and communities that experience discrimination and exclusion (social, political, and economic) because of unequal power relationships across economic, political, social, and cultural dimensions (National Collaborating Centre for Determinants of Health n.d.).

Identifying concentrations of socially vulnerable and underserved populations can assist communities in targeting preparedness and mitigation actions. Often, populations and communities are categorized based on shared characteristics that create additional barriers to accessing resources leading to increased vulnerability.

Baltimore City will need to ensure that considerations for socially vulnerable populations and underserved communities are included in the decision-making process when identifying projects to mitigate risk and build community resilience.

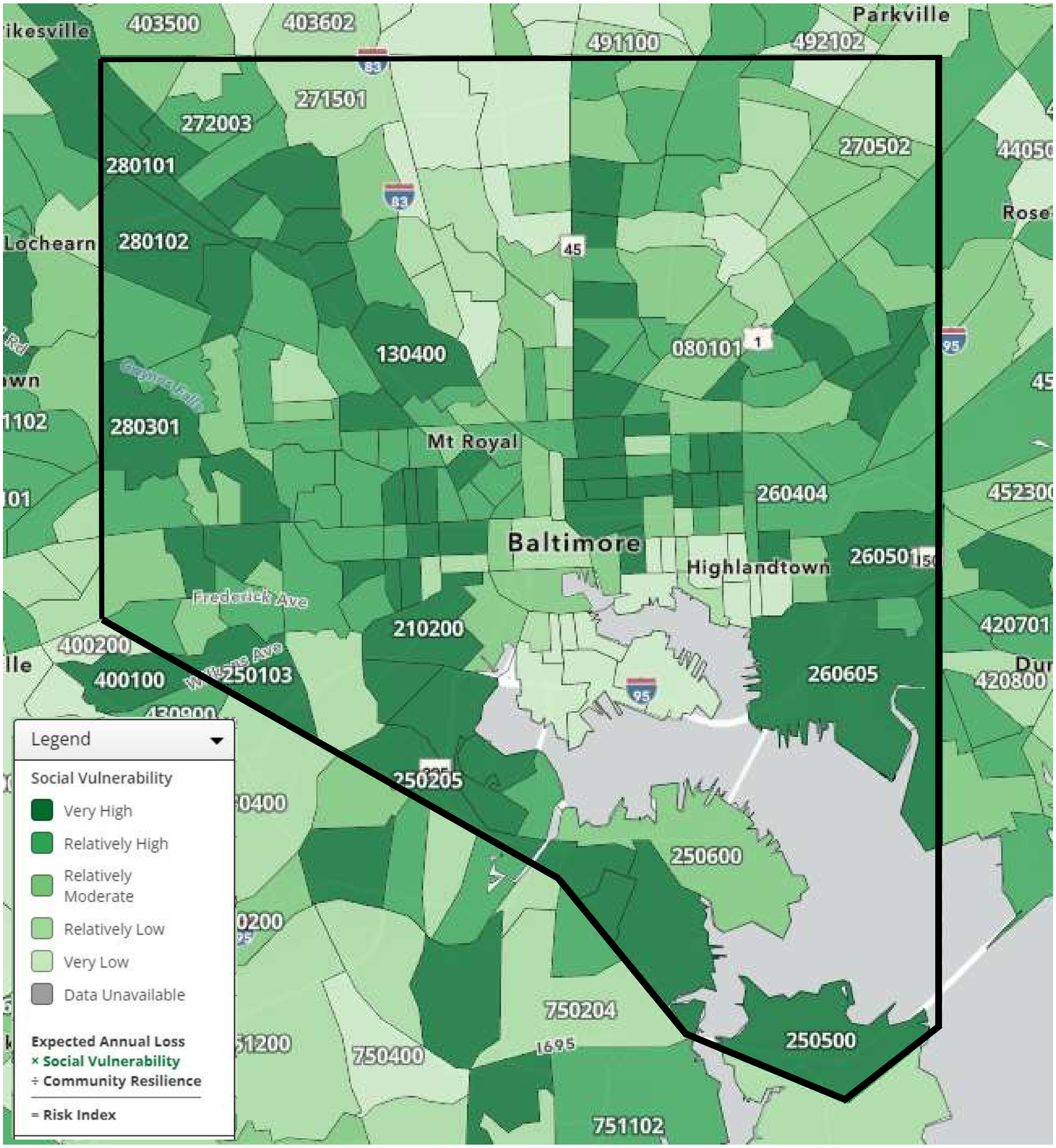
Data Sources

For this plan, information collected through the National Risk Index (NRI), CDC/ATSDR SVI, U.S. Census Bureau, ACS, and other sources is used to provide data on vulnerable populations and barriers contributing to social vulnerability. It is important to note that there are multiple resources available to assess social vulnerability and more specific barriers and challenges.

National Risk Index

The NRI is a resource made available by FEMA to provide data to communities for 18 natural hazards. The NRI defines risk as the potential for negative impacts as a result of a natural hazard. The tool incorporates expected annual loss from natural hazards, social vulnerability, and community resilience. Within the NRI tool, a social vulnerability score and rating represents the relative level of a community's social vulnerability compared to all other communities at the same level; the score is measures on a national percentile starting at 0 and increasing to 100 with 100 being the highest (FEMA n.d.). Baltimore City's overall NRI social vulnerability is 86.82, meaning social vulnerability in Baltimore City is greater than 86.82 percent of all U.S. communities. A score is also calculated for each census tract. Figure 2-10 depicts the social vulnerability score for census tracts in Baltimore City; the north-central area and areas surrounding the Patapsco River have a lower score while all other areas have higher rates of social vulnerability.

Figure 2-10. NRI Social Vulnerability Score for Census Tracts in Baltimore City

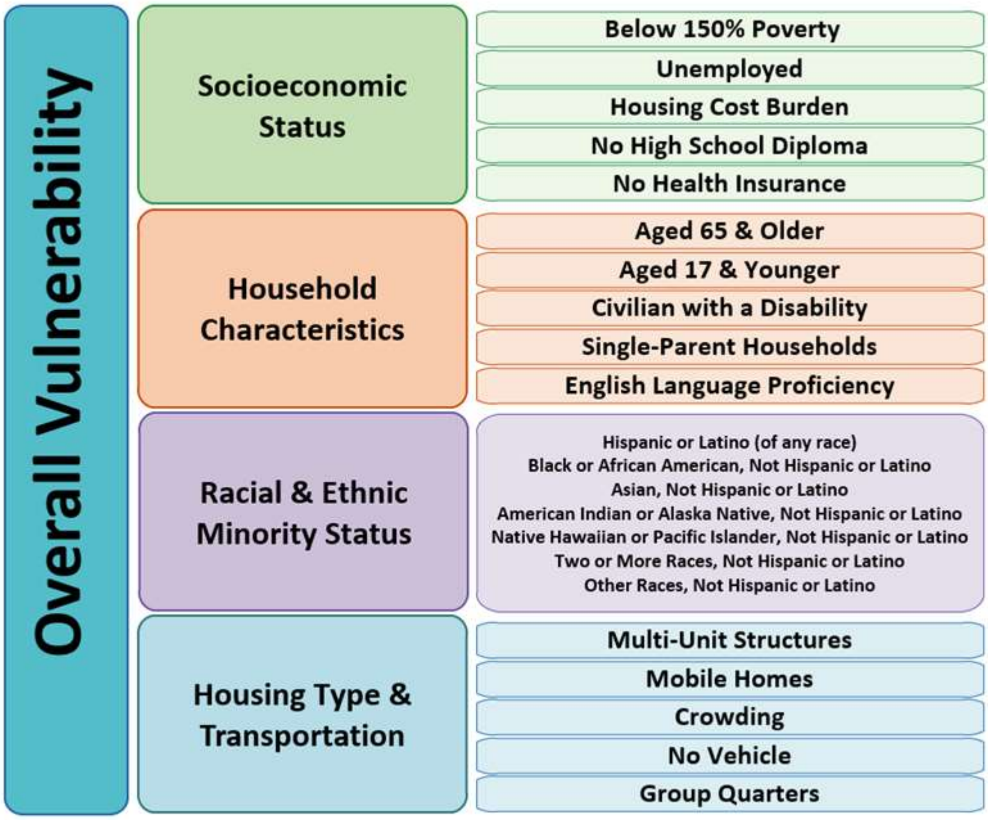


Source: FEMA 2023

Centers for Disease Control and Prevention/Agency for Toxic Substances and Disease Registry Social Vulnerability Index

The CDC/ATSDR SVI is a combination of 16 different social factors that contribute to social vulnerability as shown in Figure 2-11. These social factors are grouped together in four themes to provide an indication of social vulnerability concerning socioeconomic status, household characteristics, racial and ethnic minority status, and housing type and transportation. By combining all factors, a vulnerability index is established. The rankings are based on a percentile ranging from 0 to 1, with higher values indicating greater vulnerability.

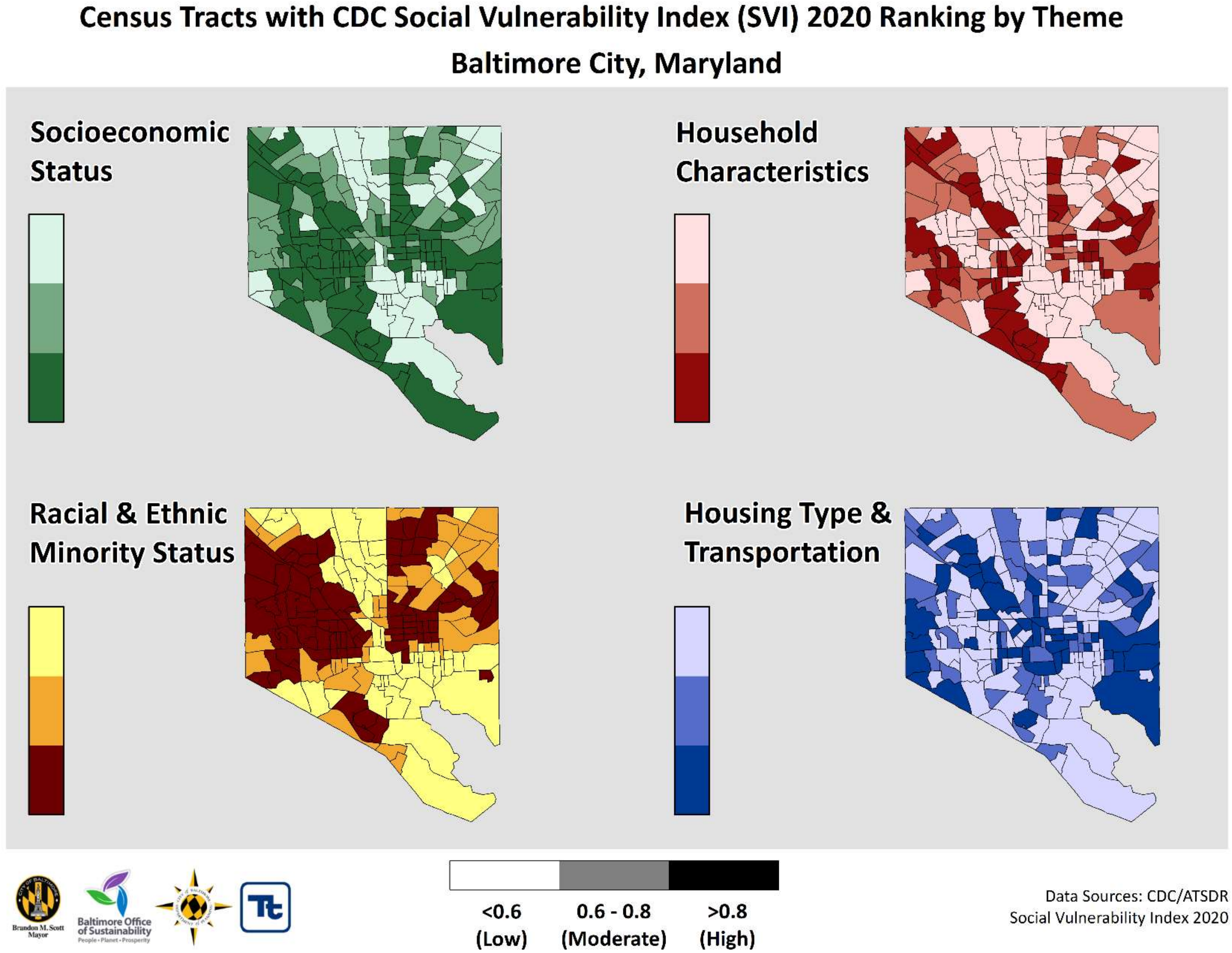
Figure 2-11. CDC/ATSDR SVI Social Factors



Source: CDC/ATSDR 2020

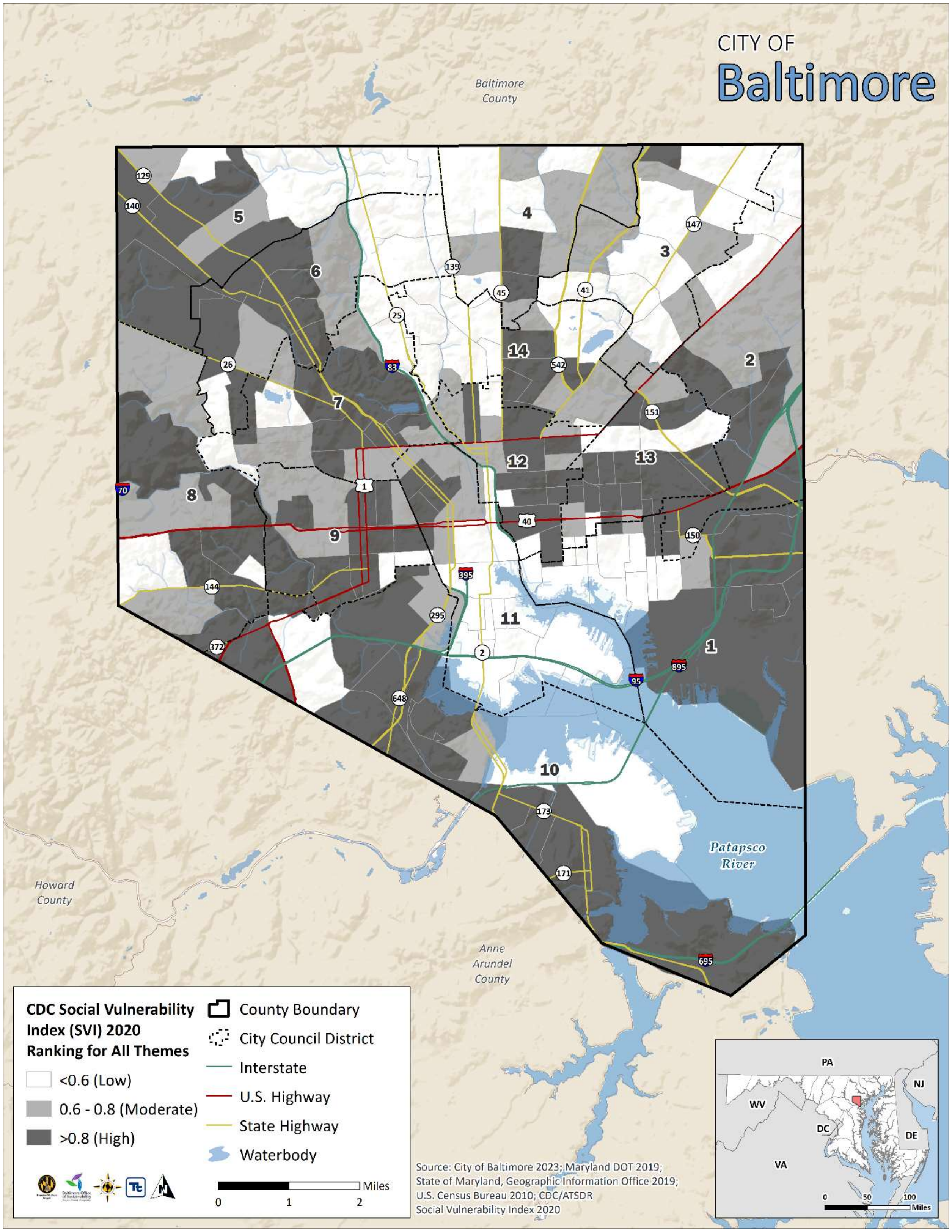
To identify geographic areas in Baltimore City experiencing a higher rate of social vulnerability the SVI data was utilized to provide a visualization of geographic areas with higher social vulnerability. Figure 2-12 depicts the ranking for each of the four themes that make up the SVI. In general, most areas within Baltimore City have an increased vulnerability with the exception of areas located in the North central portion of Baltimore City and around the Patapsco River. Figure 2-13 depicts the SVI (all four themes combined) for census tracts with an SVI of 0.6 or greater. This map demonstrates that most areas within Baltimore City have an increased vulnerability the exception of areas located in the north-central, northeast, and areas around the Patapsco River.

Figure 2-12. Baltimore City SVI by Theme



Source: CDC/ATSDR 2020

Figure 2-13. Baltimore City SVI > 0.6



Source: CDC/ATSDR 2020

U.S. Census and American Community Survey

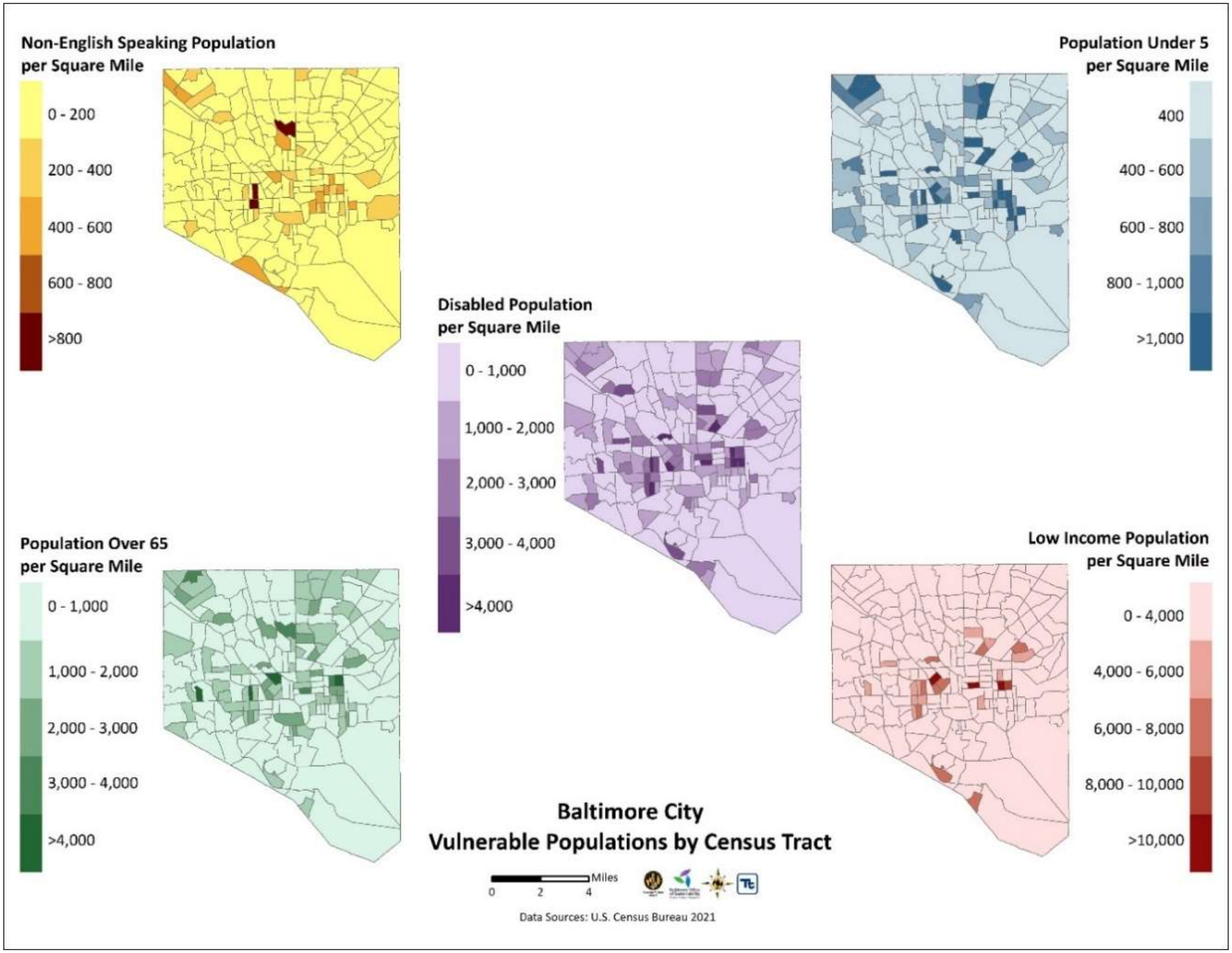
When assessing social vulnerability, an individual may be categorized into one or more populations that experience a disproportionately higher vulnerability to emergencies and disasters. Population figures and percentages provide quantitative data on who is represented within the community. Applying a lens of intersectionality provides additional qualitative data on how and why these individuals may be impacted disproportionately by disasters. It is important to recognize that this data only accounts for those individuals who participated and responded to the 2020 U.S. Census and 2017 – 2022 ACS. Census data may be incomplete and not provide a full depiction of Baltimore City's population due to multiple factors including distrust of government, immigration status, or other factors.

Within Baltimore City, there are a number of individuals and groups who may experience one or more factors that contribute to heightened vulnerability. Approximately 19.5 percent of Baltimore City's population is below the poverty line, accounting for 115,625 individuals. The second highest percentage of individuals experiencing heightened social vulnerability are those individuals with a disability, representing 15.7 percent of Baltimore City's total population. Figure 2-14 shows the geographic concentration of vulnerable populations by Census tract. Table 2-7 provides a breakdown of vulnerable populations, as identified in the U.S. Census, for Baltimore City. The sections that follow provide a brief overview of how social vulnerability contributes to heightened risk to hazards.

Children

Risk is disproportionately higher for children due to their dependency on others to safely access resources during emergencies and the potential for long-term impacts of trauma experienced during a crisis. During an emergency, children may not be able to avoid hazards or make critical decisions for their safety; this requires them to depend on others. Extended disruptions in education systems during recovery can have lifelong impacts on the developmental capabilities of children (UNICEF 2016). Additionally, children may often experience increased health risks from exposure to hazards. There are 36,468 children under the age of 5 in Baltimore City who may struggle with responding to emergencies and may not be able to use critical thinking skills to prioritize their safety. Strategies such as Child-Centered Disaster Risk Reduction prioritize preparing and protecting children by focusing on six sectors where children have the highest vulnerabilities (UNICEF 2016).

Figure 2-14. Vulnerable Populations by Census Tract



Source: U.S. Census 2021

Table 2-7. Vulnerable Population Statistics

City Council District	Over 65	Percent of District Total	Under 5	Percent of District Total	Non-English Speaking	Percent of District Total	Disability	Percent of District Total	Poverty Level	Percent of District Total	Limited Transportation [1]	Percent of District Total	BIPOC	Percent of District Total	Group Quarters	Percent of District Total	LGBTQIA+ [2]	Percent of District Total
1	4,481	10.2%	3,344	7.6%	1,141	2.6%	4,200	9.6%	5,851	13.4%	6,044	13.8%	10,613	24.3%	393	0.9%	226	0.5%
2	5,528	12.2%	3,009	6.6%	1,376	3.0%	5,394	11.9%	6,530	14.4%	8,195	18.1%	34,798	76.9%	466	1.0%	222	0.5%
3	5,988	14.2%	1,669	4.0%	470	1.1%	5,485	13.0%	3,539	8.4%	3,828	9.1%	29,033	68.7%	4,246	10.0%	222	0.5%
4	6,401	14.2%	3,113	6.9%	371	0.8%	5,601	12.4%	6,218	13.8%	7,852	17.4%	33,183	73.7%	2,498	5.5%	184	0.4%
5	8,122	18.6%	3,762	8.6%	1,176	2.7%	6,613	15.2%	7,155	16.4%	7,626	17.5%	24,258	55.6%	733	1.7%	150	0.3%
6	8,355	20.1%	2,356	5.7%	546	1.3%	7,741	18.6%	7,910	19.0%	11,043	26.5%	32,354	77.8%	2,566	6.2%	186	0.4%
7	6,177	15.6%	1,895	4.8%	349	0.9%	7,764	19.6%	9,082	22.9%	13,979	35.3%	31,724	80.0%	988	2.5%	244	0.6%
8	7,799	16.8%	2,947	6.4%	392	0.8%	8,376	18.1%	8,014	17.3%	11,365	24.5%	40,489	87.3%	659	1.4%	172	0.4%
9	4,927	13.7%	2,024	5.6%	641	1.8%	8,523	23.8%	11,821	33.0%	17,555	48.9%	31,009	86.5%	421	1.2%	117	0.3%
10	4,755	11.5%	3,468	8.4%	1,054	2.5%	7,685	18.5%	12,283	29.6%	12,544	30.2%	26,654	64.2%	249	0.6%	59	0.1%
11	5,774	12.0%	2,182	4.5%	907	1.9%	6,231	13.0%	8,651	18.0%	17,477	36.4%	20,276	42.2%	2,094	4.4%	296	0.6%
12	4,203	11.3%	1,690	4.6%	575	1.5%	6,388	17.2%	9,816	26.4%	15,493	41.7%	26,663	71.8%	4,722	12.7%	229	0.6%
13	4,701	12.1%	2,684	6.9%	582	1.5%	6,814	17.6%	11,674	30.1%	10,700	27.6%	31,551	81.4%	126	0.3%	255	0.7%
14	6,316	14.8%	2,325	5.4%	703	1.6%	5,892	13.8%	7,091	16.6%	9,560	22.4%	23,022	54.0%	4,028	9.4%	327	0.8%
Baltimore City (Total)	**83,527**	**14.1%**	**36,468**	**6.2%**	**10,283**	**1.7%**	**92,707**	**15.7%**	**115,625**	**19.5%**	**153,259**	**25.9%**	**395,627**	**66.9%**	**24,189**	**4.1%**	**2,889**	**0.5%**

Source: Source: U.S. Census Bureau 2021, ACS
Notes:
1: Persons per household = 2.32. Number used to calculate Limited Transportation population.
2: Population based upon Same-sex spouses and Same-sex unmarried partners.

Older Adults

Older adults are susceptible to a myriad of increased risks due to several factors, including health, finances, and mobility. Those living on their own may have more difficulty evacuating their homes, and those living in group quarters, such as senior care and living centers, depend upon facility operators executing emergency preparedness measures. Older adults may face greater limitations with driving and therefore require special evacuation plans. They may also have hearing or vision impairments that could make receiving emergency instructions difficult. Baltimore City has a growing population of 83,527 individuals who are age 65 or older, all of whom could experience greater difficulty when dealing with emergencies.

Persons with Disabilities

The Centers for Disease Control and Prevention (CDC) defines a disability as a "condition of the body or mind (impairment) that makes it more difficult for the person with the condition to do certain activities (activity limitation) and interact with the world around them (participation restrictions)" (CDC 2020). These impairments may increase the level of difficulty that individuals face during a hazard event. Cognitive impairments may reduce an individual's capacity to receive, process, and respond to emergency information or warnings. Individuals with a physical or sensory disability may face issues of mobility, sight, hearing, or reliance on specialized medical equipment. Table 2-8 shows the population in Baltimore City that may be vulnerable due to a disability.

Table 2-8. Disabilities in Baltimore City

Disability	Number of People
Hearing Difficulty	15,936
Vision Difficulty	20,236
Cognitive Difficulty	41,419
Ambulatory Difficulty	51,459
Self-Care Difficulty	17,116
Independent Living Difficulty	31,222

Source: U.S. Census 2020

Economically Disadvantaged

Limited finances pose a barrier to obtaining resources and supplies to prepare for emergencies and disasters. Individuals and households facing financial challenges are likely to evaluate their risk and make decisions based on the major economic impact to their family, including determining if they have the financial means to safely evacuate. Economically disadvantaged individuals and households may require additional support and resources in the following areas:

Housing and utility disruption (including long-term displacement, homelessness, and utility shutoffs)

Food security and access

Access to affordable healthcare

Ability and resources to evacuate during emergencies

Access to transportation

Limited Access to Transportation

Individuals with limited or no access to transportation face a higher risk during emergencies due to the challenges of being unable to move out of harm's way. With people remaining in place during emergencies, first responders may be unable to render assistance due to inaccessible roadways or other conditions present during an emergency or disaster. In total, it is estimated that 40,174 people in Baltimore City have no vehicle available for them to use (US Census Bureau 2020).

Limited English Proficiency

Individuals who are not fluent or do not possess a working proficiency in English may have difficulty understanding information being conveyed to them. Cultural differences can also add complexity to how information is being conveyed to populations with limited English proficiency (CDC 2021). Baltimore City is home to over 57,000 individuals (over 10% of the total population 5 years of age and older) who speak a language other than English at home, and nearly 20,000 of those individuals speak English less than very well (3.7% of the total population 5 years of age and older) (U.S. Census 2021).

These individuals are Limited English Proficient, meaning that they do not speak English as their primary language and have limited ability to speak, write, or understand English. Currently, the top five languages spoken in Baltimore are Spanish, French, Chinese (including Mandarin and Cantonese), Arabic, and Korean (U.S. Census 2021). City schools have the following languages represented among their families Spanish, French, Swahili, Arabic, Amharic, Tigrinya, Dari, Pashto. Table 2-9 provides a breakdown of the top five languages spoken at home in Baltimore City.

Table 2-10 shows the breakdown of the 4,239 households that are classified as "limited English-speaking households." Over 1.7 percent of households in Baltimore City are classified as limited English-speaking households.

Table 2-9. Top 5 Languages Spoken at Home and English Proficiency

Primary Language	Number of People	Number of Limited English Proficient People
Spanish	23,017	8,837
French	5,017	1,335
Chinese (including Mandarin or Cantonese)	3,307	1,419
Arabic	2,336	798
Korean	1,485	712

Source: U.S. Census 2020

Table 2-10. Limited English-Speaking Households

Limited English-Speaking Households	Total Households
Spanish	1,567
Other Indo-European Languages	925
Asian and Pacific Island Languages	1,114
Other Languages	633
Total	**242,499**

Source: U.S. Census 2020

Black, Indigenous, and People of Color (BIPOC)

Often BIPOC populations make up frontline communities. Frontline communities are "neighborhoods or populations of people who are directly affected by climate change [and other natural hazards] and inequity in society at higher rates than people who have more power in society. They are on the frontlines of the problem." (NAACP 2018). This poses a greater risk to BIPOC populations as structural and institutional inequities often create additional barriers that prevent these populations from being adequately prepared to withstand and recover from a disaster or emergency. "Decades of underinvestment and unjust systems have left frontline communities with high levels of poverty and pollution, a lack of quality jobs and education opportunities, outdated and weak critical infrastructure, disproportionately high costs for energy, transportation and basic necessities, and limited access to public services." (The Greenlining Institute 2019).

The social, political, and economic history of a community can have lasting impacts that perpetuate the oppression of BIPOC populations in present day. Discriminatory housing policies, such as redlining, can result in vulnerable BIPOC populations residing in hazard-prone areas and/or with housing options that are lower quality and do not provide adequate physical protection against natural hazards (NAACP 2018). Table 2-11 shows the breakdown of Baltimore City population by race and Table 2-12 shows the breakdown for Hispanic or Latino origin.

The Mayor's Office of Immigrant Affairs (MIMA) maintains a dashboard detailing demographics of foreign-born individuals in Baltimore City that may be accessed at the Baltimore City Foreign Born Demographics Dashboard.

Table 2-11. Racial Diversity for Baltimore City

Demographics	2016–2021 ACS 5-Year Estimates	Percent of City Total
White	173,079	29.2
Black or African American	364,879	61.6
American Indian and Alaska Native	1,706	0.3
Asian	14,887	2.5
Native Hawaiian and Other Pacific Islander	131	0.0
Other Race	14,438	2.4
Two or more races	23,091	4.0

Source: U.S. Census 2023

Table 2-12. Hispanic or Latino Origin for Baltimore City

Hispanic or Latino	2016–2021 ACS 5-Year Estimates	Percent of City Total
Not Hispanic or Latino	558,965	94.4
Hispanic or Latino	33,246	5.6

Source: U.S. Census 2023

Individuals Living in Group Quarters

The term “group quarters” refers to people living in communal settings, which can include inmates in a prison, students in a dorm, and older adults or individuals with access and functional needs living in group care facilities. The concentration of multiple individuals within one location compounds the impacts of a disaster should the structure incur damage. In circumstances where the group quarters house individuals with access and functional needs, residents may require additional assistance with evacuating due to mobility and/or cognitive limitations. It is important to ensure that each group quarter facility has its own emergency plan to account for the unique needs of its residents during a hazard event. In 2020, it was recorded that 18,001 people were living in group quarters. Table 2-13 breaks down the total number of people living in group quarters.

Table 2-13. Baltimore City Population Living in Group Quarters

Facilities	Population
Institutionalized Population	5,865
Correctional Facilities for Adults	2,568
Juvenile Facilities	122
Nursing Facilities	3,067
Other Institutionalized Facilities	108
Noninstitutionalized Population	12,136
College/University Student Housing	10,098
Military Quarters	0
Other Noninstitutionalized Facilities	2,038
Total	**36,002**

Source: U.S. Census 2020

Individuals Experiencing Sheltered and Unsheltered Homelessness

Individuals experiencing homeless may face a higher vulnerability to hazard impacts due to inability to evacuate or find appropriate shelter (Substance Abuse and Mental Health Services Administration 2022). Additional factors may contribute to the vulnerability of this group including an increase in exposure to disease in congregate sheltering, traumatization and mental health challenges, and discrimination at sheltering sites.

The Mayor's Office of Homeless Services (MOHS) conducted a Point-in-Time (PIT) count on the evening of February 26, 2022, to assess the number of individuals that were unsheltered, staying in emergency shelters, or in transitional housing for the specific night. Due to the transitional nature of this group, it is challenging to develop longer-term counts. Approximately, 1,600 individuals were counted during the PIT; 56 percent were staying in emergency shelters, 36 percent were staying in transitional housing, and 8 percent were unsheltered (MOHS 2022). Table 2-15 compares results of the PIT counts completed by the City since 2018.

Table 2-14. Point-in-Time Count Results, 2018 – 2022

Year	Sheltered	Emergency Shelter	Transitional Housing	Unsheltered	Total
2018	1,962	1,152	810	546[1]	2,508
2019	1,914	1,140	774	380	2,294
2020	1,895	1,147	748	298	2,193
2022	1,473	895	578	124	1,597

Source: MOHS 2022
Notes:
[1] In 2018, Baltimore did not conduct an unsheltered count. HUD's policy for when CoCs elect to conduct unsheltered counts every other year is to add numbers from the previous year's unsheltered count to approximate the total.
Baltimore did not conduct a PIT Count in 2021 as a safety precaution during the COVID-19 pandemic.

Lesbian, Gay, Bisexual, Transgender, Queer or Questioning, Intersex, Asexual, and Additional Identities (LGBTQIA+)

Historic discriminatory practices and policies towards LGBTQIA+ communities have lasting impacts on present-day efforts to execute the disaster management process. Individuals that are LGBTQIA+ and BIPOC tend to experience a greater number of discriminatory practices and policies. These communities may be excluded from policies and practices that enforce having safe, affordable housing options and therefore must reside in higher-risk, hazard-prone areas with lower-quality housing options (NAACP 2018). Access to safe and adequate sheltering is also a concern for LGBTQIA+ communities. The NAACP notes that shelters might refuse to accept transgender or gender non-conforming individuals; this may result in these individuals being physically exposed to hazards. In instances where LGBTQIA+ individuals are admitted into a shelter during an emergency, they may face discrimination leading to additional concerns regarding safety and access to medical services. These considerations should be incorporated into City and local sheltering plans.

2.5 Land Use and Development

Land use trends can significantly impact exposure and vulnerability to various hazards. For example, significant development in a hazard prone area increases the building stock and population exposed to that hazard. An understanding of these development trends can assist in planning for further development and ensuring that appropriate mitigation, planning, and preparedness measures are in place to protect human health and community infrastructure. Baltimore City has historically been composed of urban land development. This land use trend continues, with over 82 percent of land being classified as urban in 2019. The next largest land classification is water, which makes up just over 11 percent of Baltimore City and is mainly attributed to the Inner Harbor. Table 2-15 provides information about Baltimore City's land use.

Table 2-15. Baltimore City Land Use

	2019		2016		2013	
Land Use Category	**Acreage**	**Percent of City**	**Acreage**	**Percent of City**	**Acreage**	**Percent of City**
Agriculture	172	0.3%	178	0.3%	179	0.3%
Barren	139	0.2%	131	0.2%	123	0.2%
Forest	3,210	5.5%	3,239	5.5%	3,252	5.5%
Rangeland	77	0.1%	64	0.1%	58	0.1%
Urban	48,548	82.5%	48,516	82.5%	48,505	82.4%
Water	6,516	11.1%	6,540	11.1%	6,550	11.1%
Wetland	170	0.3%	164	0.3%	165	0.3%
Baltimore City (Total)	**58,832**	**100.0%**	**58,832**	**100.0%**	**58,832**	**100.0%**

Source: National Land Cover Database 2019, 2016, 2013

Baltimore City has a total land area of 81 square miles representing 51,826 acres without water bodies. The largest City Council District is District 10, which is 12.8 square miles, and the smallest City Council District is District 12, which is 3 square miles. See Table 2-16 for more information regarding land area excluding water bodies.

Since the development of the 2018 DP3, major new developments in Baltimore City include activity to develop the Baltimore Peninsula, a 235-acre waterfront neighborhood consisting of commercial and residential land uses located at the mouth of the Patapsco River. The area is partially located within the FEMA-mapped floodplain and subject to adhering to the local floodplain ordinance, Maryland's Critical Area Law, and other hazard-resistant building codes. The Baltimore Peninsula development is circled in red in Figure 2-15. Additional notable developments include the potential redevelopment of Harborplace and two retail pavilions located at the intersection of Light and Pratt Streets bordering the Inner Harbor. The potential gentrification of areas in Baltimore City may displace current residents who will no longer be able to afford the area they currently reside in. Harborplace is also located within the FEMA-mapped floodplain and subject to adhering to the local floodplain ordinance, Maryland's Critical Area Law, and other hazard-resistant building codes. A map of Baltimore's land use and land cover is shown in Figure 2-15.

Figure 2-15. Land Use and Land Cover in Baltimore City

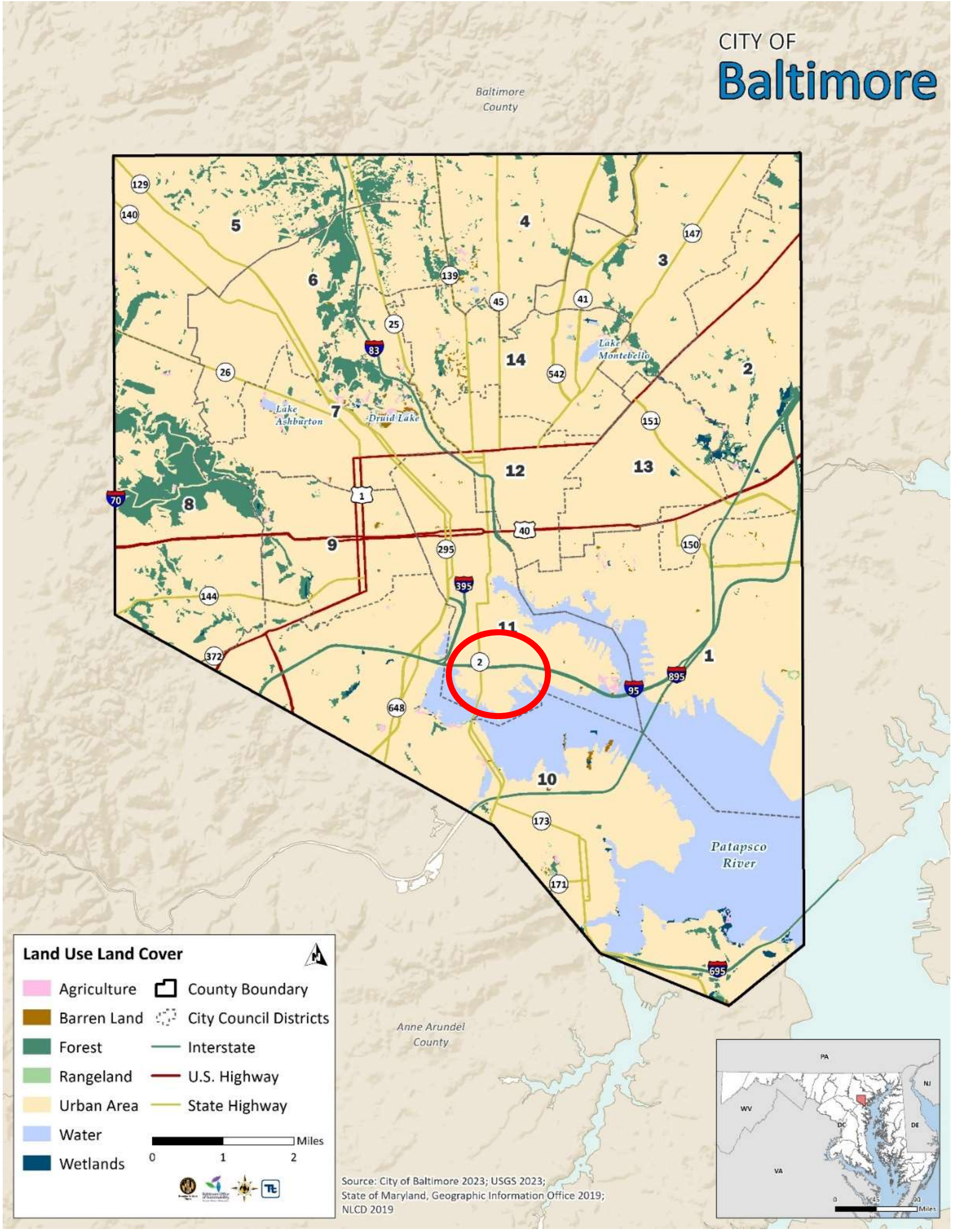


Table 2-16. Total City Council Land Area

City Council District	Total Land Area (Excluding Water Bodies) Acres	Square Miles
1	4,666	7.3
2	4,271	6.7
3	3,459	5.4
4	3,044	4.8
5	4,480	7.0
6	3,663	5.7
7	3,295	5.1
8	4,474	7.0
9	2,383	3.7
10	8,188	12.8
11	2,899	4.5
12	1,948	3.0
13	2,248	3.5
14	2,809	4.4
Baltimore City (Total)	**51,827**	**80.9**

Source: State of Maryland 2019; USGS 2023 Note: Excludes areas that are designated as water.

The Baltimore City Department of Planning maintains an interactive online map depicting ongoing development and infrastructure improvements on southwest Baltimore (Southwest Baltimore Major Attractions, Developments, and Infrastructure) and the Central Maryland Development Tracker provides information on all projects requiring a building permit.

2.6 Housing

Baltimore City has seen a decline in the total number of housing units from 2010 to 2020 as well as a decline in owner-occupied houses, vacant housing units, and housing units with a mortgage. In contrast, Baltimore City has seen an increase in renter-occupied housing units meaning that more people in Baltimore City are renting versus owning homes in Baltimore City. According to the 2020 Census Data, 293,249 housing units are located in Baltimore City. A household includes all the people who occupy a housing unit as their usual residence. A housing unit is a house, apartment, mobile home or trailer, a group of rooms, or a single room occupied as separate living quarters (or if vacant, intended for occupancy as separate living quarters). According to the 2020 Census, there are 41,770 vacant housing units in Baltimore City. Table 2-17 shows how the housing characteristics of Baltimore City have changed from 2010 to 2020.

Table 2-17. Housing Characteristics in Baltimore City in 2010 and 2020

Housing Characteristics	2010	2020
Total Housing Units	296,685	293,249
Owner-Occupied Housing Units	118,655	115,747
Renter-Occupied Housing Units	119,737	126,752
Vacant Housing Units	46,782	41,770
Median Value (dollars)	$171,200	$182,500
Housing Units with a mortgage	85,066	79,461

Source: U.S. Census 2020

2.7 Physical Assets

Physical assets such as buildings or facilities, agriculture, and resources are extremely susceptible to natural hazards. Inventorying building stock and facilities is crucial in evaluating what facilities should primarily be protected in the event of a hazard. Protecting assets that provide safety and security, energy resources, communication, transportation, and potable water as well as facilities that have a high potential loss, such as hazmat facilities, are important aspects to look at when creating a plan on how to lessen hazard impacts.

2.7.1 General Building Stock

For the purposes of this plan, 227,856 structures were identified by the tax data and spatial data available. These structures account for a replacement cost value of approximately $193 billion. Estimated content value is estimated to be $154 billion, for a total replacement cost for the structures and contents of $347 billion. Approximately 93 percent of the total buildings in Baltimore City are residential, 6 percent are commercial, and less than 1 percent are industrial. Residential structures account for a total replacement cost (structure and contents) of $100 billion. Table 2-18 provides additional building stock and replacement cost value information for Baltimore City.

2.7.2 Cultural and Natural Resources

Historic Fells Point neighborhood.

Baltimore City is full of cultural and natural resources that tend to draw people from all over to experience its rich history and culture within Baltimore City's 91 designated historic districts (see Figure 2-16). Visit Baltimore reports that 27 million people visit Baltimore City in a typical year, generating a total of $6 billion in economic impact to the local economy (Visit Baltimore n.d.). In addition, Baltimore's ideal proximity to the waterfront features open spaces for waterfront paths and parklands for residents and tourists to enjoy. Many of these features are within Baltimore City's Inner Harbor, which includes museums, historic ships redesigned to be floating museums, paddleboats, shows, and numerous restaurants.

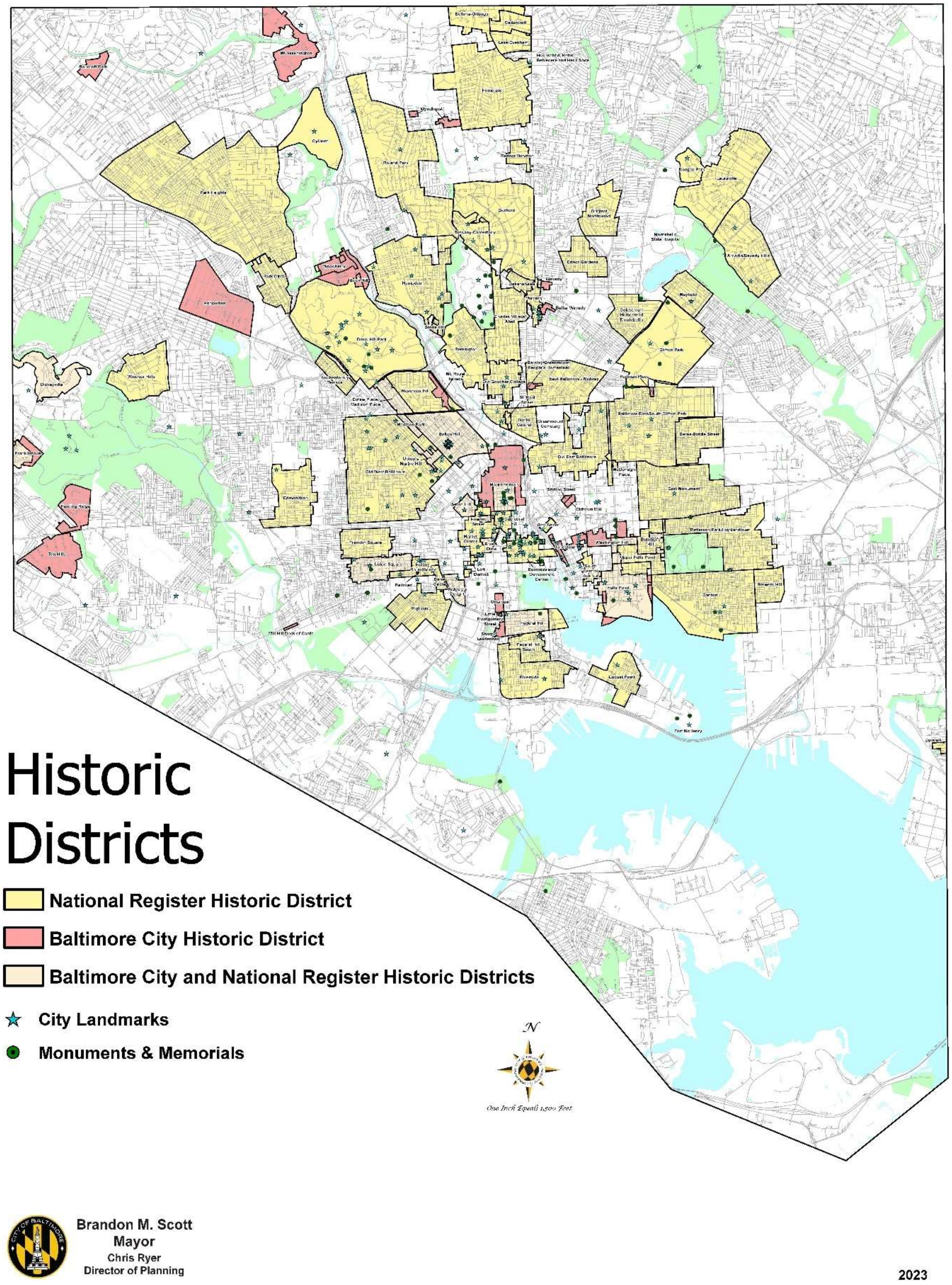
Baltimore City has several museums, including Baltimore Museum of Art, which offers a renowned and diverse selection of 19th century, modern, and contemporary art. The Walters Art Museum includes textiles, ancient art, furniture, jewelry, and armor collections from 5,000 BCE to the 21st century and is located in the Mount Vernon Cultural District. The American Visionary Art Museum includes creative pieces from self-taught artists, including farmers, mathematicians, inmates, and those with mental illness. The Reginald F. Lewis Museum includes information and cultural pieces surrounding African American history and has objects dating from 1784 to today to tell the story of the accomplishments and struggles of African Americans in Maryland (Visit Baltimore 2023). Fort McHenry is another culturally rich location where Francis Scott Key wrote the words that became the U.S. National Anthem after becoming inspired by a flag that was sewn and flown over the victorious fort after withstanding a 25-hour British bombardment (NPS 2023).

Table 2-18. Building Stock and Replacement Cost Value in Baltimore City by City Council District

City Council District	All Occupancies				Residential		Commercial		Industrial	
	Building Count	Replacement Cost Value (Structure Only)	Replacement Cost Value (Contents Only)	Total Replacement Cost Value (Structure + Contents)	Building Count	Total Replacement Cost Value (Structure + Contents)	Building Count	Total Replacement Cost Value (Structure + Contents)	Building Count	Total Replacement Cost Value (Structure + Contents)
1	22,781	$23,756,997,616	$18,969,171,602	$42,726,169,218	20,557	$10,760,811,434	1,971	$28,678,275,121	110	$1,117,389,750
2	12,746	$11,071,161,446	$8,701,899,828	$19,773,061,274	11,810	$6,531,761,854	791	$11,028,509,528	54	$548,969,400
3	14,274	$8,203,081,156	$5,992,018,617	$14,195,099,773	13,774	$6,334,242,730	372	$5,836,557,925	4	$40,664,400
4	14,536	$7,530,418,958	$5,156,329,739	$12,686,748,697	14,156	$7,035,424,347	270	$4,134,380,032	1	$10,166,100
5	12,637	$10,467,150,261	$8,108,763,160	$18,575,913,421	11,896	$6,411,355,791	604	$10,196,786,963	28	$284,650,800
6	15,009	$10,621,557,233	$8,538,411,224	$19,159,968,457	14,254	$6,074,974,779	585	$10,682,926,279	21	$213,488,100
7	17,409	$10,134,679,892	$7,872,920,901	$18,007,600,793	16,624	$6,904,496,282	548	$8,051,785,363	49	$507,127,650
8	14,350	$8,263,721,432	$5,944,718,010	$14,208,439,442	13,925	$6,855,468,761	327	$5,985,439,411	4	$40,664,400
9	21,371	$12,521,730,692	$9,469,145,205	$21,990,875,897	20,197	$7,813,683,971	941	$11,183,180,442	49	$498,138,900
10	16,334	$17,941,600,485	$15,679,848,265	$33,621,448,750	14,208	$6,775,625,021	1,658	$20,871,431,136	293	$3,031,277,925
11	17,184	$33,560,081,087	$28,784,593,126	$62,344,674,213	13,909	$9,116,612,794	2,996	$49,210,380,818	36	$374,968,350
12	15,436	$18,091,217,083	$14,950,524,568	$33,041,741,651	13,526	$5,997,395,238	1,637	$24,122,460,941	38	$386,311,800
13	18,095	$11,127,532,410	$8,304,712,985	$19,432,245,395	17,249	$6,981,280,162	668	$10,192,444,059	43	$446,131,050
14	15,694	$10,160,327,242	$7,584,472,338	$17,744,799,580	14,959	$6,773,911,422	602	$8,980,220,313	16	$162,657,600
Baltimore City (Total)	**227,856**	**$193,451,256,993**	**$154,057,529,568**	**$347,508,786,561**	**211,044**	**$100,367,044,586**	**13,970**	**$209,154,778,331**	**746**	**$7,662,606,225**

Source: Maryland Department of Planning 2020, 2022; RS Means 2022

Figure 2-16. Historic Districts in Baltimore City



Source: Department of Planning 2023

Baltimore City is also known for its National Aquarium that is dedicated to educating people on marine life through immersion films and numerous aquatic habitats. The National Aquarium provides numerous exhibits where guests can pet stingrays, watch dolphins play, be surrounded by sharks, and learn about conservation efforts. The Maryland Zoo spans 135 acres and hosts several rescued and rehabbed animals. The Inner Harbor Promenade is a seven-mile paved waterfront promenade that allows people to enjoy the scenic views of Baltimore City.

In addition, Baltimore City offers numerous parks and trails that allow residents and tourists to enjoy the local nature that Baltimore has to offer (Visit Baltimore 2023). The Department of Recreation and Parks manages 51 recreation centers, 23 pools, over 4,700 acres of parkland, 262 parks, 32 historic structures, over 25 miles of biking and hiking trails, and numerous athletic fields and playgrounds. These facilities are also used to support Baltimore City's educational curriculums and are used as informative centers to educate the public (Department of Recreation and Parks 2023).

All of these resources contribute to the liveliness of Baltimore City, but face risks posed by the natural and human-caused hazards that threaten Baltimore City. Ensuring these resources are integrated into hazard mitigation and resilience measures throughout Baltimore City aids in building overall community resilience.

2.7.3 Critical Facilities and Infrastructure

Critical infrastructure and facilities are those that are essential to the health and welfare of the population. These facilities are especially important after any hazard event. Critical facilities are those that maintain essential and emergency functions and typically include police and fire stations, schools, and emergency operations centers.

Key Terms

- Critical Asset—A resource, system, or facility that is vital for the functioning of a community or organization during and after an emergency or disaster. In can include infrastructure, communication networks, medical facilities, transportation hubs, and more.
- Community Lifeline—The most fundamental services in the community that, when stabilized, enable all other aspects of society. A lifeline enables the continuous operation of critical government and business functions and is essential to human health and safety or economic security.

Critical infrastructure can include the roads and bridges that provide ingress and egress and allow emergency vehicles access to those in need and the utilities that provide water, electricity, and communication services to the community. Also included are Tier II facilities (hazardous materials) and rail yards. Rail lines may serve as a means of transportation of significant amounts of hazardous materials, increasing the potential risk posed to public health and welfare during a hazard event. During the 2023 DP3 update process, stakeholders provided additional input on resources and facilities they consider to be critical assets, including resiliency hubs, water impoundments and dams, fiber and conduit for communications and broadband, assisted living facilities, senior living facilities, grocery stores, and behavioral healthcare centers. In addition, resources such as informational websites, manufacturing websites, entertainment facilities (e.g., convention centers, stadiums, etc.)

Beginning in 2019, FEMA developed a new concept to increase effectiveness for disaster operations and position response to catastrophic incidents. This concept, known as “community lifelines,” represents the most fundamental services in the community that, when stabilized, enable all other aspects of society. Following a disaster event, intervention is required to stabilize community lifelines. The community lifelines concept is applied in hazard mitigation planning to prioritize protecting community lifelines, mitigation potential impacts to them, building back stronger and smarter, and driving community resilience efforts (FEMA 2023). During the development of the DP3, community lifelines consisted of seven categories, which included:

- **Safety and Security** – Includes law enforcement/security, fire services, search and rescue services, government services, and community safety.
- **Food, Hydration, and Shelter** – Includes food, hydration, shelter, and agriculture.
- **Health and Medical** – Includes medical care, public health, patient movement, medical supply chain, and fatality management.
- **Energy (Power and Fuel)** – Includes the power grid and fuel.
- **Communications** – Includes infrastructure, responder communications, alert warnings and messages, finance, 911, and dispatch.
- **Transportation** – Includes highway/roadway/motor vehicle, mass transit, railway, aviation, and maritime.
- **Hazardous Materials** – Includes facilities, HAZMAT, pollutants, and contaminants.

See Table 2-19 for information regarding lifelines in Baltimore City.

Table 2-19. Community Lifelines in Baltimore City

Community Lifelines	Number of Facilities
Safety and Security	290
Health and Medical	802
Transportation	446
Food, Hydration, and Shelter	127
Energy	70
Communication	307
Hazardous Materials	0

Source: City of Baltimore 2023; Maryland Department of Transportation (MDOT) 2023; Baltimore City Department of Public Works 2023; Homeland Infrastructure Foundation-Level Data (HILFD) 2018, 2021, 2022

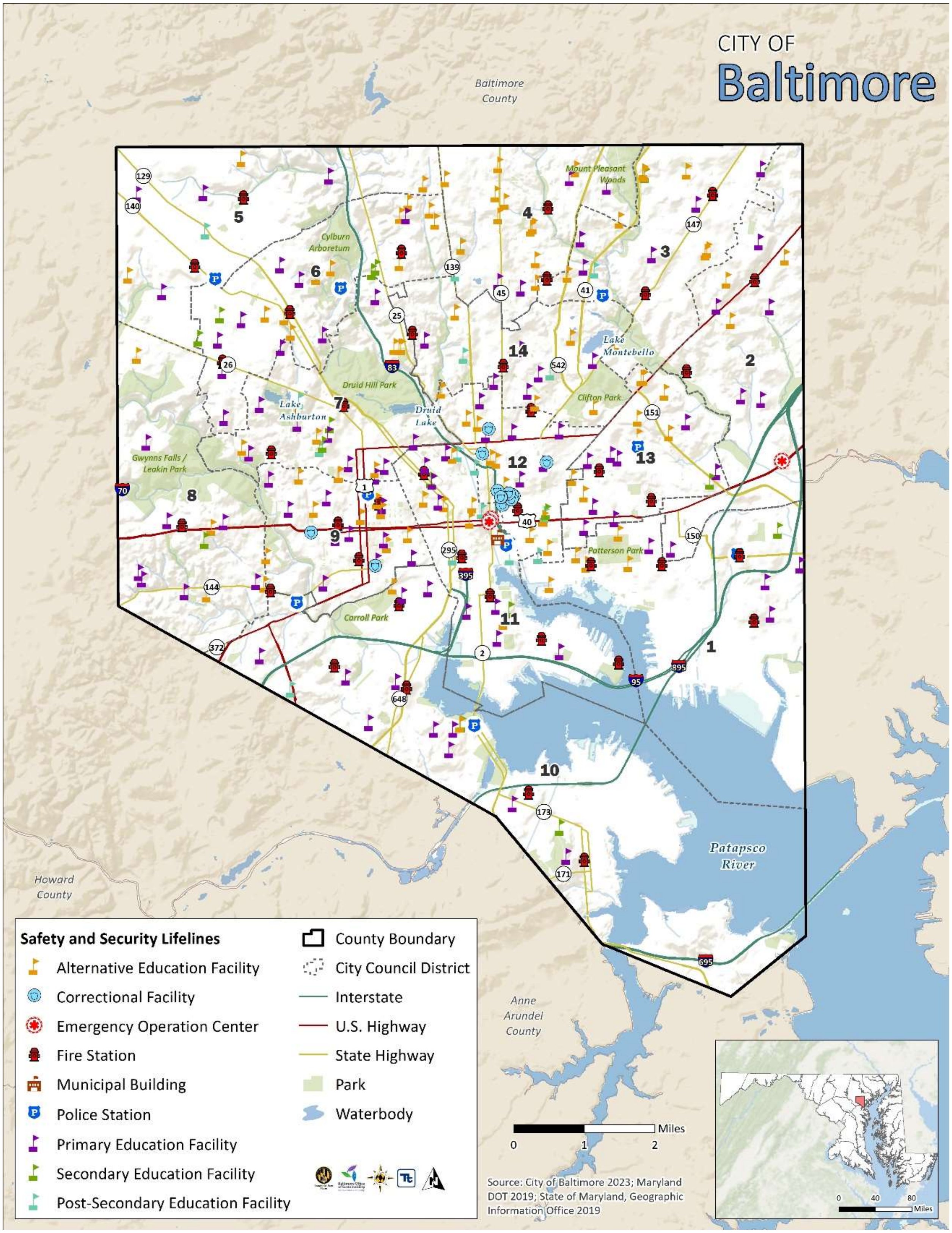
A comprehensive inventory of critical assets and community lifelines in Baltimore City was developed from various sources, including input from the CPT, HMAC, public, and stakeholders. An inventory of the most current list of critical facilities is provided in the following sections. This inventory was used to conduct the risk assessment.

Safety and Security

This section provides information on the Safety and Security lifeline. Components of this lifeline category include law enforcement/security, fire services, search and rescue services, government services, and community safety.

Figure 2-17 shows the Safety and Security lifelines within Baltimore City.

Figure 2-17. Safety and Security Lifeline



OEM

The mission of OEM is to maintain the highest level of preparedness to protect Baltimore City residents, workers, visitors, and the environment from the impact of natural and human-caused disasters; the Office also coordinates activities for Baltimore City's Emergency Operations Center.

Baltimore City Fire Department

Baltimore City Fire Department provides fire protection as well as Emergency Medical Services to Baltimore City by using 38 fire stations that are strategically located throughout Baltimore City. The Fire Department covers the entire land mass and population of Baltimore City and responds to more than 270,000 emergencies annually.

Baltimore Police Department

The Baltimore Police Department is divided into nine districts (seen below in Figure 2-18) that serve the entire City population and is the eighth-largest municipal police force in the United States (Baltimore Police Department n.d.).

Hospitals and Medical Facilities

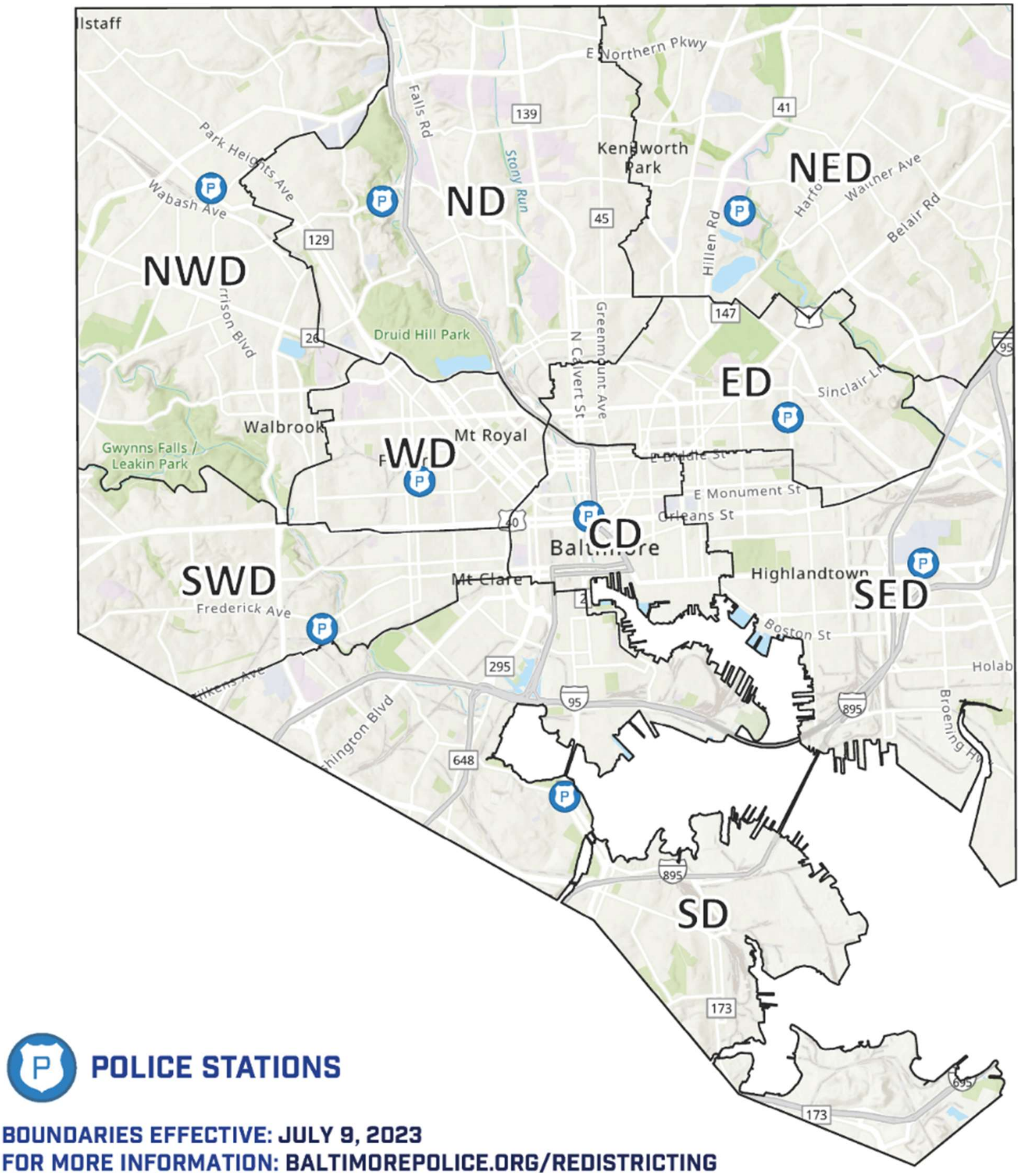
The Baltimore City Health Department is the oldest continuously operating health department in the United States, formed in 1793 when the governor appointed Baltimore City's first health officers in response to a yellow fever outbreak in the Fells Point neighborhood (Baltimore City Health Department 2018). The Health Department's areas of responsibility include acute communicable diseases, animal control, chronic disease prevention, emergency preparedness, HIV/STD, maternal-child health, restaurant inspections, school health, senior services, and youth violence issues.

The Health Department includes a workforce of approximately 800 employees and has a budget of approximately $126 million (Baltimore City Health Department 2018). The Baltimore City Health Department is organized into four divisions that encompass Baltimore City's needs:

- Finance and Administration
- Youth Wellness & Community Health
- Population Health & Disease Prevention
- Aging

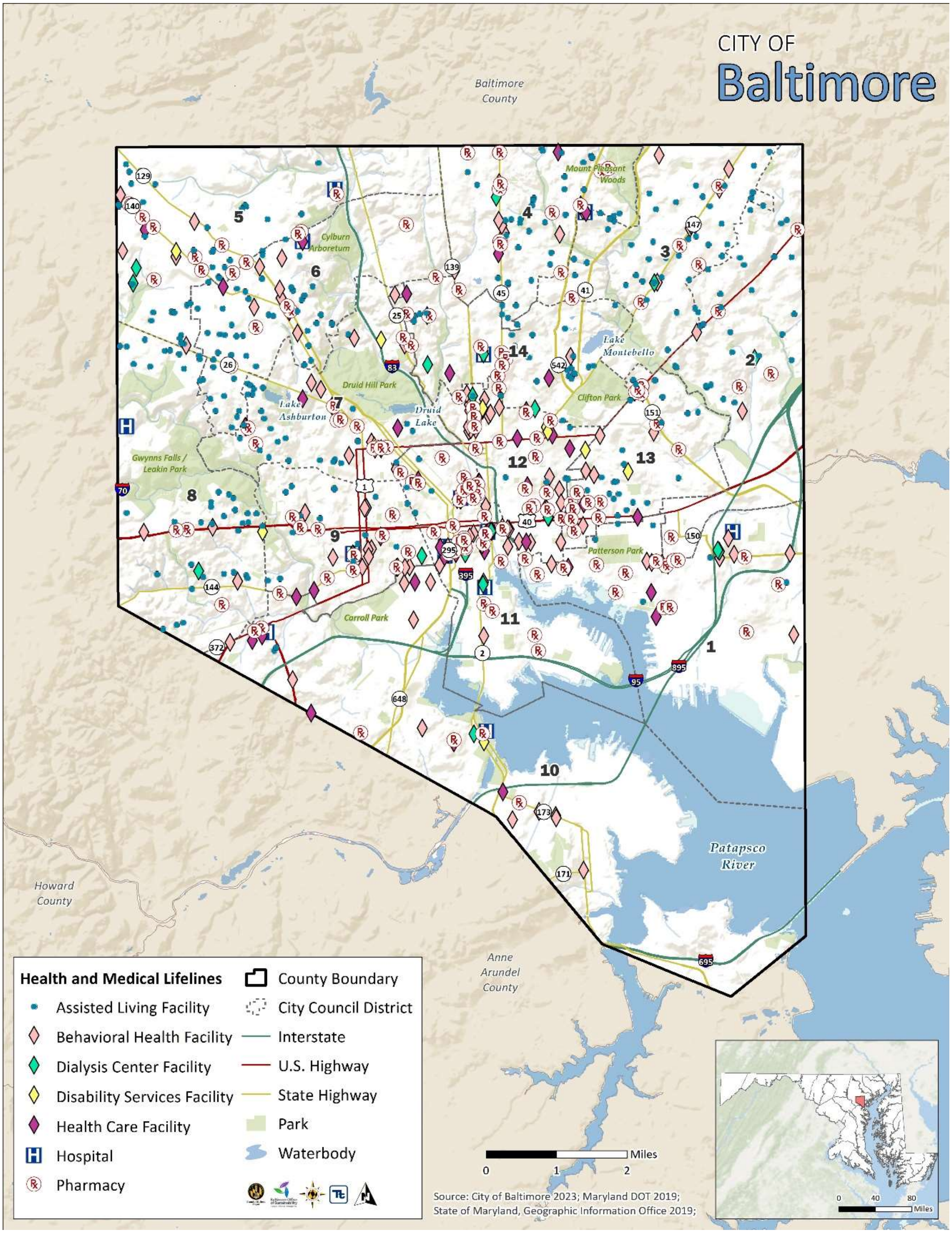
Baltimore City is also home to numerous hospital and healthcare facilities ranging in size and primary function. For non-emergency health care needs, a number of urgent care centers are located throughout and outside of Baltimore City. Figure 2-19 displays the health and medical lifelines within Baltimore City.

Figure 2-18. Baltimore Police Department District Boundaries



Source: (Baltimore Police Department 2023)

Figure 2-19. Health and Medical Lifelines



Schools

Baltimore City Public Schools had a total enrollment of 75,882 kids for the 2022–2023 school year, with 37,343 students in pre-k through grade 5, 16,677 students in grades 6 through 8, and 21,862 students in grades 9 through 12. There are 154 total schools and programs located in Baltimore City, including 42 elementary schools, 72 elementary/middle schools, 4 middle schools, 10 middle/high schools, and 26 high schools (Baltimore City Schools 2023).

Students painting INSPIRE Program artwork at Farring Baybrook Recreation Center.

Senior Care and Living Facilities

Baltimore City has numerous senior care and living facility options, including adult day services, behavioral health services, and home health services as well as retirement communities and assisted living programs. These facilities can be viewed in Figure 2-19 above.

The Baltimore City Health Department also administers a National Family Caregiver Support Program, which provides services to help families under certain circumstances, including help for people who may care for frail, older relatives, and grandparents. In addition, the Health Department provides assistance to Baltimore City caregivers to pay for respite or supplemental services, with assistance limited to $300–$600 per person annually (Baltimore City Health Department 2018).

Shelters

The MOHS operates a Shelter Hotline as a centralized system for individuals experiencing or at risk of homelessness to access Baltimore City-funded emergency shelters. There are currently five City-funded shelters to service single adults, single women, single men, families, and youth ages 18-24. MOHS provides resources for street outreach to spread awareness about the availability of shelters and includes resources for food, healthcare, showers, and treatment services.

Additionally, Baltimore City opens heating and cooling centers when official City alerts are issued for extreme temperatures.

Evacuation Routes

All major roads exiting Baltimore City can be used as evacuation routes. Baltimore City maintains plans to funnel traffic and allow contra-flow traffic to facilitate evacuation on these routes. During an evacuation, only a limited number of routes will be used based on the incident and severity. Residents can tune into the news (WBAL 1090 AM radio is the primary alerting partner) or check Facebook and Twitter pages to find which evacuation route to use (Baltimore Office of Emergency Management 2018).

Transportation Systems

Baltimore City's location and extensive transportation network offer residents and employees various options for transportation throughout Baltimore City and the region. The transportation system includes an extensive network of roads, access to national and commuter rail, citywide bus service, airport access providing domestic and international flights, and a commercial shipping port.

Major roads in Baltimore City include numerous interstates: I-95, I-70, I-83, I-395, I-695, I-895, US Highways: 1, 2, 25, 26, 40, 41, 45, 129, 134, 139, 140, 144, 147, 150, 151, 173, 295, 372, 395, 542, 648. Pulaski Highway, Perring Parkway, and University Parkway also pass through Baltimore City (GISGeography 2023).

The Baltimore City Department of Transportation is responsible for planning, designing, building, and maintaining 2,000 miles of roadways; 298 bridges and culverts; 3,600 miles of sidewalks, curbing, and gutters; 456 miles of alleys; 72,000 streetlights; 1,300 signalized intersections; and 250,000 traffic and informational signs. The Department of Transportation is also striving to create a safe, multiuse systems that can sustain bicycle, transit, pedestrian, and car transportation throughout Baltimore City (Department of Transportation 2018). Figure 2-20 shows the transportation lifelines in Baltimore City.

Bus and Other Transit Facilities

The Charm City Circulator (CCC) is a fleet of 24 free shuttles that travel four routes in the central business district of Baltimore City. The CCC consists of four separate routes: the Green Route, which runs from City Hall to Fells Point to Johns Hopkins Hospital Campus; the Purple Route, which runs from 33rd Street to Federal Hill; the Orange Route, which runs from Hollins Market to Harbor East; and the Banner Route, which runs from the Inner Harbor to Fort McHenry.

The Harbor Connector (HC) is an extension of the CCC and is Baltimore City's free maritime transit service connecting six piers through four vessels. The HC consists of three routes: HC1, which connects Maritime Park to Locust Point; HC2, which connects Canton to Fells Point; and HC3, which connects Pier 5 to Harbor View (Department of Transportation 2018).

Airports

The Baltimore/Washington International Airport is located 9 miles south of downtown Baltimore and 32 miles northeast of Washington D.C. The airport is the busiest in the area, serving over 27 million passengers. A total of 36 airlines serve an average of 51,694 passengers per day. Five cargo airlines fly over 600 million pounds of cargo/freight per year (BWI n.d.).

Ferry Service and Ports

Baltimore's Water Taxi also offers harbor connection to Baltimore City's public transportation system as well as tours and cruises (Baltimore's Water Taxi 2022).

Figure 2-20. Transportation Lifelines

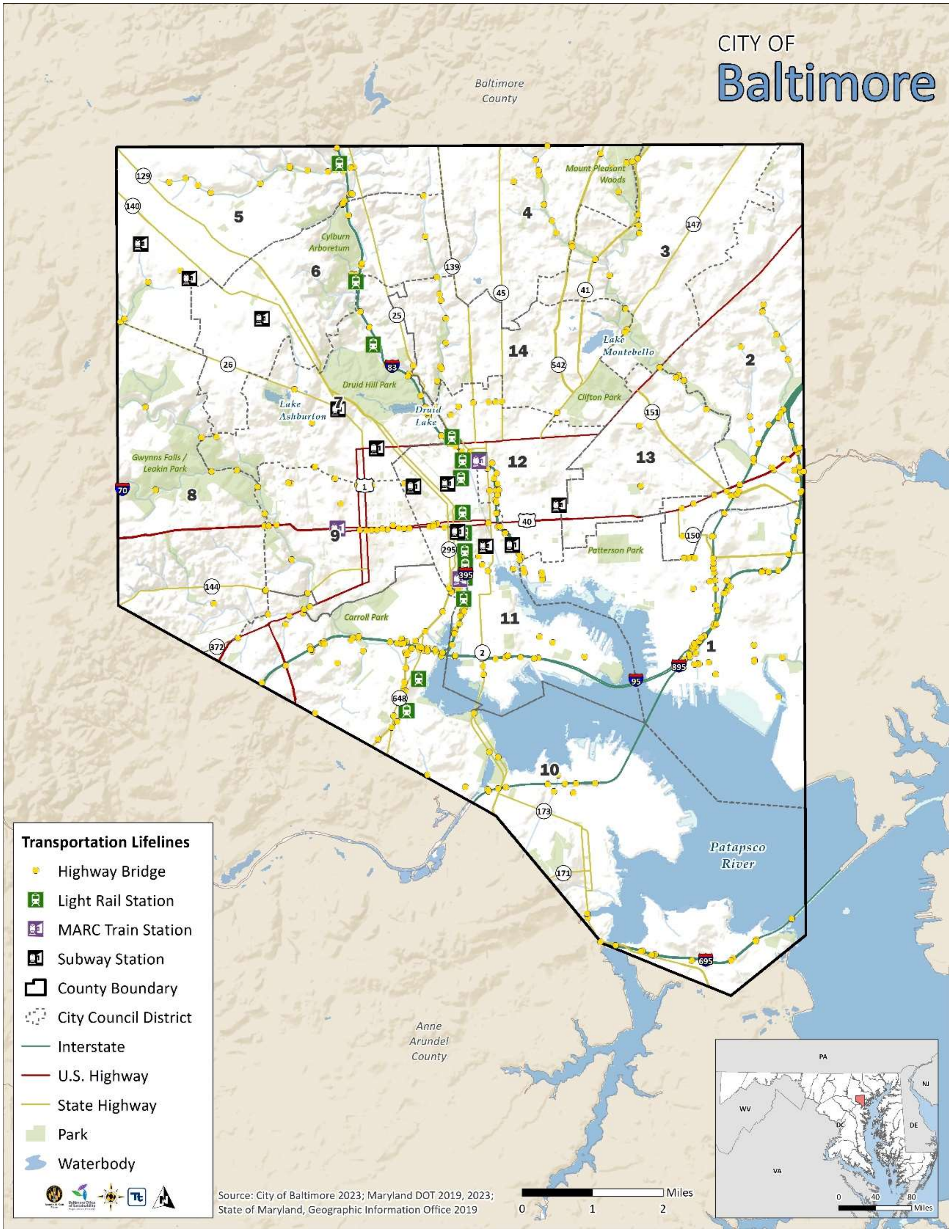
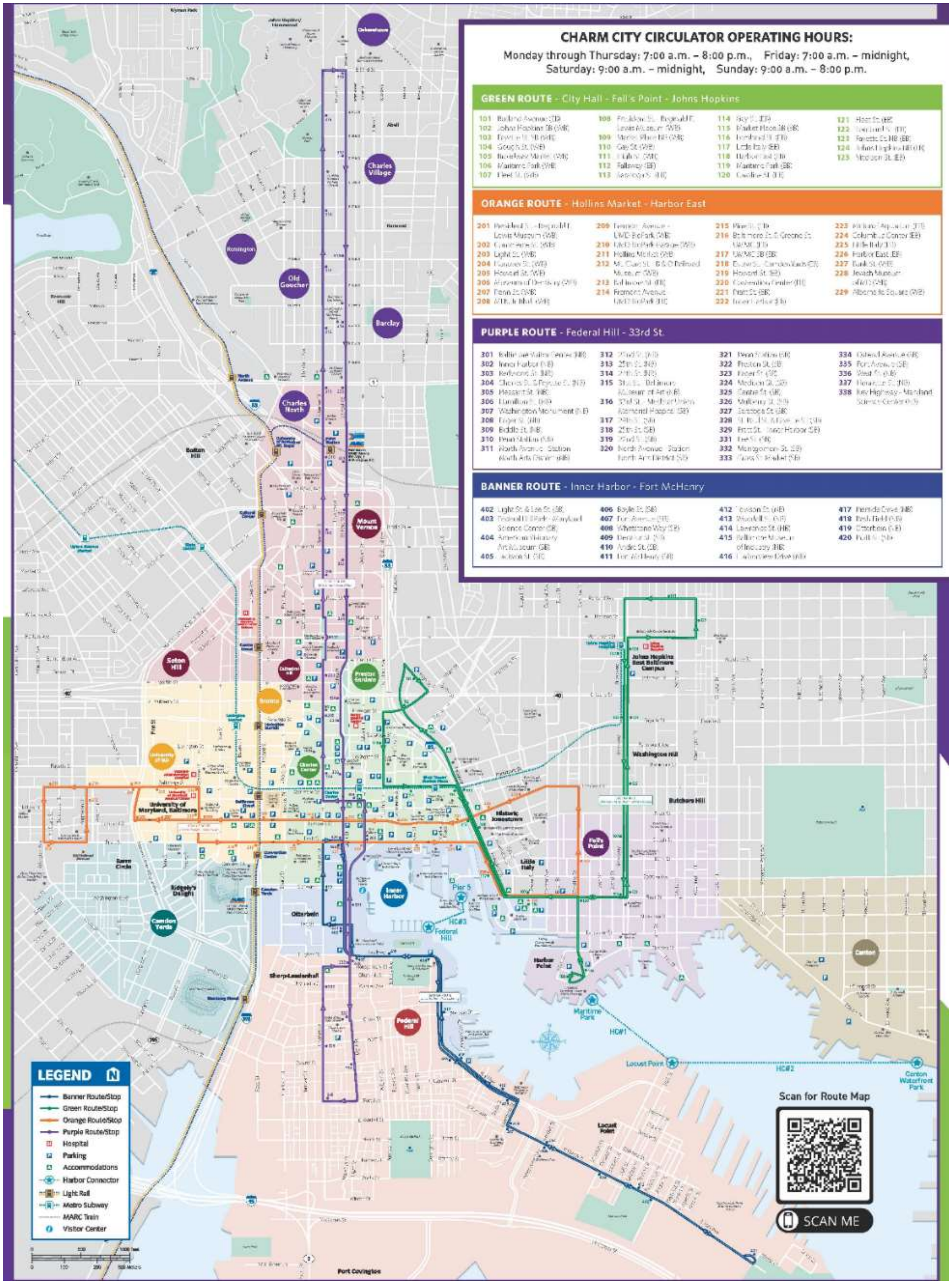


Figure 2-21. Charm City Circulator Map



Source: Baltimore City Department of Transportation 2021

Lifeline Utility Systems

This section presents data and information on potable water, wastewater, energy resource, and communication utility systems. Figure 2-22 shows the Food, Water, and Shelter lifelines in Baltimore City.

Potable Water

Baltimore City uses surface water from rainfall and snowmelt as the source of Baltimore City's water. Baltimore City's supply system is sourced by the Gunpowder Falls, the North Branch of the Patapsco River, and the Susquehanna River. There are three reservoirs located outside of Baltimore City limits that collect and store water/

Liberty Reservoir is located between Baltimore and Carroll Counties along the North Branch Patapsco River. It collects water from a 163.4 square mile drainage area. Liberty Dam impounds approximately 43 billion gallons of untreated water (Baltimore City Department of Public Works 2018). Water from the reservoir flows through a 12.7-mile-long tunnel to the Ashburton Water Filtration Plant for water treatment.

Loch Raven Reservoir is north of Baltimore City, and the source of the water is Gunpowder Falls. The Loch Raven Reservoir's capacity is approximately 23 billion gallons of water (Baltimore City Department of Public Works 2018). Water from the reservoir flows through a 7.3-mile-long tunnel to the Montebello Filtration Plant for water treatment.

Prettyboy Reservoir is northwest of Baltimore City and impounds roughly 19 billion gallons of water. It collects water from an 80 square mile watershed. The reservoir impounds 19 billion gallons of water and covers 1,5000 acres (Baltimore City Department of Public Works 2018). Water from Prettyboy is transferred to Local Raven Reservoir via Gunpower Falls rather than directly to Baltimore.

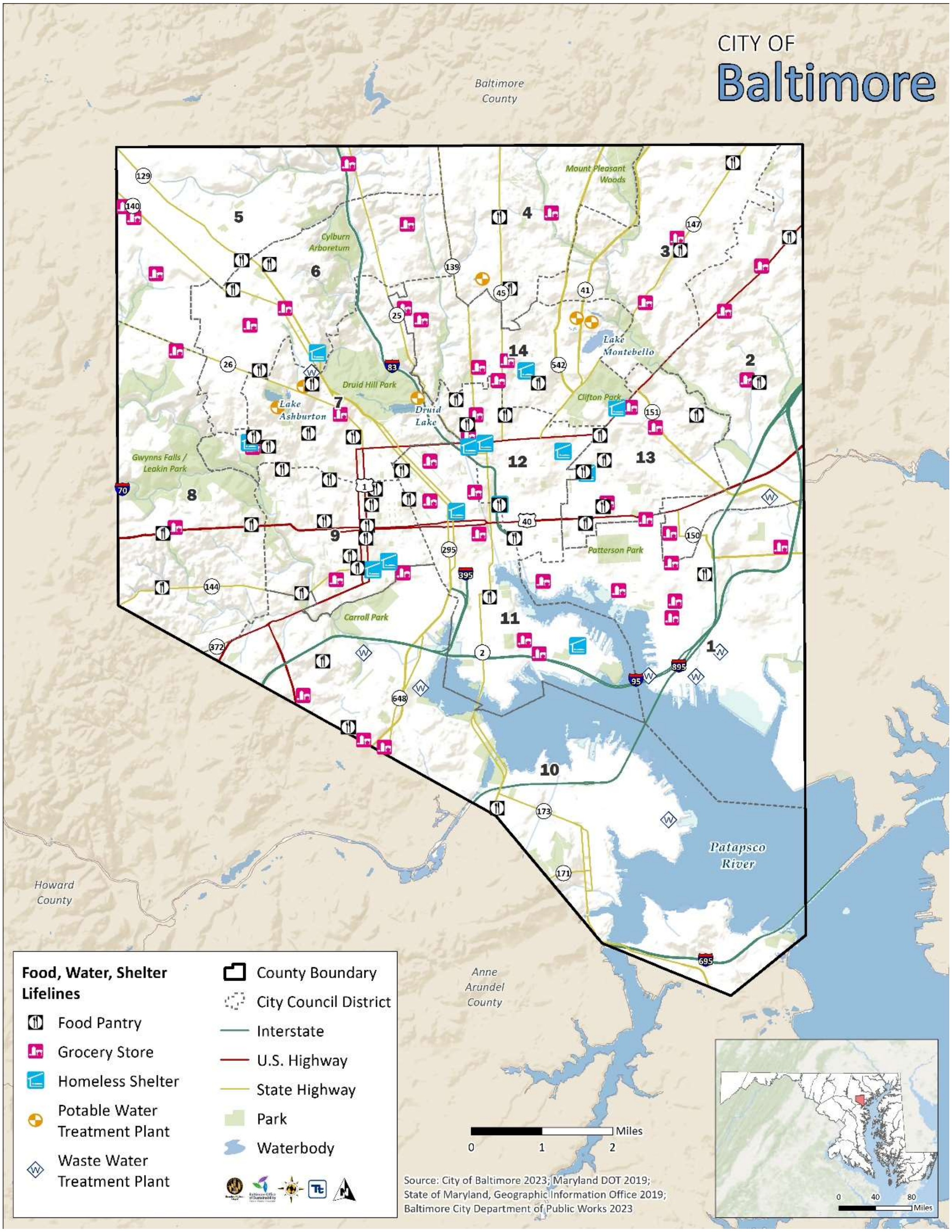
Water from the Susquehanna River is pumped via the Dear Creek Pumping Station to the Montebello Filtration Plants through the 38-mile-long Susquehanna Conduit. This source is used during times of extreme drought when storage is depleted in the reservoirs. It has a present capacity of about 150 million gallons per day with a planned future capacity of 200 million gallons per day (Baltimore City Department of Public Works 2018).

Baltimore City provides drinking water to over 1.8 million people in the Baltimore region (Baltimore City Department of Public Works n.d.). The water system has a current capacity of 360 million gallons per day but is projected to have a capacity of 480 million gallons per day by 2030 (Baltimore City Department of Planning n.d.).

Wastewater Facilities

Baltimore City has two wastewater treatment plants: Back River Wastewater Treatment Plant (BRWWTP) and the Patapsco Wastewater Treatment Plant. There are a total of 3,100 miles of sanitary mains within the entire system which runs throughout the Baltimore region. Approximately 1,400 miles of the sanitary mains are located within Baltimore City limits and maintained by Baltimore City (Baltimore City Department of Public Works n.d.). The Patapsco Wastewater Treatment Plant also services portions of Anne Arundel, Baltimore, and Howard Counties, which maintain their portions of the remaining 1,700 miles of sanitary mains (City of Baltimore 2006). Baltimore City also collects and treats an average flow of 200 million gallons of wastewater daily and operates 8 major wastewater pumping stations and 10 minor installations (Baltimore City Department of Public Works 2018).

Figure 2-22. Food, Water, and Shelter Lifelines



The BRWWTP is owned and operated by Baltimore City and is situated on the west shore of the Back River, a tributary of the Chesapeake Bay. The plant occupies a 466-acre site and serves an estimated 1.3 million residents in Baltimore City and Baltimore County. The

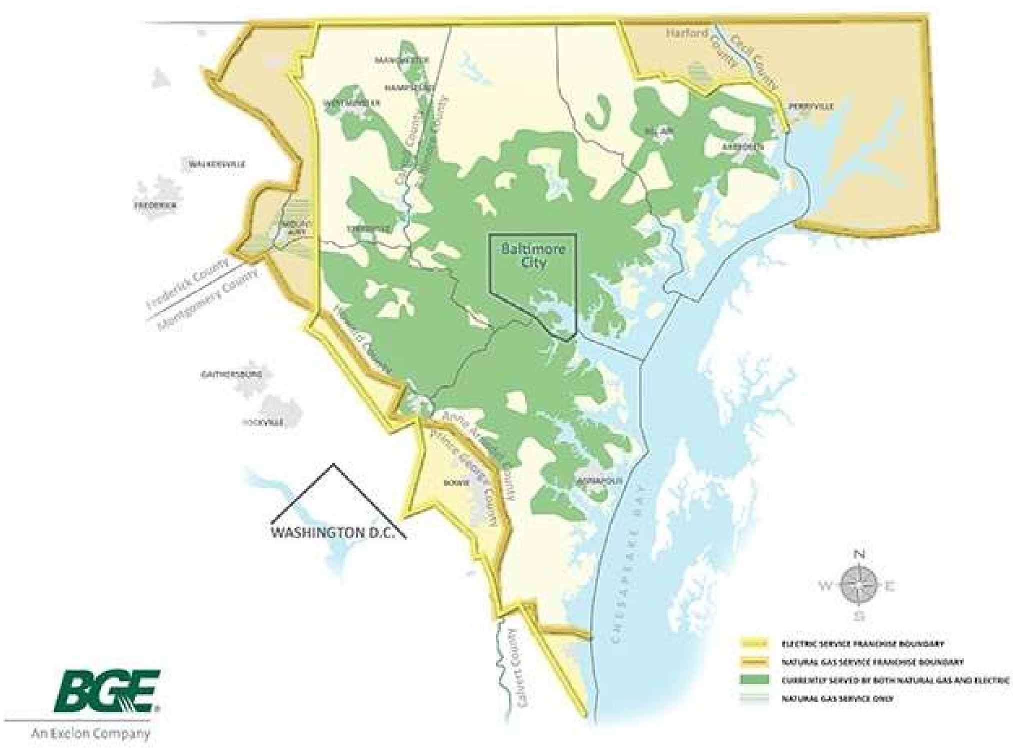
BRWWTP currently employs approximately 300 people, including supervisory, operations, maintenance, and laboratory personnel. Twenty-four-hour, year-round plant operation is maintained. The facility has evolved into a tertiary treatment plant and is currently designed to treat 180 million gallons per day of wastewater utilizing fine bubbles and air-distributed activated sludge (Baltimore City Department of Public Works 2018).

The Patapsco Wastewater Treatment Plant is a secondary treatment facility with enhanced nutrient removal (ENR), chlorination, and de-chlorination, situated on 69 acres on the Patapsco River at Wagner's Point. The plant has grown from a capacity of 5 million gallons per day in 1940 to its present-day capacity 63.0 million gallons per day. It serves an area of approximately 184 square miles and an estimated population of approximately 450,000. The plant employs approximately 180 people to treat wastewater generated from Baltimore City as well as Baltimore, Howard, and Anne Arundel Counties. Wastewater treatment at Patapsco consists of grit removal, screening out large solid materials, settling out solids during an hour's retention, and removal of suspended and dissolved materials (Baltimore City Department of Public Works 2018).

Energy Resources

Baltimore Gas and Electric (BGE) is a subsidiary of Exelon Corporation. The utility provides both electric and gas service in the central Maryland area, including Baltimore City; Baltimore County; Anne Arundel County; most of Howard, Carroll, and Harford Counties; and parts of Prince George's, Montgomery, and Calvert Counties (Baltimore Gas and Electric Company 2022). The service area is shown in Figure 2-23.

Figure 2-23. BGE Service Area Map



Source: Baltimore Gas and Electric Company 2022

BGE serves more than 1.3 million electric customers and more than nearly 700,000 gas customers, including the entirety of Baltimore City (see Figure 2-23 for BGE's service area). Overall, BGE has a service area of 2,300 square miles for electric service and 800 square miles for gas service. The company maintains 244 substations, plus an additional 92 located on private property. BGE has 26,600 circuit miles distribution and 1,300 circuit miles transmission. Finally, the company has 7,600 miles of natural gas pipeline, of which 5.76 miles intersect the boundaries of Baltimore City (Baltimore Gas and Electric Company 2022).

Renewable energy in the form of biomass is generated in Baltimore City at the Wheelabrator Baltimore, located in the Westport neighborhood of Baltimore City. The 61-megawatt facility also produces steam for a downtown piping system that supplies heat to more than 250 businesses (U.S. Energy Information Administration 2022).

Communications

Baltimore City is served by a variety of communications systems, including traditional landline, fiber optic, and cellular service provided by multiple companies. Each carrier has individual plans for emergency situations during hazard events and post-disaster recovery efforts. In addition to landline, fiber optic, and cellular communications systems, Baltimore City has an extensive radio communications network that is utilized by emergency services agencies, hospitals, law enforcement, public works, transportation, and other supporting organizations. Figure 2-24 displays the communication lifelines in Baltimore City.

High-Potential Loss Facilities

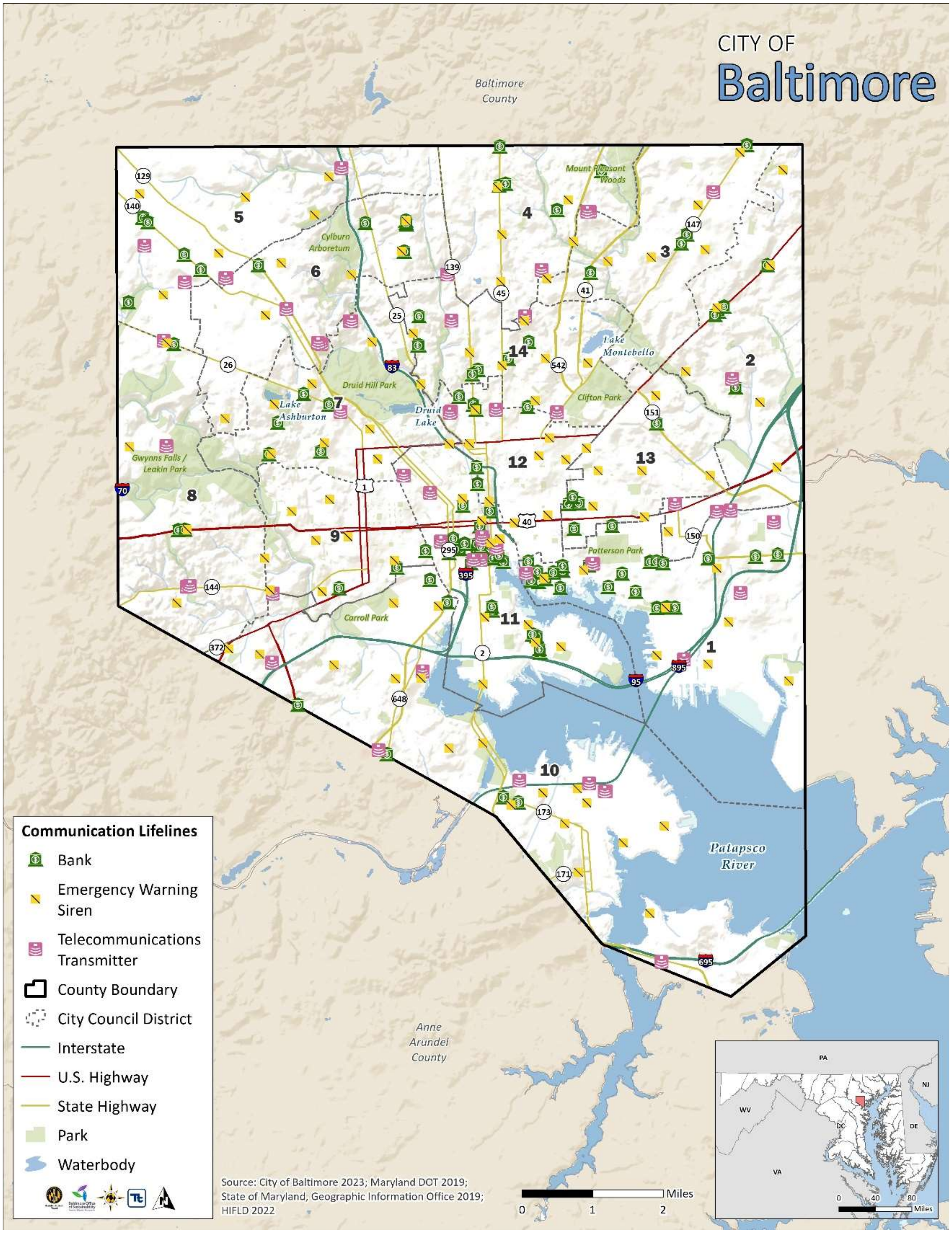
High-potential loss facilities include hazardous materials (HAZMAT) facilities and dams and levees.

HAZMAT Facilities

The public access database for the U.S. Environmental Protection Agency's (EPA) Comprehensive Environmental Response, Compensation and Liability Information System (Superfund) reports that there are currently two Superfund sites in Baltimore City (USEPA 2023). Superfund sites are polluted locations requiring a long-term response to clean up hazardous material contaminations.

The Chemical Metals Industries (CMI) Site is located on two non-contiguous parcels of land on Annapolis Road in the residential, commercial, and industrial mixed-use area of Westport. At one of the properties, CMI operated a chemical manufacturing facility and recovered precious metals (Site 2). CMI used the other property, an inactive gas station, for storage of waste and scrap metal (Site 1). Site activities and leaking drums on both properties contaminated soil and groundwater with hazardous chemicals, including elevated concentrations of metals and volatile organic compounds. Mass removal of impacted surficial shallow soils was performed under U.S. EPA and Maryland Department of the Environment (MDE) oversight. MDE continues to provide direct regulatory oversight and monitor soil gas and groundwater concentrations of contaminants (EPA 2023).

Figure 2-24. Communication Lifelines



The Kane & Lombard Street Drums Superfund Site consists of two former waste disposal areas located near the intersection of Kane and Lombard Streets. The two former waste areas are also known as operable units (OU). The groundwater beneath the site and in the vicinity is contaminated with volatile organic compounds (VOC), including trichloroethene, 1,2-dichloroethene, and vinyl chloride as a result of past waste disposal (EPA 2023).

Dams and Levees

Dams are classified in terms of potential for downstream damage if the dam were to fail. Hazard classifications are as follows (Maryland Department of the Environment 2015):

- Low Hazard (Class A) is a dam located in an area where failure is unlikely to result in loss of life, and only minor increases to existing flood levels at roads and buildings is expected. These structures are referred to as “Category III” dams in Code of Maryland Regulations (COMAR 26.17.04.05) and “Class A” ponds by the US Natural Resources Conservation Service (NRCS).
- Significant Hazard (Class B) is a dam located in an area where failure could possibly result in loss of life or increase flood risks to roads and buildings, with no more than two houses impacted and less than six lives in jeopardy. These are referred to as “Category II” dams in COMAR and “Class B” by NRCS.
- High Hazard (Class C) is a dam located in an area where failure would likely result in loss of human life, extensive property damage to homes and other structures, or cause flooding of major highways such as State roads or interstates. High hazard dams are referred to as “Category I” dams in COMAR and “Class C” by NRCS.

According to the United States Army Corps of Engineers (USACE) National Inventory of Dams (NID), there are 10 dams located within Baltimore City with 6 listed as high hazard, 2 listed as significant hazard, and 2 listed as low hazard. Out of the 10 dams present in Baltimore City, 7 have an Emergency Action Plan (EAP) prepared. According to the National Levee Database maintained by USACE, there are no levees in Baltimore City (USACE 2023).

Section 3. Risk Assessment

3.1 Identification of Hazards of Concern

FEMA Planning Policy Element B1: 44 CFR 201.6(c)(2)(i): The plan must describe the type, location, and extent of all natural hazards that can affect the jurisdiction, including information on previous occurrences of hazard events and the probability of future hazard events.

To provide a strong foundation for mitigation strategies considered in Section 14 (Mitigation Strategy), Baltimore City considered a full range of natural and human-caused hazards that could impact the area and then identified and ranked those hazards that presented the greatest concern. The hazards of concern identification process incorporated input from Baltimore City and its stakeholders; review of the State of Maryland Hazard Mitigation Plan and previous hazard identification efforts; research and local, state, and federal information on the frequency, magnitude, and costs associated with the various hazards that have previously, or could feasibly, impact the region; and qualitative or anecdotal information regarding hazards and the perceived vulnerability of Baltimore City's assets to them.

For the purposes of this planning effort, the Planning Team chose to group some natural hazards together based on the similarity of hazard events, their typical concurrence or their impacts, consideration of how hazards have been grouped in FEMA guidance documents (FEMA 386-1, "Understanding Your Risks, Identifying Hazards and Estimating Losses; FEMA's "Multi-Hazard Identification and Risk Assessment – The Cornerstone of the National Mitigation Strategy"), and consideration of hazard grouping in the State of Maryland HMP.

3.1.1 Hazards of Concern for the 2023 DP3

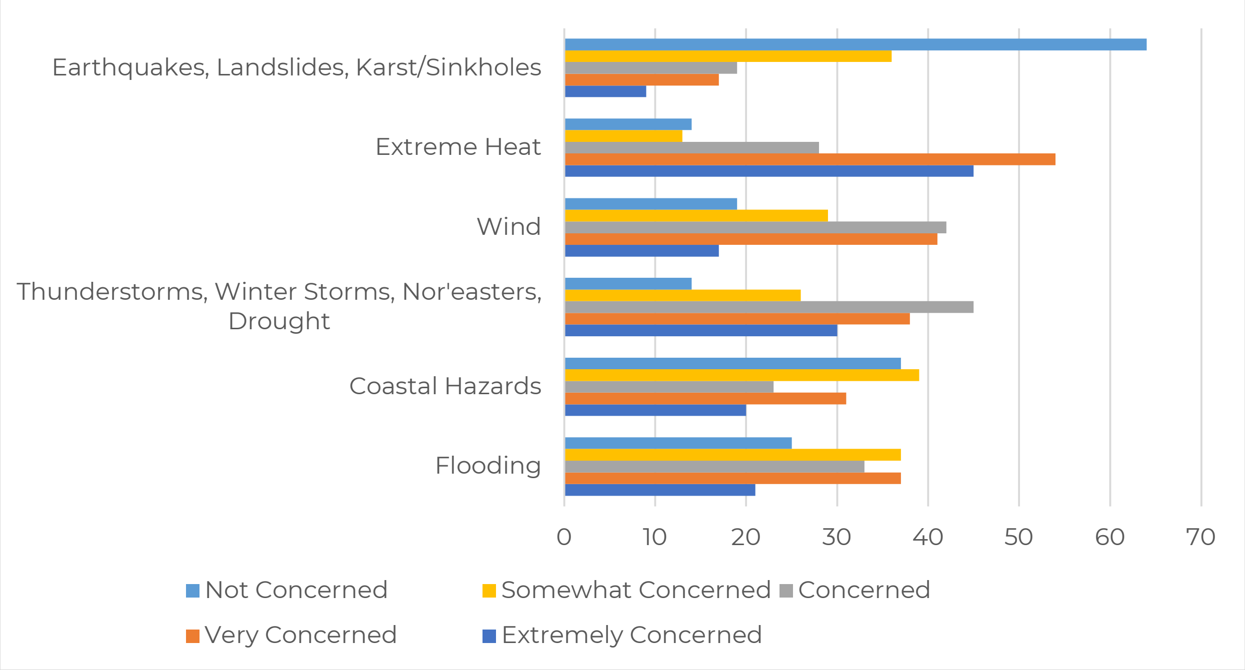
Based on input from the CPT, HMAC, stakeholder and community members and review of all available resources, eight hazards of concern were identified as significant hazards affecting the entire City to be addressed in this plan:

- Coastal Hazards
- Drought
- Earthquakes
- Extreme Temperature
- Flooding
- Human-caused (cyber-attack and hazardous materials)
- Severe Storms
- Soil Movement

Other natural and human-caused hazards of concern have occurred within Baltimore City but have a low potential to occur and/or result in significant impacts within Baltimore City or are covered in other plans that specifically address technological and intentional hazards. Therefore, these hazards will not be further addressed within this version of the plan. However, if deemed necessary by Baltimore City, these hazards may be considered in future versions of the DP3.

During the initial stages of the planning process, surveys were distributed to the CPT, HMAC, stakeholders, and the general public. The survey assessed respondents' perception of risk and vulnerability to natural and human-caused hazards in Baltimore City. Select survey results are shown below in Figure 3-1. The hazard groupings shown reflect those of surveys sent by the Department of Planning and Office of Emergency Management in 2018 and align with the 2018 DP3 hazard groupings. Respondents provided additional comments regarding concerns for public health, climate change, and overheating as a result of extreme temperatures and lack of tree canopy.

Figure 3-1. Concern for Naturally Occurring Hazards



In addition to this data, the results from prior surveys distributed for the 2018 DP3 and planning efforts conducted by OEM informed the identification of human-caused hazards to include in the 2023 update. In addition to the survey results, historic event occurrences influenced the identification of human-caused hazards, including a cyber-attack on Baltimore City Police Department in 2017, a citywide governmental cyber-attack in 2018, a train derailment in the Howard Street tunnel, and an understanding of hazardous materials transported on major throughways within Baltimore City. The results of the 2018 DP3 are shown in Figure 3-2, and the results of OEM's efforts are shown in Figure 3-3.

Table 3-1 documents the process of identifying the natural and human-caused hazards of concern for further profiling and evaluation.

Figure 3-2. 2018 DP3 Concern for Human-Caused Hazards

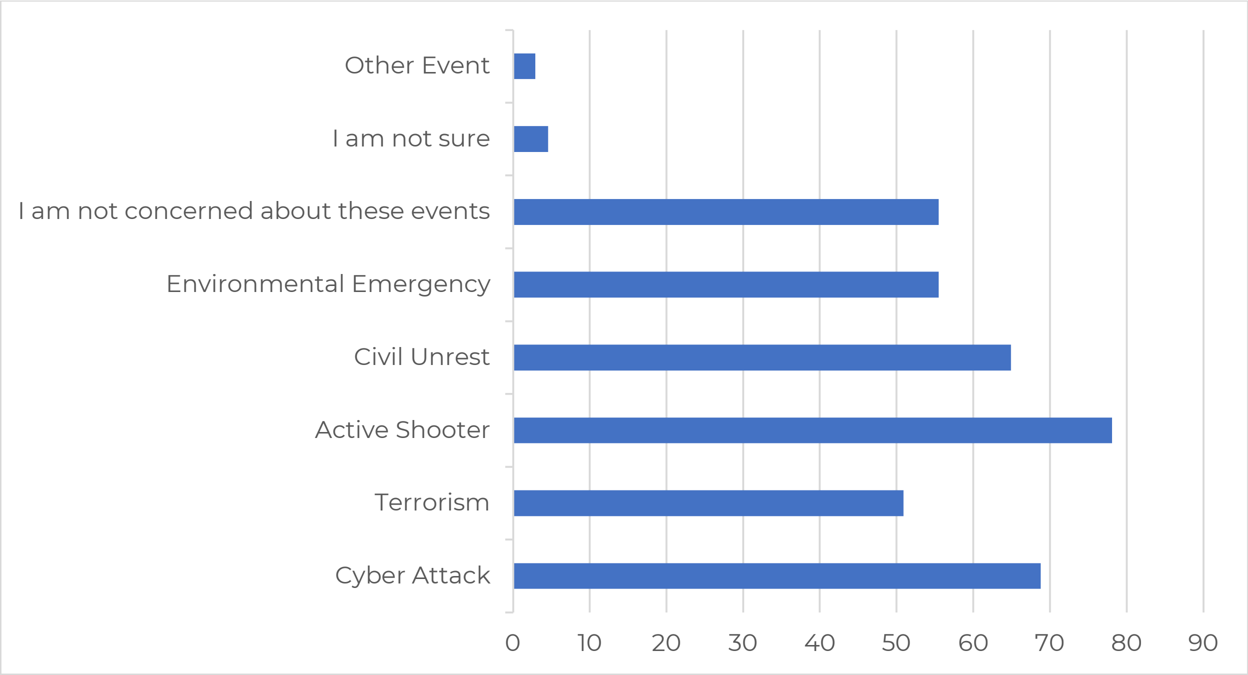


Figure 3-3. Interest in Disaster Preparedness by Hazard Type

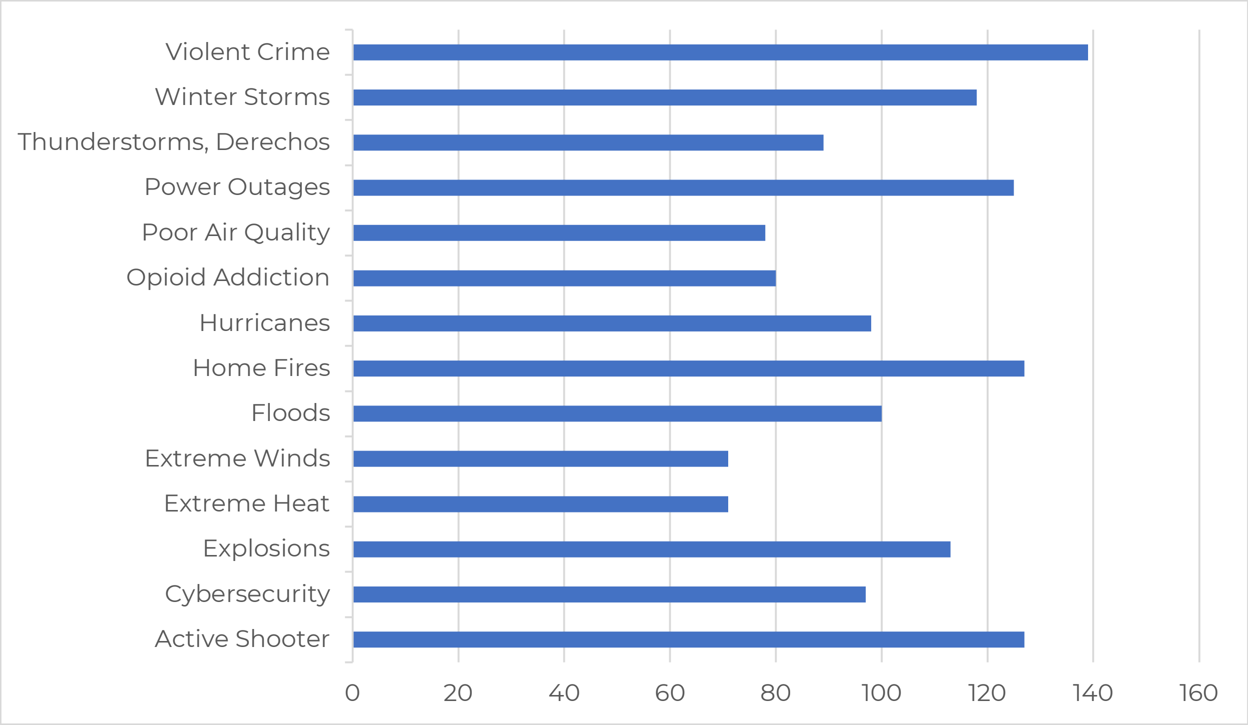


Table 3-1. Identification of Hazards of Concern for Baltimore City

Hazard	Is this a hazard that may occur in Baltimore City?	Why was this determination made?	Source(s)
Coastal Hazards	Yes – tropical storms, hurricanes, and nor'easters	The Maryland State HMP identifies coastal hazards as a hazard of concern for Maryland. The CPT and HMAC identified coastal hazards as a hazard of concern for Baltimore City.	Maryland State HMP CPT and HMAC Input Stakeholder and Public Surveys NOAA
Dam Failure	Yes	The Maryland State HMP identifies dam failure as a hazard of concern for Maryland. The CPT and HMAC included dam failure as a hazard of concern within the flooding hazard profile for Baltimore City.	Maryland State HMP CPT and HMAC Input Stakeholder and Public Surveys
Drought	Yes	The Maryland State HMP identifies drought as a hazard of concern for Maryland. Maryland has entered periods of drought, and Baltimore City has experienced droughts classified in the moderate and severe categories. The CPT and HMAC identified drought as a hazard of concern for Baltimore City.	Maryland State HMP Core Planning and Planning Team Input Stakeholder and Public Surveys NOAA
Earthquake	Yes	Baltimore City experienced impacts from an earthquake in the greater Mid-Atlantic region in 2011 and 2021. The CPT and HMAC identified earthquake as a hazard of concern for Baltimore City.	Maryland State HMP CPT and HMAC Input NOAA
Extreme Temperature	Yes – extreme cold and extreme heat	The Maryland State HMP identifies extreme temperature as a hazard of concern for Maryland. Baltimore City has been included in 13 documented extreme temperature events since 2000; 3 extreme cold/wind chill events and 10 excessive heat events. The CPT and HMAC identified extreme temperature as a hazard of concern for Baltimore City.	Maryland State HMP CPT and HMAC Input Stakeholder and Public Surveys NOAA
Flooding	Yes – riverine, flash, urban, coastal and nuisance flooding, sea level rise, and dam failure	The Maryland State HMP identifies flooding as a hazard of concern for Maryland. Baltimore City was part of three statewide emergency declarations for flooding (DR-309, DR-341, and DR-489). Baltimore City has experienced numerous flood and flash flood events since 2018. Baltimore City has six high hazard classified dams as well as two dams with a significant hazard potential classification.	Maryland State HMP CPT and HMAC Input Stakeholder and Public Surveys FEMA NOAA National Inventory of Dams

Hazard	Is this a hazard that may occur in Baltimore City?	Why was this determination made?	Source(s)
		The CPT and HMAC identified flooding as a hazard of concern for Baltimore City.	
Human-caused Hazards	Yes – cyber-attack and hazardous materials	The Maryland State HMP identifies human-caused hazards as a hazard of concern for Maryland. Baltimore City has been victim to two cyber-attacks and experienced several hazardous materials events. The CPT and HMAC identified cyber-attack and hazardous materials as the human-caused Hazards for Baltimore City.	Maryland State HMP CPT and HMAC Input Stakeholder and Public Surveys
Public Health Emergencies	No	The Maryland State HMP identifies public health emergencies as a hazard of concern for Maryland. The CPT and HMAC did not identify this as a hazard of concern for inclusion in the DP3 for Baltimore City. In 2021, the Mayor's Office of Recovery Programs published the *Baltimore City Recovery Plan,* which addresses the COVID-19 pandemic. Within each hazard profile, cascading public health impacts are described.	Maryland State HMP CPT and HMAC Input Stakeholder and Public Surveys
Severe Storms	Yes – winter storms, thunderstorms, extreme wind events (i.e., derecho), and tornadoes	The Maryland State HMP identifies thunderstorm, tornado, wind, and winter storm as hazards of concern for Maryland. Baltimore City was included in 11 FEMA declarations between January 1950 – June 2023 in relation to severe storms. The CPT and HMAC identified severe storms as a hazard of concern for Baltimore City.	Maryland State HMP CPT and HMAC Input Stakeholder and Public Surveys NOAA FEMA
Soil Movement	Yes – landslides, sinkholes, and urban karst	The Maryland State HMP identifies soil movement as a hazard of concern for Maryland. Baltimore has experienced landslide and sinkhole events that resulted in significant damage. The CPT and HMAC identified soil movement as a hazard of concern for Baltimore City.	Maryland State HMP CPT and HMAC Input Event Frequency Past Occurrences
Thunderstorm	Yes	The Maryland State HMP identifies thunderstorm as a hazard of concern for Maryland. The CPT and HMAC included thunderstorm as a hazard of concern within the Severe Storms hazard profile for Baltimore City.	Maryland State HMP CPT and HMAC Input Stakeholder and Public Surveys NOAA
Tornado	Yes	The Maryland State HMP identifies tornado as a hazard of concern for Maryland.	Maryland State HMP CPT and HMAC Input

Hazard	Is this a hazard that may occur in Baltimore City?	Why was this determination made?	Source(s)
		The CPT and HMAC included tornado as a hazard of concern within the Severe Storms hazard profile for Baltimore City.	Stakeholder and Public Surveys NOAA
Tsunami	No	The Maryland State HMP does not identify tsunami as a hazard of concern for Maryland. Baltimore City included this hazard in its 2018 DP3 but has elected not to include it in this 2023 DP3 update due to its low probability of occurrence.	Maryland State HMP CPT and HMAC Input Stakeholder and Public Surveys
Wind	Yes	The Maryland State HMP identifies wind as a hazard of concern for Maryland. The CPT and HMAC included wind as a hazard of concern within the Severe Storms hazard profile for Baltimore City.	Maryland State HMP CPT and HMAC Input Stakeholder and Public Surveys
Wildfire	No	The Maryland State HMP does identify wildfire as a hazard of concern for Maryland; however, the Planning Team did not identify this as a hazard of concern for Baltimore City. No wildfire events have been reported by the National Centers for Environmental Information (NCEI) database, which has been reporting events since 1950; therefore, the CPT and the HMAC elected not to include this hazard. According to the Maryland Department of Natural Resources, Baltimore City is primarily developed with minimal deciduous forest; therefore, wildfire is not of major concern to Baltimore City.	Maryland State HMP CPT and HMAC Input Stakeholder and Public Surveys NOAA Maryland Forest Service Maryland Department of Natural Resources

3.1.2 Hazard Groupings

The CPT reviewed the grouping of hazards based on the similarity of hazard events, typical concurrence or impacts, consideration of how hazards have been grouped in FEMA guidance documents (*FEMA 386-2 Understanding Your Risks, Identifying Hazards and Estimating Losses*; *Multi-Hazard Identification and Risk Assessment – The Cornerstone of the National Mitigation Strategy*; *Local Mitigation Planning Handbook*), and consideration of hazard grouping in the State of Maryland HMP. The 2018 plan did not identify human-caused hazards, such as cyber terrorism and hazardous materials releases. The 2023 DP3 update includes many of the same hazards from the 2018 DP3, which have been updated based on feedback from stakeholders and community members and scientific data. Below is a summary of the hazard groupings.

The *Coastal Hazards* hazard profile specifically addresses tropical storms, hurricanes, and nor'easter events that have occurred in Baltimore City.

The *Drought* hazard profile specifically addresses drought events that occurred in Baltimore City.

The *Earthquakes* hazard profile addresses earthquake events that occurred in Baltimore City.

The *Extreme Temperature* hazard profile specifically addresses periods of extreme heat and cold that occurred in Baltimore City.

The *Flooding* hazard includes riverine, flash, urban, coastal and nuisance flooding, sea level rise, and dam and levee failure. Inclusion of the various forms of flooding is consistent with that used in FEMA's *Multi-Hazard Identification and Risk Assessment* guidance.

The *Human-Caused* hazard profile specifically addresses cyber-attack and hazardous material events in Baltimore City.

The *Severe Storms* hazard profile specifically addresses winter storms, thunderstorms, extreme wind events (i.e., derecho), and tornadoes that occurred in Baltimore City.

The *Soil Movement hazard* profile addresses settling of Earth's surface due to removal or displacement of earth materials, specifically in regard to land subsidence, landslides, sinkholes, and urban karst.

3.2 Methodology and Tools

Risk assessment is the process of measuring the potential loss of life, personal injury, economic injury, and property damage resulting from identified hazards. It allows emergency management personnel to establish early response priorities by identifying potential hazards and vulnerable assets.

The risk assessment for this HMP update evaluates the risk of natural and human-caused hazards prevalent in Baltimore City and meets requirements of the Disaster Mitigation Act

(44 CFR, Section 201.6(c)(2)). To protect individual privacy and the security of critical facilities, information on properties assessed is presented in aggregate, without details about specific individual personal or public properties.

The following describes the methodology and tools used to conduct the risk assessment for the Baltimore City DP3 2023 update.

3.2.1 Risk Assessment Tools

Mapping

National, state, and City databases were reviewed to locate available spatially based data relevant to this planning effort. Maps were produced using geographic information system (GIS) software to show the spatial extent and location of hazards when such datasets were available. These maps are included in the hazard profile chapters of this document.

Hazus

In 1997, FEMA developed the standardized Hazards U.S. (Hazus) model to estimate losses caused by earthquakes and identify areas that face the highest risk and potential for loss. Hazus was later expanded into a multi-hazard methodology with new models for estimating potential losses from hurricanes and floods.

Hazus is a GIS-based software program used to support risk assessments, mitigation planning, and emergency planning and response. It provides a wide range of inventory data, such as demographics, building stock, critical facility, transportation and utility lifeline, and multiple models to estimate potential losses from natural disasters. The program maps and displays hazard data and the results of damage and economic loss estimates for buildings and infrastructure. Its advantages include the following:

- Provides a consistent methodology for assessing risk across geographic and political entities.
- Provides a way to save data so that they can readily be updated as population, inventory, and other factors change and as mitigation planning efforts evolve.
- Facilitates review of mitigation plans because it helps to ensure that FEMA methodologies are incorporated.
- Supports grant applications by calculating benefits using FEMA definitions and terminology.
- Produces hazard data and loss estimates that can be used in communication with local stakeholders.
- Is administered by the local government and can be used to manage and update an HMP throughout its implementation.

Level of Detail for Evaluation

Hazus provides default data for inventory, vulnerability, and hazards; these default data can be supplemented with local data to provide a more refined analysis. The model can carry out three levels of analysis, depending on the format and level of detail of information about Baltimore City. A level 2 analysis was conducted for the HMP update for the hazards evaluated in Hazus

- **Level 1** — All of the information needed to produce an estimate of losses is included in the software's default data. These data are derived from national databases and describe in general terms the characteristic parameters of Baltimore City.
- **Level 2** — More accurate estimates of losses require more detailed information about Baltimore City. To produce Level 2 estimates of losses, detailed information is required about local geology, hydrology, hydraulics, and building inventory as well as data about utilities and critical facilities. This information is needed in a GIS format.
- **Level 3** — This level of analysis generates the most accurate estimate of losses. It requires detailed engineering and geotechnical information to customize it for Baltimore City.

3.2.2 Risk Assessment Approach

The risk assessment in this plan describes the risks associated with each hazard of concern. The following steps were used to define the risk of each hazard:

- **Identify and profile each hazard** — The following information is given for each hazard:
  - Geographic areas most affected by the hazard
  - Event frequency estimates
  - Severity estimates
- **Determine exposure to each hazard** — Exposure was assessed by overlaying hazard maps with an inventory of structures, facilities, and systems to decide which of them would be exposed to each hazard.
- **Assess the vulnerability of exposed facilities** — Vulnerability of exposed structures and infrastructure was evaluated by interpreting the probability of occurrence of each event and assessing structures, facilities, and systems that are exposed to each hazard. Tools such as GIS and FEMA's hazard-modeling program (Hazus) were used for this assessment for the earthquake and flood. Outputs similar to those from Hazus were generated for other hazards using data generated through GIS.

Coastal Hazards

A Hazus v5.1 probabilistic analysis was performed to analyze the wind hazard losses for Baltimore City for the 100-year mean return period event. The probabilistic Hazus hurricane model activates a database of thousands of potential storms that have tracks and intensities reflecting the full spectrum of Atlantic hurricanes observed since 1886 and identifies those with tracks associated with Baltimore City. Hazus contains data on historic hurricane events and wind speeds. It also includes surface roughness and vegetation (tree coverage) maps for the area. Surface roughness and vegetation data support the modeling of wind force across various types of land surfaces. Default demographic and updated building and critical facility inventories in Hazus v5.1 were used for the analysis. Although damage is estimated at the Census tract level, results were presented at Baltimore City Council District level. Because there are multiple Census tracts that contain more than one City Council District, an area analysis was used to extract the percent of each tract that falls within individual jurisdictions. The percentage was multiplied against the results calculated for each tract and summed for each City Council District.

Storm Surge

Storm surge hazard data available from the NOAA was used for this analysis to understand the assets within communities projected to be impacted by hurricane storm surge (refer to Section 6: Coastal Hazards). This risk assessment used NOAA's 2023 Sea Lake Overland Surge from Hurricanes (SLOSH) data to analyze the assets at risk from impacts of hurricane storm surge.

SLOSH represents potential flooding from worst-case combinations of hurricane direction, forward speed, landfall point, and high astronomical tide were used to estimate exposure. Please note these inundation zones do not include riverine flooding caused by hurricane surge or inland freshwater flooding. The model, developed by the NOAA National Hurricane Center to forecast surges that occur from wind and pressure forces of hurricanes, considers only storm surge height and does not consider the effects of waves. The SLOSH spatial data includes boundaries for Category 1 through Category 4 hurricane events.

To estimate exposure to the SLOSH Category 1 through Category 4 flood hazard areas, the spatial flood hazard boundaries were overlaid on centroids of updated assets (population, building stock, critical facilities, and lifelines). Centroids that intersected the hazard areas were totaled to estimate the building replacement cost value and population vulnerable to the storm surge inundation areas.

Drought

To assess the vulnerability of Baltimore City to drought and its associated impacts, a qualitative assessment was conducted. Resources from the 2018 Baltimore DP3, the 2021 State of Maryland HMP, University of Maryland's Center for Environmental Science, and the National Drought Mitigation Center were used to assess the potential impacts to the population from a drought event.

Earthquakes

A probabilistic assessment was conducted for Baltimore for the 500-year mean return period earthquake through a Level 2 analysis in Hazus to analyze the earthquake hazard and provide a range of loss estimates. The probabilistic method uses information from historic earthquakes and inferred faults, locations, and magnitudes and computes the probable ground shaking levels that may be experienced during a recurrence period by Census tract.

As noted in the Hazus Earthquake User Manual, "Although the software offers users the opportunity to prepare comprehensive loss estimates, it should be recognized that uncertainties are inherent in any estimation methodology, even with state-of-the-art techniques. Any region or city studied will have an enormous variety of buildings and facilities of different sizes, shapes, and structural systems that have been constructed over a range of years under diverse seismic design codes. There are a variety of components that contribute to transportation and utility system damage estimations. These components can have differing seismic resistance" (FEMA 2022). However, Hazus' potential loss estimates are acceptable for the purposes of this HMP.

Ground shaking is the primary cause of earthquake damage to structures, and soft soils amplify ground shaking. One contributor to the site amplification is the velocity at which the rock or soil transmits shear waves (S-waves). The National Earthquake Hazard Reductions Program (NEHRP) has developed five soil classifications defined by their shear-wave velocity that impact the severity of an earthquake. The soil classification system ranges from A to E, where A represents hard rock that reduces ground motions from an earthquake and E represents soft soils that amplify and magnify ground shaking and increase building damage and losses. NEHRP Class D and E soils are the two classes most susceptible to amplified ground motion during an earthquake. Baltimore City did not have an available dataset to indicate class D or E class soils.

Groundwater was set at a depth of 5 feet (default setting). The default assumption is a magnitude 7.0 earthquake for all return periods. Although damage is estimated at the Census tract level, results were presented at the municipal level. Because there are multiple Census tracts that contain more than one jurisdiction, the general building stock was used to determine the percent coverage of Census tracts within a City Council District. The percentage was multiplied against the results calculated for each tract and summed for each City Council District.

Damage estimates are calculated for losses to buildings (structural and non-structural) and contents; structural losses include load-carrying components of the structure; and non-structural losses include those to architectural, mechanical, and electrical components of the structure, such as nonbearing walls, veneer and finishes, HVAC systems, boils, etc.

Extreme Temperature

All of Baltimore City is exposed to extreme temperature events. A qualitative assessment was conducted for the extreme temperatures hazard (heat and cold). Information from the National Weather Service (NWS), Centers for Disease Control and Prevention, stakeholder plans/reports, the Baltimore City Department of Health, the State of Maryland Department of Health, the 2018 Baltimore DP3, the 2021 State of Maryland HMP, and the CPT were used to assess the potential impacts to Baltimore City's assets.

Flooding

The 1 percent flood has a 1 in 100 chance of happening in a given year, while the 0.2 percent chance flood has a 1 in 500 chance of occurring in a given year. The 1 percent and 0.2 percent chance flood events were examined to evaluate Baltimore City's risk and vulnerability to the riverine flood hazard. The effective Baltimore City FEMA Digital Flood Insurance Rate Map (DFIRM) dated June 16, 2021, was used to evaluate exposure and determine potential future losses. These flood events are generally those considered by planners and evaluated under federal programs such as the NFIP.

The flood risk areas for the 1 percent and 0.2 percent annual chance flood events were published on the FEMA map service center June 2021. The flood risk area was used to divide the zones in the 2014 and 2021 effective DFIRMs into coastal and riverine zones. The coastal V zones were merged with 2014 and 2021 VE zones to create the coastal flood hazard boundary, which was used to create the coastal depth grids for the 1 percent annual chance flood. The riverine AE zones were merged with the AO and A zones to create the 1 percent annual chance flood event riverine depth grid.

The final coastal and riverine depth grids were processed using a 2014 United States Geological Survey (USGS) 1-meter resolution DEM. These depth grids were integrated into the Hazus v5.1 riverine and coastal flood models used to estimate potential losses for the 1 percent annual chance flood event.

To estimate exposure to the 1 percent- and 0.2 percent annual chance flood events, the DFIRM flood boundaries were overlaid on centroids of updated assets (population, building stock and critical facilities). Centroids that intersected the flood boundaries were totaled to estimate the building replacement cost value and population vulnerable to the flood inundation areas. A Level 2 Hazus v5.1 riverine flood analysis was performed. Both the critical facility and building inventories were formatted to be compatible with Hazus v5.1 and its Comprehensive Data Management System (CDMS). Once updated with the inventories, the Hazus v5.1 riverine and coastal flood model was run to estimate potential losses in Baltimore City for the 1 percent annual chance flood events. A user-defined analysis was also performed for the building stock. Buildings located within the floodplain were imported as user-defined facilities to estimate potential losses to the building stock at the structural level. Hazus v5.1 calculated the estimated potential losses to the population (2017–2021 American Community Survey 5-year estimate), potential damage to the general building stock, and potential damage to critical facility inventories based on the depth grids generated and the default Hazus v5.1 damage functions in the flood model.

Sea Level Rise

The sea level rise hazard data was provided by Eastern Shore Regional GIS Cooperative. This data is the 1 percent annual chance flood event, projected for 2050, inclusive of sea level rise. For this risk assessment, the sea level rise hazard area data along the coastal sections of Baltimore City were utilized to determine what assets are exposed. Population, general building stock, and critical facility datasets were overlaid with the hazard area. Assets with their centroid or polygon in the hazard area were totaled to estimate the totals and values at risk from impacts of a sea level rise hazard event. Please note these inundation zones do not include riverine flooding caused by sea level rise.

Human-Caused

A qualitative analysis was conducted for the human-caused hazard. All of Baltimore City is considered exposed due to the historical existence and evidence of human-caused hazards in the State of Maryland and City of Baltimore. Data from the US EPA, United States Energy Information Administration, Maryland Department of Emergency Management, the Baltimore City Police Department, OEM, and the Baltimore City Fire Department was used to develop the hazard profile and to determine risk and exposure.

Hazardous materials were analyzed as a buffered hazard area in the following ways: major roadways and railroads were assigned a 0.5-mile buffer around them. Inventory data (population, general building stock, and critical facilities) were overlaid with the buffered hazard areas. Assets with their centroid in the hazard area were totaled to estimate the totals and values at risk from impacts of a hazardous materials event. A qualitative discussion on risk from fixed hazardous material facilities was included in the hazard profile.

Severe Storms

All of Baltimore City is exposed and vulnerable to severe storm events. A qualitative assessment was conducted for the severe storm hazard. Information from National Oceanic and Atmospheric Administration, U.S. EPA, U.S. Department of Health and Human Services, the 2018 Baltimore DP3, the 2021 State of Maryland HMP, and the Centers for Disease Control and Prevention were used to assess the potential impacts to Baltimore City's assets.

Soil Movement

Best available data was used to assess Baltimore City's vulnerability to landslide events. Baltimore City assessed the landslide hazard area using 2014 1-meter digital elevation model (DEM) created by USGS. The 1-meter DEM was used to determine areas where land area is sloping greater than 30 percent grade. Asset data (population, building stock, and critical facilities) were used to support an evaluation of assets at risk from potential impacts and losses associated with this hazard. To determine what assets are at risk from landslide events, assets with their centroid located within the steep slope hazard areas were totaled to estimate the number of persons, buildings, and facilities at risk from impacts of the landslide events.

3.2.3 Sources of Data Used in Hazus Modeling and Exposure Analyses

Baltimore City assets were identified to assess potential exposure and loss associated with the hazards of concern. For the DP3 update, Baltimore City assessed exposure vulnerability of the following types of assets: population, buildings, and critical facilities/infrastructure. Some assets may be more vulnerable because of their physical characteristics or socioeconomic uses. To protect individual privacy and the security of critical facilities, information on properties assessed is presented in aggregate, without details about specific individual personal or public properties.

Buildings and Cost Data

The building stock inventory was updated using the Maryland Department of Planning's spatial data. To develop the building inventory, parcels from the 2023 Department of Planning and 2022 CAMA (Computer-Assisted Mass Appraisal) Building Point data building points were used.

Parcel data records were joined to the CAMA building point spatial files to further define each structure in terms of occupancy class, construction type, year built, foundation type, etc. Default information was used to fill in the gaps for buildings that could not be assigned attributes from the assessor's data or from the data provided by the County and jurisdictions. If a building point was not located in a parcel due to limited spatial data, parcels that had assessor's information supporting the presence of a building were given a centroid to represent the location of a structure.

Structural and content Replacement Cost Values were calculated for each building utilizing available assessor data and RS Means 2022 values. A regional location factor for Baltimore City was applied based on the individual building stock's zip code location:

- 0.93 for residential structures
- 0.94 for non-residential structures

Replacement cost value is the current cost of returning an asset to its pre-damaged condition, using present-day cost of labor and materials. Total replacement cost value consists of both the structural cost to replace a building and the estimate value of contents of a building. The occupancy classes available in Hazus v5.1 were condensed into the following categories (residential, commercial, industrial, agricultural, religious, governmental, and educational) to facilitate the analysis and the presentation of results. Residential loss estimates address both multi-family and single-family dwellings.

Critical Facilities and Lifelines

The 2023 DP3 critical facility inventory, which includes essential facilities, utilities, transportation features, and user-defined facilities, was provided by Baltimore City's Information Technology: GIS Department. The update involved a review for accuracy, identification of backup power for each asset (if known), and whether the critical facility is considered a lifeline in accordance with FEMA's definition (i.e., systems which enable the continuous operation of critical government and business functions and is essential to human health and safety or economic security). To protect individual privacy and the security of assets, information is presented in aggregate without details about specific individual properties or facilities.

Population

Total population statistics from the 2017–2021 American Community Survey 5-year estimate were used to estimate the exposure and potential impacts to the County's population in place of the 2020 U.S. Census block estimates. Population counts were evenly distributed by the number of residential buildings per City Council District generated from the building stock inventory used in the HMP update. This estimate is a more precise distribution of population across the County compared to only using the Census block or Census tract boundaries. Limitations of these analyses are recognized, and thus the results are used only to provide a general estimate for planning purposes.

As discussed in Section 2 (City Profile), research has shown that some populations are at greater risk from hazard events because of decreased resources or physical abilities. Vulnerable populations in Baltimore City included in the risk assessment are children (population under 5); older adults (population over 65); low-income population; economically disadvantaged populations; persons with limited access to transportation; non-English speaking population; persons with limited English proficiency; Black, Indigenous, and People of Color; individuals living in group quarters; Lesbian, Gay, Bisexual, Transgender, Queer, Intersex, Asexual or Ally, and Additional Identities (LGBTQIA+); and persons institutionalized with a disability.

Data Summary Source

Table 3-2 summarizes the data sources used for the risk assessment for this plan.

Table 3-2. Data Source Summary

Data	Source	Date	Format
Population Data	U.S. Census Bureau, American Community Survey 5-Year Estimates	2017–2021;	Digital (GIS) Format; CSV
Building Inventory	Maryland Department of Planning	2022–2023	Digital (GIS) Format
Critical Facilities and Lifelines	City of Baltimore	2023	Digital (GIS) Format
Digitized Effective FIRM Data	FEMA	2021	Digital (GIS) Format
Digital Elevation Model	USGS	2014	Digital (GIS) Format
Flood Depth Grids	FEMA; USGS	2021; 2014	Digital (GIS) Format

Data	Source	Date	Format
Landslide/Steep Slope	USGS	2014	Digital (GIS) Format
Sea Level Rise	ESRGC	2016	Digital (GIS) Format
SLOSH (Categories 1-4)	NOAA	2023	Digital (GIS) Format

FEMA: Federal Emergency Management Agency
USGS: United States Geological Survey
ESRGC: Eastern Shore Regional GIS Cooperative
NOAA: National Oceanic and Atmospheric Administration

3.2.4 Limitations

Loss estimates, exposure assessments, and hazard-specific vulnerability evaluations rely on the best available data and methodologies. Uncertainties are inherent in any loss estimation methodology and arise in part from incomplete scientific knowledge concerning natural hazards and their effects on the built environment. Uncertainties also result from the following:

- Approximations and simplifications necessary to conduct a study
- Incomplete or outdated inventory, demographic, or economic parameter data
- The unique nature, geographic extent, and severity of each hazard
- Mitigation measures already employed
- The amount of advance notice residents have to prepare for a specific hazard event.

These factors can affect loss estimates by a factor of two or more. Therefore, potential exposure and loss estimates are approximate and should be used only to understand relative risk. Over the long term, Baltimore City will collect additional data to assist in estimating potential losses associated with other hazards.

3.3 Hazard Ranking

FEMA Planning Policy Element B2: 44 CFR 201.6(c)(2)(ii): The plan must include a summary of the jurisdiction's vulnerability and the impacts on the community from the identification of hazards, including addressing NFIP-insured structures that have been repetitively damaged by floods.

A comprehensive range of hazards that pose a significant risk to Baltimore City were selected and considered during the development of this plan (see Section 3.1: Identification of Hazards of Concern). However, Baltimore City should note that each neighborhood within Baltimore City may have differing levels of exposure and vulnerability to each of these hazards. It is important for Baltimore City to recognize those hazards that pose the greatest risk to its various neighborhoods and districts. Baltimore City must direct attention and resources accordingly to manage risk and reduce losses most effectively and efficiently among the neighborhoods and districts within Baltimore City limits.

To this end, a hazard risk ranking process was conducted for Baltimore City using the method described below. This method includes four risk assessment categories—probability of occurrence, impact (population, property, and economy), adaptive capacity, and changing future conditions (i.e., climate change). Each was assigned a weighting factor to calculate an overall ranking value for each hazard of concern. Depending on the calculation, each hazard was assigned a high, medium, or low ranking. Details regarding each of these categories are described below.

3.3.1 Hazard Ranking Methodology

Estimates of hazard risk for Baltimore City were developed using methodologies promoted by FEMA's hazard mitigation planning guidance, generated by FEMA's Hazus risk assessment tool, and with input from Baltimore City.

As described in Section 3.2 Methodology and Tools, three different levels of analysis were used to estimate potential impacts: (1) historic loss/qualitative analysis, (2) exposure analysis, and (3) loss estimation. All three levels of analysis are suitable for planning purposes; however, with any risk analysis, there is underlying uncertainty resulting from assumptions used to describe and assess vulnerability and the methodologies available to model impacts. Impacts from any hazard event within Baltimore City will vary from the analysis presented here based on the factors described for each hazard of concern, namely location, extent, warning time, and mitigation measures in place at the time of an event.

The hazard ranking methodology for some hazards of concern is based on a scenario event, while others are based on their potential risk to Baltimore City as a whole. In order to account for these differences, the quantitative hazard ranking methodology was adjusted using professional judgment and subject matter input; assumptions are included, as appropriate, in the following subsections. The limitations of this analysis are recognized, given the scenarios do not have the same likelihood of occurrence; nonetheless, there is value in summarizing and comparing the hazards using a standardized approach to evaluate relative risk. The following categories were considered when evaluating the relative risk of the hazards of concern.

- **Probability of Occurrence** — The probability of occurrence of the scenario evaluated was estimated by examining the historic record and/or calculating the likelihood of annual occurrence. When no scenario was assessed, an examination of the historic record and judgment was used to estimate the probability of occurrence of an event that will impact Baltimore City.
- **Impact** — The following three hazard impact subcategories were considered: impact to people; impact to buildings; and impact to the economy. The results of the updated risk assessment and/or professional judgment were used to assign the numeric values for these three impact subcategories. A factor was applied to each subcategory, giving impact on population the greatest weight.
    - **Population** — Numeric value x 3
    - **Buildings** — Numeric value x 2
    - **Economy** — Numeric value x 1
- **Adaptive Capacity** — Adaptive capacity describes Baltimore City's current ability to provide protection from or withstand a hazard event. This includes capabilities and capacity in the following areas: administrative, technical, planning/regulatory, and financial. Mitigation measures already in place increase Baltimore City's capacity to withstand and rebound from events (e.g., codes/ordinances with higher standards to

withstand hazards due to design or location, deployable resources, or plans and procedures in place to respond to an event). In other words, assigning "weak" for adaptive capacity means Baltimore City does not have the capability to effectively respond, which increases vulnerability, whereas "strong" adaptive capacity means Baltimore City does have the capability to effectively respond, which decreases vulnerability. These ratings were assigned using the results of the core capability assessment.

- **Climate Change (Changing Future Conditions)** — Current climate change projections were considered as part of the hazard ranking to ensure the potential for an increase in severity/frequency of the hazard was included. This was important for Baltimore City to include because the hazard ranking helps guide and prioritize the mitigation strategy development, which should have a long-term future vision to mitigate the hazards of concern. The potential impacts climate change may have on each hazard of concern are discussed in the hazard profiles found in Sections 4 through 12. The benchmark values in the methodology are similar to confidence levels outlined in the National Climate Assessment 2017 (U.S. Global Change Research Program 2018).

Hazard Ranking Equation

[Probability of Occurrence x 0.3] + [(Impact on Population x 3) + (Impact on Property x 2) + (Impact on Economy x 1) x 0.3] + [Adaptive Capacity x 0.3] + [Climate Change x 0.1]

Table 3-3 summarizes the categories, benchmark values, and weights used to calculate the risk factor for each hazard. Using the weighting applied, the highest possible risk factor value is 6.9. The higher the number, the greater the relative risk. Based on the total for each hazard, a priority ranking is assigned to each hazard of concern (high, medium, or low). The rankings were categorized as follows: Low = Values less than 3.9; Medium = Values between 3.9 and 4.9; High = Values greater than 4.9.

Table 3-3. Summary of Hazard Ranking Approach

Category		Level / Category	Degree of Risk / Benchmark Value	Numeric Value	Weighted Value
Probability of Occurrence		Unlikely	A hazard event is not likely to occur or is unlikely to occur with less than a 1% annual chance probability.	0	30%
		Rare	Between 1 and 10% annual probability of a hazard event occurring.	1	
		Occasional	Between 10 and 100% annual probability of a hazard event occurring.	2	
		Frequent	100% annual probability; a hazard event may occur multiple times per year.	3	
Impact (Sum of all 3)	Population (Numeric Value x 3)	Low	14% or less of your population is exposed to a hazard with potential for measurable life safety impact, due to its extent and location.	1	30%

Category		Level / Category	Degree of Risk / Benchmark Value	Numeric Value	Weighted Value
		Medium	15% to 29% of your population is exposed to a hazard with potential for measurable life safety impact, due to its extent and location.	2	
		High	30% or more of your population is exposed to a hazard with potential for measurable life safety impact, due to its extent and location.	3	
	Property (Numeric Value x 2)	Low	Property exposure is 14% or less of the total number of structures for your community.	1	
		Medium	Property exposure is 15% to 29% of the total number of structures for your community.	2	
		High	Property exposure is 30% or more of the total number of structures for your community.	3	
	Economy (Numeric Value x 1)	Low	Loss estimate is 9% or less of the total replacement cost for your community.	1	
		Medium	Loss estimate is 10% to 19% of the total replacement cost for your community.	2	
		High	Loss estimate is 20% or more of the total replacement cost for your community.	3	
Adaptive Capacity		Weak	Weak/outdated/inconsistent plans, policies, codes/ordinances in place; no redundancies; limited to no deployable resources; limited capabilities to respond; long recovery.	1	30%
		Moderate	Plans, policies, codes/ordinances in place and meet minimum requirements; mitigation strategies identified but not implemented on a widespread scale; City can recover but needs outside resources; moderate City capabilities.	0	
		Strong	Plans, policies, codes/ordinances in place and exceed minimum requirements; mitigation/protective measures in place; City has ability to recover quickly because resources are readily available, and capabilities are high.	-1	
Climate Change		Low	No local data is available; modeling projections are uncertain on whether there is increased future risk; confidence level is low (inconclusive evidence).	1	10%
		Medium	Studies and modeling projections indicate a potential for exacerbated conditions due to climate change; confidence level is medium to high (suggestive to moderate evidence).	2	
		High	Studies and modeling projections indicate exacerbated conditions/increased future risk due to	3	

Category	Level / Category	Degree of Risk / Benchmark Value	Numeric Value	Weighted Value
		climate change; very high confidence level (strong evidence, well documented and acceptable methods).		

Note: A numerical value of zero is assigned if there is no impact.
**For the purposes of this exercise, "impacted" means exposed for population and property and estimated loss for economy. For non-natural hazards, although they may occur anywhere in Baltimore City, an event will not likely cause citywide impacts; therefore, impact to population was scored using an event-specific scenario.*

In an attempt to summarize the confidence level regarding the input utilized to populate the hazard ranking, a gradient of certainty was developed. A certainty factor of high, medium, or low was selected and assigned to each hazard to provide a level of transparency and increased understanding of the data utilized to support the resulting ranking. The following scale was used to assign a certainty factor to each hazard:

- **High** — Defined scenario/event to evaluate; probability calculated; evidenced-based/quantitative assessment to estimate potential impacts through hazard modeling.
- **Moderate** — Defined scenario/event or only a hazard area to evaluate; estimated probability; combination of quantitative (exposure analysis, no hazard modeling) and qualitative data to estimate potential impacts.
- **Low** — Scenario or hazard area is undefined; there is a degree of uncertainty regarding event probability; majority of potential impacts are qualitative.

3.3.2 Hazard Ranking Results

Using the process described above, the ranking for the identified hazards of concern was determined for Baltimore City (refer to Table 3-4). The hazard ranking is detailed in the subsequent tables that present the stepwise process for the ranking. The results support the appropriate selection and prioritization of initiatives to reduce the highest levels of risk for each municipality. Baltimore City had the ability to alter rankings based on local knowledge and experience in handling each hazard.

This hazard ranking exercise serves four purposes: (1) to describe the probability of occurrence for each hazard; (2) to describe the impact each would have on the people, property, and economy; (3) to evaluate the capabilities a community has with regards to the hazards of concern; and (4) to consider changing future conditions (i.e., climate change) in Baltimore City.

Table 3-5 presents the total calculations for each hazard ranking value for the hazards of concern in Baltimore City.

Table 3-4. Ranking for Hazards of Concern for Baltimore City

Hazard of Concern	Probability		Impact										Adaptive Capacity	Climate Change
			Population			Property			Economy			Total Impact Value		
	Category	Numeric Value	Impact	Numeric Value	Weighted Value (x3)	Impact	Numeric Value	Weighted Value (x2)	Impact	Numeric Value	Weighted Value (x1)			
Coastal Hazards	Occasional	2	Low	1	1 x 3 = 3	Medium	2	2 x 2 = 4	High	3	3 x 1 = 3	10	Medium	High
Drought	Occasional	2	High	3	3 x 3 = 9	Low	1	1 x 2 = 2	Low	1	1 x 1 = 1	12	Medium	High
Earthquakes	Rare	1	Low	1	1 x 3 = 3	Low	1	1 x 2 = 2	Low	1	1 x 1 = 1	6	Medium	Low
Extreme Temperature	Frequent	3	High	3	3 x 3 = 9	Low	1	1 x 2 = 2	Low	1	1 x 1 = 1	12	Medium	High
Flooding	Frequent	3	Medium	2	2 x 3 = 6	Medium	2	2 x 2 = 4	Low	1	1 x 1 = 1	11	Medium	High
Human-caused	Occasional	2	High	3	3 x 3 = 9	High	3	3 x 2 = 6	High	3	3 x 1 = 3	18	Medium	Low
Severe Storms	Frequent	3	High	3	3 x 3 = 9	Low	1	1 x 2 = 2	Low	1	1 x 1 = 1	12	Medium	High
Soil Movement	Occasional	2	Low	1	1 x 3 = 3	Low	1	1 x 2 = 2	Low	1	1 x 1 = 1	6	Medium	Medium

Table 3-5. Total Hazard Ranking Values for the Hazards of Concern for Baltimore City

Hazard of Concern	Probability x 30%	Total Impact x 30%	Adaptive Capacity x 30%	Changing Future Conditions x 10%	Total Hazard Ranking Value	Hazard Ranking
Coastal Hazards	0.6	3.0	0	0.3	3.9	Medium
Drought	0.6	3.6	0	0.3	4.5	Medium
Earthquakes	0.3	1.8	0	0.1	2.2	Low
Extreme Temperature	0.9	3.6	0	0.3	4.8	Medium
Flooding	0.9	3.3	0	0.3	4.5	Medium
Human-caused	0.6	5.4	0	0.1	6.1	High
Severe Storms	0.9	3.6	0	0.3	4.8	Medium
Soil Movement	0.6	1.8	0	0.2	2.6	Low

Note: Low = Values less than 3.9; Medium = Values between 3.9 and 4.9; High = Values greater than 4.9

Section 4. Flood

Key Changes from the 2018 DP3:

- The discussion on the hazard description, including location, extent, previous occurrences, and future probability, has been updated.
- The vulnerability assessment has been combined with the hazard description
- Integration of preliminary FEMA Flood Insurance Rate Maps (FIRMs) and Flood Insurance Study (FIS).
- Identification of how climate change will impact the flood hazard
- Integration of cascading and compounding impacts
- The vulnerability assessment of population, structures, and natural, historic, and cultural resources impacted by the Flood hazard have been updated and expanded
- Discussion on future changes that may impact vulnerability

4.1 Description

Floods are one of the most frequent and costly natural hazards in Baltimore City in terms of human hardship and economic loss, particularly to communities that lie within flood prone areas or floodplains of a major water source.

A flood is an overflow of water from oceans, rivers, groundwater, or rainfall that submerges areas that are usually dry. This natural phenomenon can be exacerbated by features of the built environment.

Flooding is a natural hazard that can occur during any season. Flooding typically occurs during prolonged rainfalls over several days, intense rainfalls over a short period of time, or when an ice or debris jam causes a river or stream to overflow onto the surrounding area. Flooding can also result from the failure of a water control structure, such as a dam or levee (NWS 2019).

Flood can be exacerbated by other hazards such as sea level changes and increased precipitation or severe storms. Additional information regarding severe storms is available in Section 7.

Key Terms

- Floodplain—The flat land adjacent to a river, creek, or stream that is subject to periodic inundation (FEMA 2019).
- Special Flood Hazard Area (SFHA) — The area that will be inundated by the flood event having a 1-percent chance of being equaled or exceeded in any given year. In this area, the National Flood Insurance Program's (NFIP) floodplain management regulations are enforced, and the purchase of flood insurance is mandatory (FEMA 2020).
- 1-Percent Annual Chance Flood— Known as the base flood or 100-year flood and has a 1-percent probability of being equaled or exceeded in any given year (FEMA 2020).
- 0.2-Percent Annual Chance Flood— Referred to as the 500-year flood and has a 0.2-percent probability of occurring in any given year (FEMA 2020).
- Flood Insurance Rate Map (FIRM) — The official map of a community which defines the SFHAs and the flood zones applicable to a community (FEMA 2018).

Flooding events are a common occurrence in Baltimore City. A variety of flood types can cause widespread damage throughout urban areas, causing loss of life, injury, and severe water damage to residential and commercial buildings, bridge and road closures, transit service disruptions, and damage to electrical and communication networks.

Flooding is a temporary condition of partial or complete inundation on normally dry land from the following (NWS 2019):

- Riverine overbank flooding
- Flash floods
- Alluvial fan floods
- Mudflows or debris floods
- Dam- and levee-break floods
- Local draining or high groundwater levels
- Fluctuating lake levels
- Ice-jams
- Coastal flooding

For the purpose of the DP3, and as deemed appropriate by Baltimore City Core Planning Team, riverine and inland, flash, urban and stormwater, coastal and nuisance, sea level rise, and dam failure are the main flood types of concern for Baltimore City. These types of flooding are further discussed below.

4.1.1 Riverine and Inland Flooding

Riverine flooding is when streams or rivers exceed the capacity of their natural or constructed channels to accommodate water flow and water overflows the banks, spilling into adjacent low-lying, dry land. This occurs when the flow of a river exceeds the bank sides and causes damage or obstruction to a nearby floodplain. Riverine flooding can turn into a flash flood if the river is at or above flood stage and if the soil is saturated (FEMA 2019).

4.1.2 Flash Flooding

A flash flood is a rapid inundation of low-lying areas caused by heavy rain associated with severe thunderstorms, tropical systems, or melting water from ice or snow. Flash flooding also occurs far away from water bodies when a large volume of water cannot be absorbed by the soil or storm water systems and travels overland unimpeded (NWS 2019).

4.1.3 Urban and Stormwater Flooding

Urban flooding is the inundation of property in a built environment caused by rain falling on increased amounts of impervious surfaces and overwhelming the capacity of drainage systems. This definition excludes flooding in undeveloped or agricultural areas and includes situations in which stormwater enters buildings through a) windows, doors, or other openings; b) water backup through pipes and drains; c) seepage through walls and floors. The definition was expanded to include specific issues, such as sewer water backing up into homes, water seeping through foundation walls, clogged street drains, and overflow from sound walls, roads, or other barriers that restrict stormwater runoff (University of Maryland and Texas A&M University 2018).

Blocked storm drain during flooding on Hillen Road on June 10, 2021.

Image provided by OEM.

Flooded intersection during flooding on Hillen Road on June 10, 2021. Image provided by OEM

Flooded intersection during flooding on Hillen Road on June 10, 2021. Image provided by OEM

4.1.4 Coastal and Nuisance Flooding

Coastal flooding is when water inundates or covers normally dry coastal land as a result of high or rising tides or storm surges (FEMA 2023). Coastal areas can experience various kinds of flooding. Other types include moderate and major floods that can be caused by heavy rains (rain with a high rate of accumulation per unit of time), storm surges (water pushed on land by strong winds), and wave action (the movement of waves) that occur during coastal storms (CDC 2017) (NOAA 2023) (US EPA 2023). The combination of these events can result in the total perceived coastal flooding event. More information on coastal flooding and hazards related to coastal storms can be found in Section 6 (Coastal Storms).

Nuisance flooding (also called high-tide or sunny day flooding), a form of coastal flooding, is minor tidal flooding that occurs at high tide and is often associated with minor impacts such as old sea walls being overtopped, water in low-lying areas of roads, and storm water systems that have water coming in through the outtake pipes. Nuisance flooding is not widespread or damaging but causes short-term public inconveniences (NOAA 2015).

As stated in the *2020 Baltimore City Nuisance Flood Plan*, “the impacts of nuisance flooding may generate area closures, standing water that blocks access to homes and businesses, and impacts on pedestrian and road traffic flow. Additionally, nuisance floods can lead to significant trash accumulation following water recession. This can impact area aesthetics and is costly to clean-up, as public works crews must remove the debris and diverge pedestrian traffic away from the affected spaces. These disruptive flood events overwhelm stormwater management systems and cause financial burdens by placing additional stress on local government agencies and businesses located at or near the waterfront.”

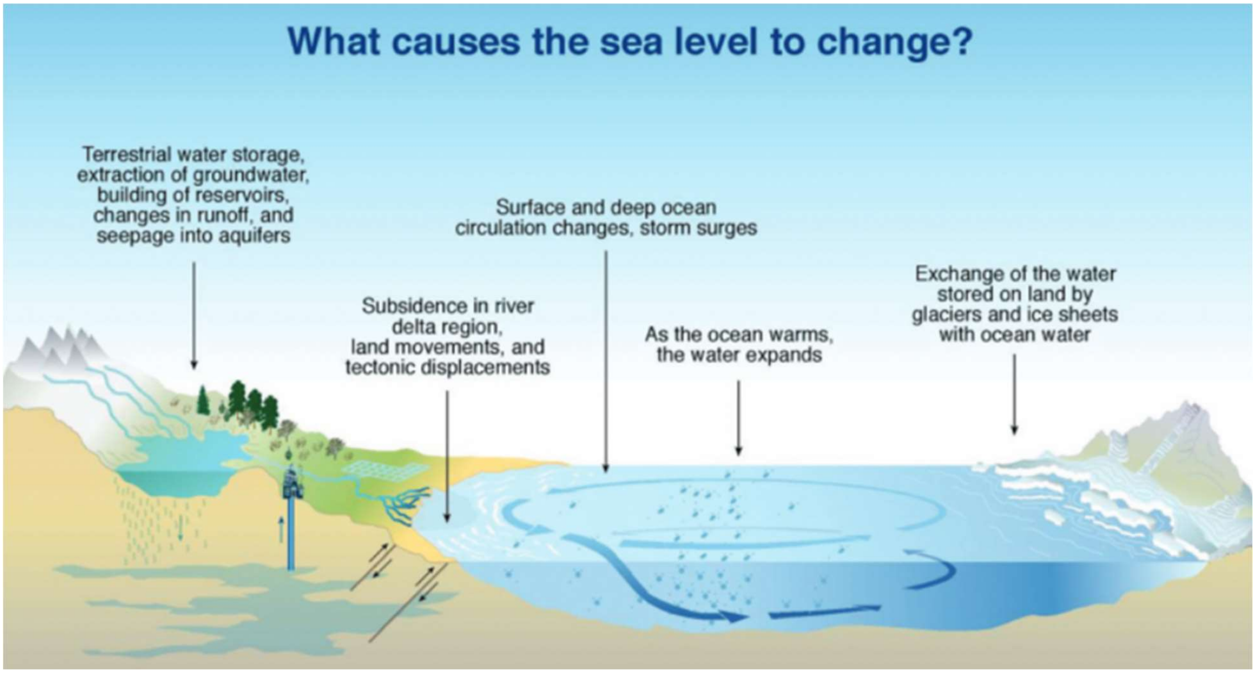
Source: Baltimore City Office of Sustainability 2020

4.1.5 Sea Level Rise

There are two types of sea level rise: global and relative (local). Global sea level rise refers to the increase currently observed in the average global sea level trend. This is primarily attributed to changes in ocean volume due to land ice melting and thermal expansion. The melting of glaciers and continental ice masses can contribute significant amounts of freshwater input to the earth’s oceans. In addition, increases in global ocean temperature causes an expansion of seawater, increasing ocean volume (NASA 2020). Refer to Figure 4-1 for an illustration of what causes sea level to change.

Relative or local sea level is affected by global sea level fluctuations, changes in land elevation, winds, and ocean circulation. It refers to the height of the water as measured along the coast relative to a specific point on land. Tide stations measure local sea level rise. Water measurements at the tide stations are referenced to stable vertical points on the land, and a known relationship is established. Measurements at any given tide station include both local sea level rise and vertical land motion (subsidence, glacial rebound, or large-scale tectonic motion).

Figure 4-1. Causes of Sea Level Change



Source: NASA 2020

Since the heights of both the land and water change, the land-water interface can vary spatially and temporally and must be defined over time. Depending on the rates of vertical land motion relative to changes in sea level, observed local sea level trends may differ greatly from the average rate of global sea level rise and vary widely from one location to the next. Relative sea level trends reflect changes in local sea levels over time and are typically the most critical sea level trend for many coastal applications, including coastal mapping, marine boundary delineation, coastal zone management, coastal engineering, sustainable habitat restoration design, and the general public enjoying their favorite beach (NOAA 2022).

4.2 Location

Baltimore City's topographic, climatological, meteorological, and land use features create an environment conducive to year-round flooding. Warm weather flooding is caused by severe thunderstorms bringing heavy rainfall that leads to flash floods and riverine or overbank flooding; in cold weather fast-melting snow overwhelm waterways leading to flooding; Baltimore City is heavily developed and covered by impervious surfaces exacerbating stormwater and urban flooding. Bank erosion and sediment deposits exacerbate flooding by blocking and re-directing the natural flow of waterways. Baltimore City is also affected by storm surge from hurricanes or tropical storms; the rainfall associated with these systems can result in additional flooding (National Geographic 2022) (FEMA 2022). Additionally, stormwater infrastructure is a major factor as well. The age and size of infrastructure can dictate whether a particular area may be vulnerable to flooding.

Areas that are more likely to have an increased risk of flooding include the following:

- Low-lying coastal areas.
- Areas with poor drainage.

- Locations on or near construction projects.
- The FEMA defined Special Flood Hazard Areas (SFHA).
- Developed areas with excess amounts of impermeable surfaces.
- Locations that will flood in the future because of sea level rise.

Specific areas of frequent flooding in Baltimore City include:
- Culverts prone to blockage during rain events such as Stony Run at Wyndhurst and the Jones Falls at Union Avenue.
- Topographic depressions with large drainage areas such as the intersection of 35th Street and Hillen Road.
- Areas adjacent and near streams such as Frederick Avenue along Maidens Choice.

Flooded streets in Harbor East during flash flooding on August 6, 2019.

Source: Blue Water Baltimore 2019

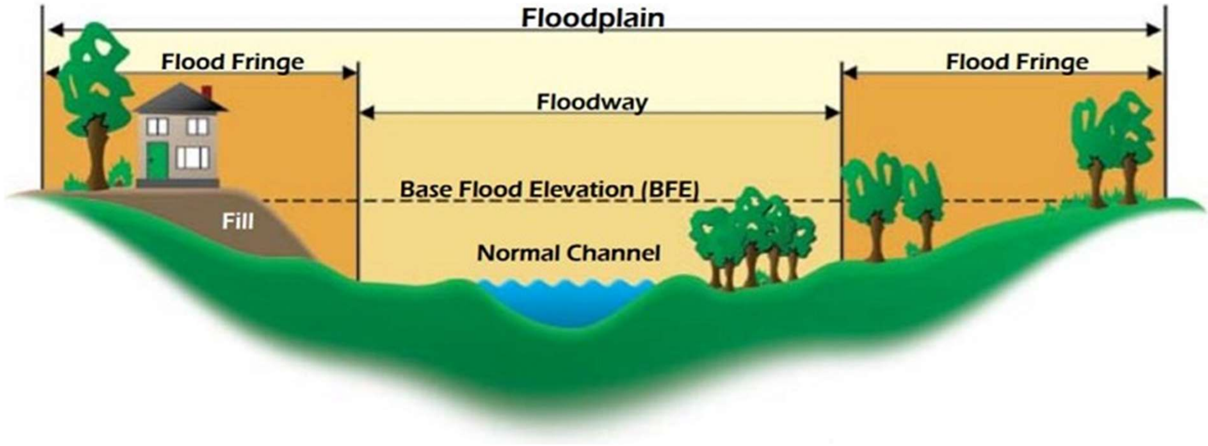
4.2.1 Floodplains

A floodplain is flat land adjacent to a river, creek, or stream that is subject to periodic inundation. The floodplain describes the area inundated by the "100-year" flood, or a flood that has a 1-percent chance in any given year of being equaled or exceeded. A floodplain is designated when floodwater exceeds the capacity of the main channel, or water escapes the channel through bank erosion. A floodplain is made up of different sections (FEMA 2019) (US DHS 2019):

- **Flood Fringe:** the area within the floodplain but outside the floodway; this area extends from the outer banks of a floodway to the river valley, where the elevation begins to rise.
- **Floodway:** the channel of a river or other waterway and the adjacent land areas that are under water or reserved to carry and discharge the overflow of water caused by flooding.
- **Base Flood Elevation (BFE):** the value that indicates the height of flood waters during a base flood; the BFE dictates the lowest level at which a living space can be built without being impacted by floods.

Refer to Figure 4-2 for a visual example of a floodplain.

Figure 4-2. Characteristics of a Floodplain



Source: FEMA 2022

In Baltimore City, floodplains line the rivers, streams, and coastal waters. Floodplains serve multiple functions. They moderate flooding, maintain water quality, recharge groundwater, reduce erosion, redistribute sand and sediment, and support fish and wildlife habitat. The boundaries of the floodplains are altered as a result of changes in land use, the amount of impervious surface, placement of obstructing structures in floodways, changes in precipitation and runoff patterns, improvements in technology for measuring topographic features, and utilization of different hydrologic modeling techniques.

Floodplain mapping is based on riverine and coastal flooding conditions. Urban and stormwater flooding is not reflected in floodplain mapping. Future flooding conditions (from factors such as sea level rise and changes in rainfall) are not included in FEMA's development of floodplain mapping. As such, floodplain maps may underestimate flood risk in many areas in the region. As a result, the public may also underestimate risk.

FEMA designated SFHAs are where the National Flood Insurance Program's (NFIP's) floodplain management regulations must be enforced and the area where the mandatory purchase of flood insurance applies. These areas have special flood, mudflow or flood-related erosion hazards and are shown on a Flood Hazard Boundary Map or a FIRM (FEMA 2020). SFHA are defined as the area that will be inundated by the flood event having a 1-percent chance of being equaled or exceeded in any given year. SFHAs are labeled as Zone A, Zone AO, Zone AH, Zones A1-A30, Zone AE, Zone A99, Zone AR, Zone AR/AE, Zone AR/AO, Zone AR/A1-A30, Zone AR/A, Zone V, Zone VE, and Zones V1-V30. Moderate flood hazard areas, labeled Zone B or Zone X (shaded) are also shown on the FIRM, and are the areas between the limits of the base flood and the 0.2-percent-annual-chance (or 500-year) flood. The areas of minimal flood hazard, which are the areas outside the SFHA and higher than the elevation of the 0.2-percent-annual-chance flood, are labeled Zone C or Zone X (unshaded) (FEMA 2020).

- 1-Percent Annual Chance Flood: also known as the base flood or 100-year flood and has a 1-percent probability of being equaled or exceeded in any given year.
- 0.2-Percent Annual Chance Flood: also referred to as the 500-year flood and has a 0.2-percent probability of occurring in any given year (FEMA 2020).

Figure 4-3, shows the FEMA designated flood hazard area for Baltimore City.

It should be noted that areas located outside of the SFHA can be subject to flooding and may even function as an unofficial floodplain. Flooding outside of the SFHA area may include stormwater/urban flooding and flash flooding (see Section 4.1).

In Baltimore City, 2,314 acres of land, or 4.5-percent of Baltimore City's total land area, is located within the 1-percent annual chance flood event. 3,352 acres of land, or 6.5-percent of Baltimore City's total land area, is located within the 0.2-percent annual chance flood event. It is also worth noting that 3 percent of Baltimore City's overall land, primarily in the Inner Harbor area and the Fells Point Historic District, is within the coastal floodplain. By the end of the century, approximately 115,200 acres, or 180 square miles, of currently dry land along Maryland's coastline is expected to be inundated, coupled with more frequent and extreme precipitation events (City of Baltimore 2018). View Table 4-1 for the total land acreage located in 1-percent and 0.2-percent flood extents in Baltimore City.

Flooded pier at the Inner Harbor facing Harbor East

Source: The Baltimore Sun 2021

Figure 4-3. Flood Hazard Area for Baltimore City

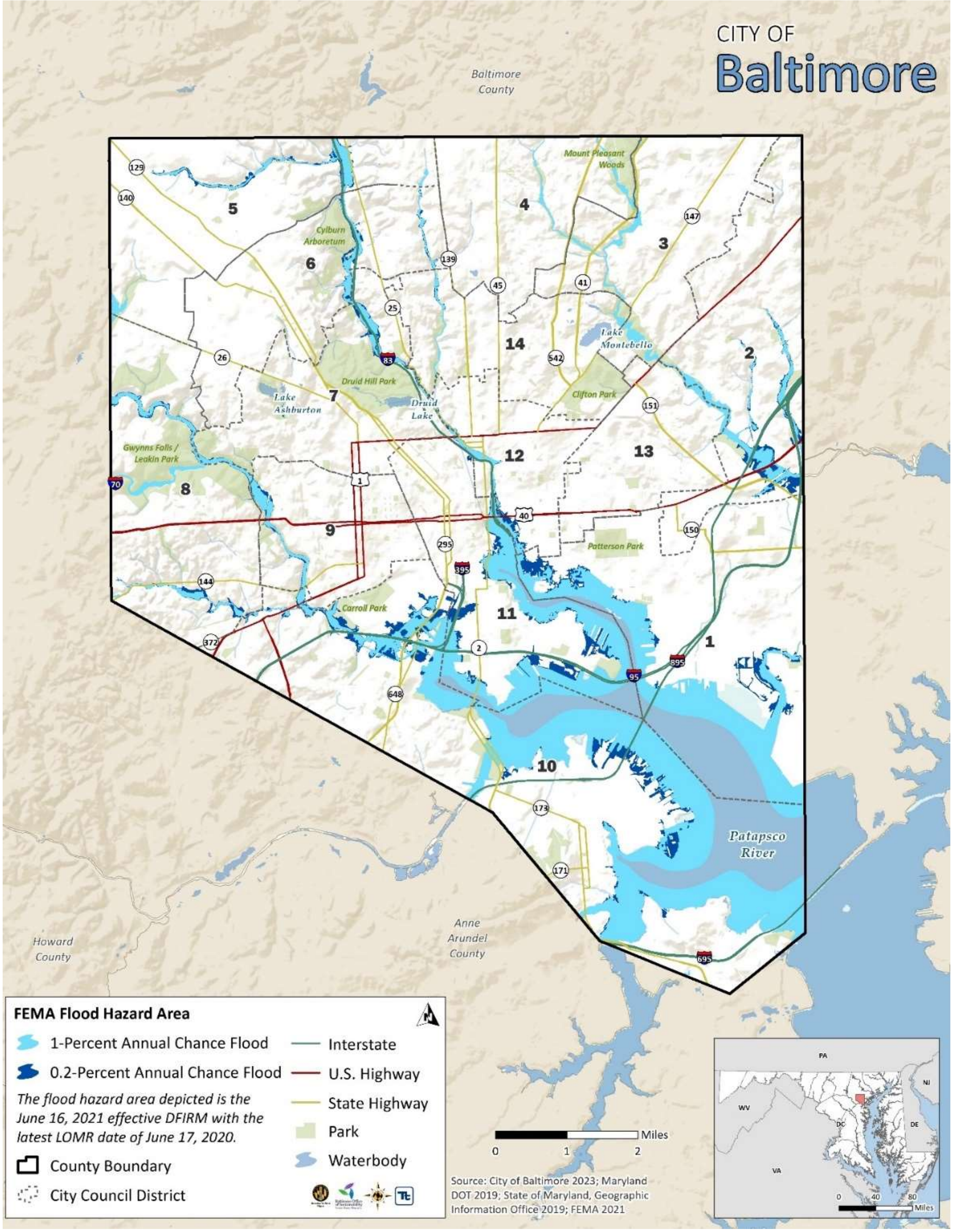


Table 4-1. Land Acreage in Baltimore City Located in 1% and 0.2% Flood Extents

City Council District	Total Acres of Land Area	Total Acres of Land Area (Excluding Waterbodies) Located in the Flood Hazard Areas			
		Total Acres Located in the 1-Percent Annual Chance Flood Event	Percent of Total	Total Acres Located in the 0.2-Percent Annual Chance Flood Event	Percent of Total
1	4,666	152	3.3%	318	6.8%
2	4,271	244	5.7%	357	8.4%
3	3,459	126	3.6%	126	3.6%
4	3,044	61	2.0%	61	2.0%
5	4,480	144	3.2%	192	4.3%
6	3,663	90	2.5%	125	3.4%
7	3,295	111	3.4%	140	4.2%
8	4,474	198	4.4%	248	5.5%
9	2,383	94	4.0%	114	4.8%
10	8,188	709	8.7%	1,055	12.9%
11	2,899	212	7.3%	402	13.9%
12	1,948	92	4.7%	127	6.5%
13	2,248	42	1.9%	42	1.9%
14	2,809	40	1.4%	45	1.6%
Baltimore City (Total)	**51,826**	**2,314**	**4.5%**	**3,352**	**6.5%**

Source: City of Baltimore 2023; USGS 2023; FEMA 2021

4.2.2 Repetitive Loss

FEMA's National Flood Insurance Program (NFIP) is a program that makes federally backed flood insurance available in those states and communities that agree to adopt and enforce flood-plain management ordinances to reduce future flood damage. The NFIP identifies properties as repetitive loss (RL) and severe repetitive loss (SRL), differing on the various criteria described below.

The NFIP defines RL properties as structures that meet one of the following qualifiers:

- Two or more claims of more than $1,000 paid by NFIP within any rolling 10-year period, since 1978.
- Two or more claims (building payments only) that, on average, equal or exceed 25 percent of the market value of the property (FEMA 2022).

The NFIP defines SRL properties as structures that meet one of the following qualifiers:

- Received four or more separate claim payments of more than $5,000 each (including building and contents payments).

- Received two or more separate claim payments (building payments only) where the total of the payments exceeds the current value of the property (FEMA 2022).

The Flood Mitigation Assistance (FMA) grant program is a competitive grant program that provides funding to states, local communities, federally recognized tribes, and territories. Funds can be used for projects that reduce or eliminate the risk of repetitive flood damage to buildings insured by the National Flood Insurance Program (FEMA 2023). FMA defines RL and SRL properties differently than the NFIP; see below for the FMA criteria.

FMA defines RL properties as structures covered by a contract for flood insurance made available under the NFIP that meet the following two qualifiers:

- Has incurred flood-related damage on two occasions, in which the cost of the repair, on average, equaled or exceeded 25 percent of the market value of the structure at the time of each such flood event.
- At the time of the second incidence of flood-related damage, the contract for flood insurance contains increased cost of compliance coverage (FEMA 2022).

FMA defines SRL properties as structures covered by a contract for flood insurance made available under the NFIP that has incurred flood related damage and meet one of the following qualifiers:

- Four or more separate claims payments (includes building and contents) have been made under flood insurance coverage with the amount of each such claim exceeding $5,000, and with the cumulative amount of such claim payments exceeding $20,000.
- At least two separate claims payments (includes only building) have been made under such coverage, with the cumulative amount of such claims exceeding the market value of the insured structure (FEMA 2022).

Figure 4-4 displays the Repetitive Loss Areas in the Northern Half of Baltimore City; Figure 4-5 displays the Repetitive Loss Areas in the Southern Half of Baltimore City. A repetitive loss area is a portion (or portions) of a community that includes buildings on FEMA's list of repetitive losses and any nearby properties that are subject to the same or similar flooding conditions (FEMA 2015).

FEMA provided a list of properties with NFIP policies, past claims, and multiple claims. Table 4-2 summarizes the NFIP policies, claims, and repetitive loss statistics for Baltimore City. All the SRL properties are non-residential structures; the RL properties are a combination of residential and non-residential structures. This information is current as of February 23, 2023.

Table 4-2. NFIP Policies, Claims, and Repetitive Loss Statistics

Total Claims	Total Payments (Building + Contents)	Number of NFIP Repetitive Loss (RL) Properties
200	$17,542,926	69

Source: FEMA Region 3, 2023

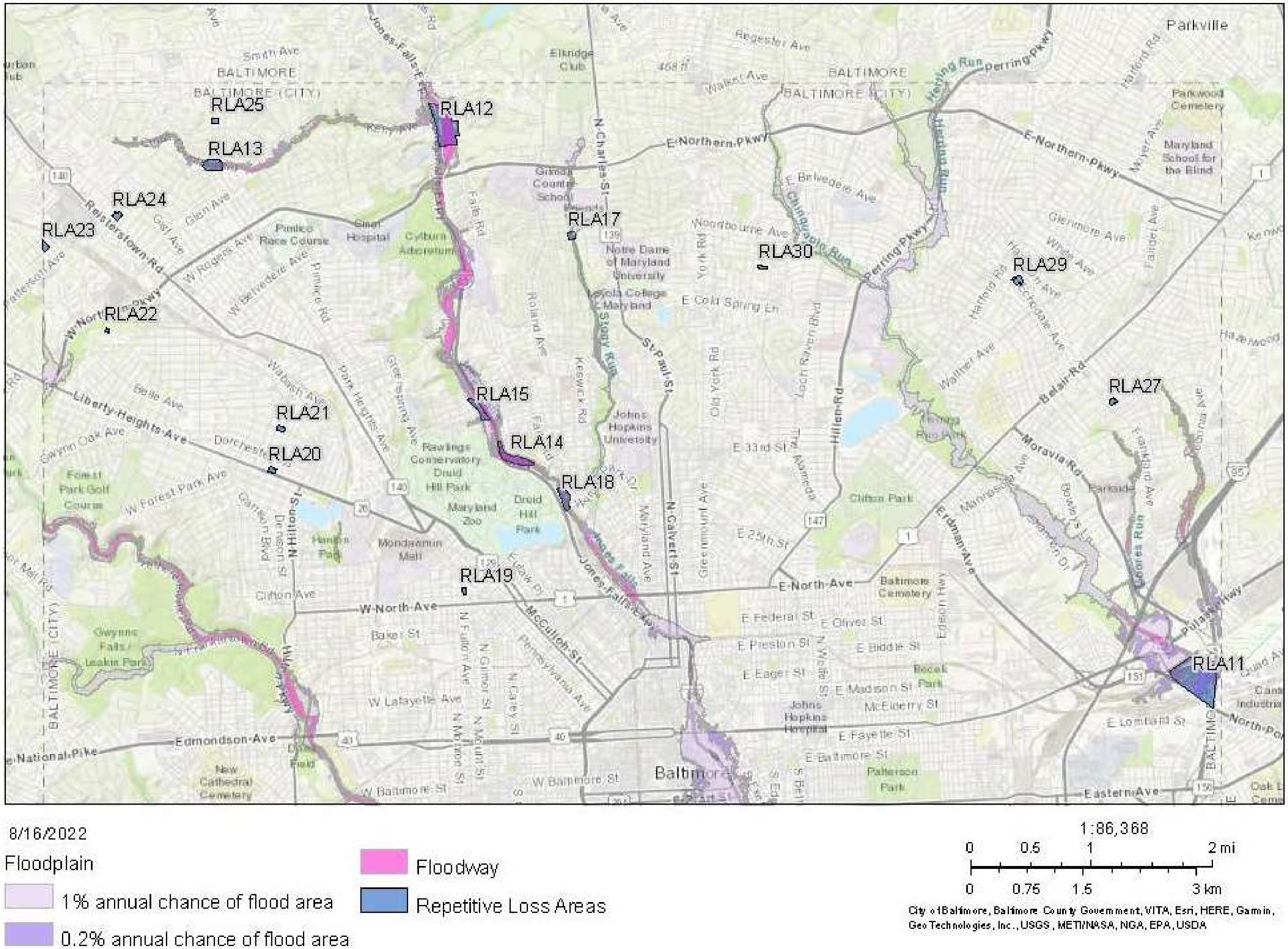
FEMA provided a list of RL and SRL statistics specifying the type of structure. Table 4-3 summarizes the NFIP RL and SRL statistics by structure type for Baltimore City.

Table 4-3. Number of RL Properties by Structure Type

	Structure Type			
Loss Type	**Single Family**	**Other Residential**	**Commercial**	**Other Non-Residential**
Baltimore City (Total)	33	3	16	17

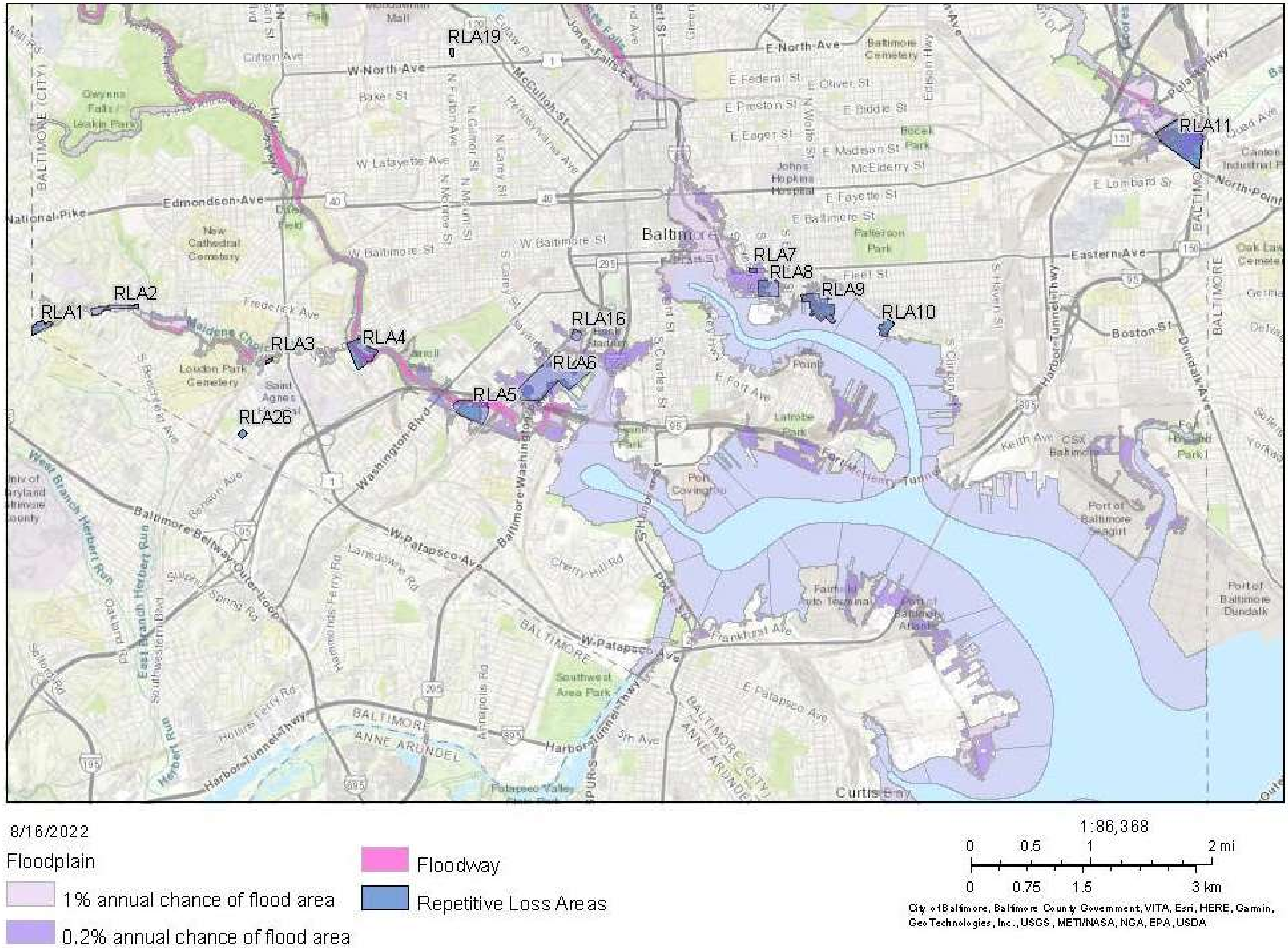
Source: FEMA Region 3, 2023

Figure 4-4. Repetitive Loss Areas in the Northern Half of Baltimore City



Source: Baltimore Department of Planning 2022

Figure 4-5. Repetitive Loss Areas in the Southern Half of Baltimore City



Source: Baltimore Department of Planning 2022

4.2.3 Riverine and Inland Flooding

Flooding occurs throughout Baltimore City, but primarily along the bodies of water that flow through it. Baltimore City lies within two major drainage basins—the Patapsco River Basin and Back River Basin. The Gwynns Falls drains the northwest and western portions of Baltimore City, and the Jones Falls drains the upper northwest and central portions of Baltimore City, both emptying into the Patapsco River (Baltimore City OEM 2018). There are three stream systems in Baltimore City: Gwynn Falls, Jones Falls, and Herring Run.

Gwynns Falls is situated in the western areas of Baltimore City; the stream system flows from Baltimore County, through Baltimore City, to its confluence with the Middle Branch of the Patapsco River. The angular reaches and steep-sided valleys contribute to the irregular drainage pattern of the Gwynns Falls watershed, causing it to have multiple branches. Flooding damage occurs at several locations within the watershed, with the most severe occurring in the lower Gwynns Falls (Westport/Morrell Park area), along Maiden's Choice Run, and in the upper City portion of the Gwynns Falls (Dickeyville area) (Maryland Department of the Environment 1981). Flooding also occurs along Frederick Avenue along Maiden's Choice Run. Gwynns Run, from Hanlon Park to Gwynns Falls, flows through an underground storm sewer. The restricted natural drainage for this storm sewer area causes flooding in the streets in this vicinity (FEMA 2018).

The Jones Falls stream system begins in the Greenspring Valley of Baltimore County, enters through the northwest and central portion of Baltimore City, and empties into Baltimore Harbor and the Chesapeake Bay. The varying landscape which the stream system traverses through includes urban and commercial areas and parklands; urban and commercial areas are more apt to flood due to poorly draining and disturbed soils. Flooding damage occurs at several locations within the watershed, with the most severe occurring in the vicinity of the confluence with Western Run and in the area around Union Avenue and 41st Street; the Mount Washington-Falls Village and Hampden-Woodberry areas are also impacted (Maryland Depart of the Environment 1981). From south of North Avenue to the Northwest Harbor, Jones Falls flows through an underground triple-celled concrete box storm sewer. This sewer lacks adequate conveyance capacity to carry the major Jones Falls floodwaters; therefore, sheet flooding is common on streets in the vicinity of the storm sewer during heavy rain periods. It should also be noted that three bridges across Jones Falls are undersized and cause major backwater flooding. These are the Union Avenue bridge, the Smith Avenue bridge, and the Amtrak box culvert in the vicinity of North Avenue. In addition, Maidens Choice Run has three major culverts that cause backwater flooding, which include the culverts under Boswell Road, North Bend Road, and Stonecroft Road (FEMA 2018).

Herring Run is a highly urbanized stream that discharges into the Back River before reaching the Chesapeake Bay, east of Baltimore City. Herring Run drains an approximately 31 mi^2 area (to the Back River confluence) of the Chesapeake Bay watershed. Headwaters originate outside the northeastern limits of Baltimore City. The landscape of Herring Run within Baltimore City limits is relatively flat with low, broad rolling hills; however, steep slopes are most prevalent in the area between Belvedere Avenue and Lake Montebello (City of Baltimore 2004). During periods of heavy rainfall, the stream system can be subject to riverine flooding; many of the flooding events from Herring Run occur outside of City limits.

Riverine flooding in Baltimore City is caused from excessive rainfall or snowmelt, which force the excess water outside of the floodway and into the floodplain, as depicted in Figure 4-3.

Several additional factors contribute to riverine flooding including soil saturation, ground freeze, severe wind events and inadequate drainage systems.

4.2.4 Flash Flooding

Flash flooding, like riverine and inland flooding, occurs throughout Baltimore City, primarily along the bodies of water that flow through it, which includes the Patapsco River and its tributaries – the Gwynns Falls and the Jones Falls, as well as their own tributaries, or from tidal flooding in the Inner Harbor and Middle Branch of the Patapsco River. Severe thunderstorms and periods of heavy rainfall can lead to flash floods if local bodies of water reach and/or surpass its capacity. A flash flood, unlike a riverine and inland flood, occurs within 6 hours of the rain event and spills excess water into an area in a short span of time (NWS 2014).

4.2.5 Urban Flooding

Urbanization increases runoff two to six times over what would occur on natural terrain. During periods of urban flooding, streets can become swift moving rivers. This type of flooding occurs throughout Baltimore City, particularly in areas with impermeable surfaces; this causes the ground to lose its ability to absorb rainfall (NWS 2014).

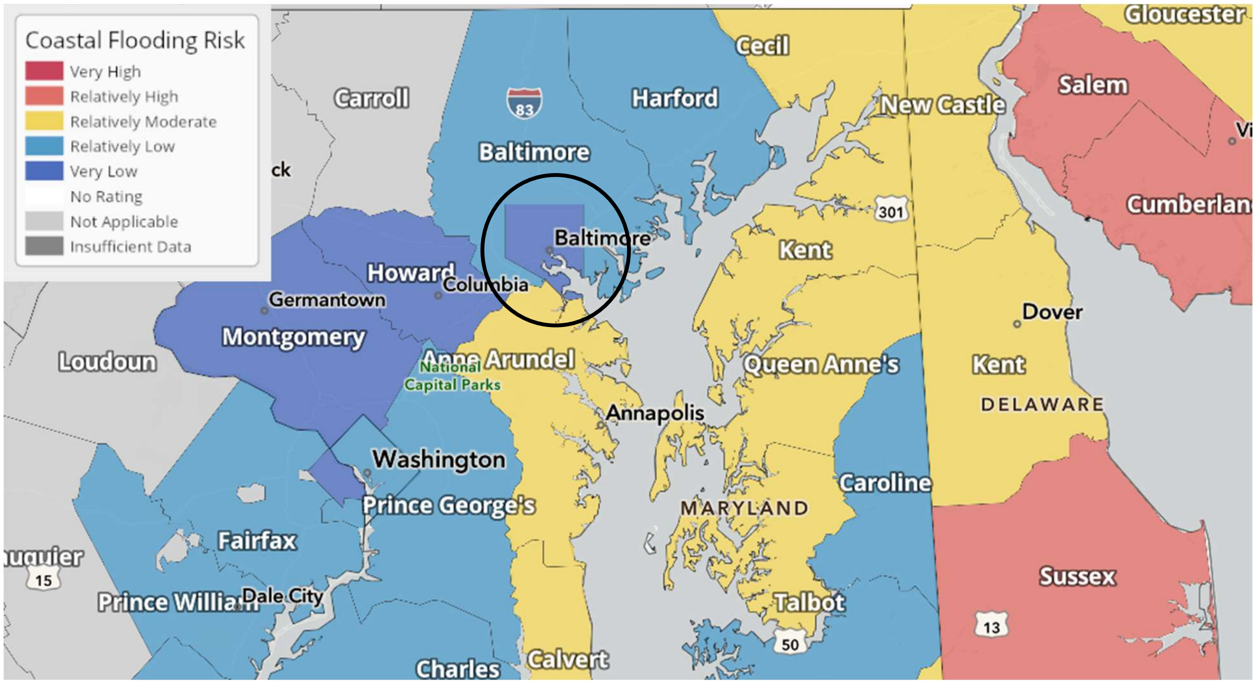
Much of the area where urban flooding occurs in not located within the 100-year floodplain, or the Special Flood Hazard Area (SFHA), as seen above in Figure 4-3. In fact, nationwide, approximately 25-percent of all National Flood Insurance Program (NFIP) claims are submitted by policyholders whose property is outside of the FEMA defined 100-year flood zone, according to a 2018 urban flooding report performed by the University of Maryland and Texas A&M University (University of Maryland and Texas A&M University 2018).

4.2.6 Coastal and Nuisance Flooding

According to the United States Environmental Protection Agency (EPA), the East Coast suffers the most frequent coastal flooding and has experienced the largest increases in the number of flood days. When comparing data from 1950-1959 to data from 2011-2020, Baltimore City is experiencing, on average, 5.4 more average number of flood days per year according to the EPA's Climate Indicator (EPA 2022). In Baltimore City, areas most susceptible to coastal flooding are those which border the Patapsco River. As a tidal river, the Patapsco is subject to waters pushed in from storms. More information on coastal flooding and hazards related to coastal storms can be found in Section 6 (Coastal Storms).

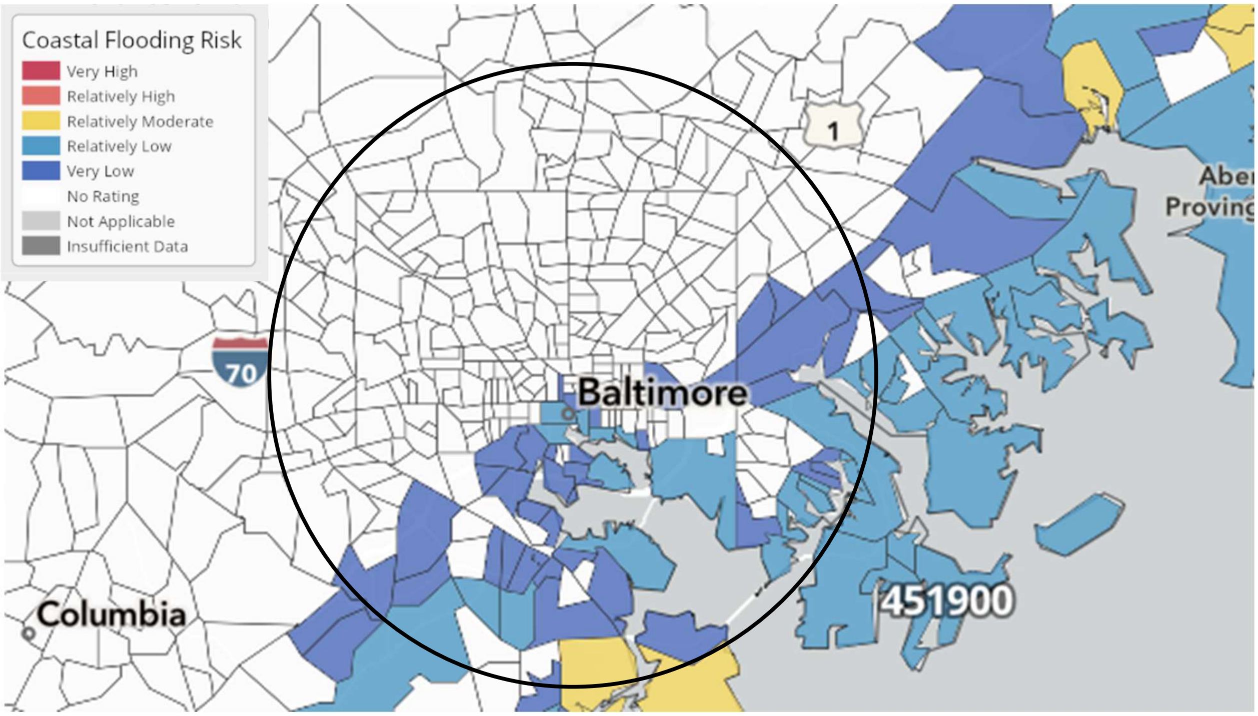
Figure 4-6 displays the Coastal Flood Risk Index for the United States (the black circle is representative of Baltimore City vicinity). According to the National Risk Index, on the county scale, Baltimore City has a very low risk to coastal flooding; on the census tract scale (Figure 4-7), Baltimore City ranges from a very low risk to a relatively low risk for coastal flooding (FEMA 2023).

Figure 4-6. National Risk Index, Coastal Flood Risk Index Score Using the County Scale



Source: FEMA 2023
Note: The vicinity of Baltimore City is within the black circle

Figure 4-7. National Risk Index, Coastal Flood Risk Index Score Using the Census Tract Scale



Source: FEMA 2023
Note: The vicinity of Baltimore City is within the black circle

4.2.7 Sea Level Rise

Similar to coastal flooding, in Baltimore City, the areas most susceptible to sea level rise are those which border the Patapsco River. As a tidal river, the Patapsco is subject to elevated water levels due to sea level rise. According to the 2018 Sea-Level Rise Projections for Maryland Report, the water level of the Chesapeake Bay (of which the Patapsco River is a tributary) with respect to the land is now rising about three time as fast as it was during Colonial times, threatening more densely built communities and infrastructure that developed over the interim (UMCES 2018). As the sea level rises, the starting elevation of coastal flooding events will also rise. This means coastal floods are likely to reach a higher elevation and push farther inland. As a result, the floodplain will expand and the base flood elevation will rise. Figure 4-8 depicts the potential footprint of the 1 percent annual chance flood area with 1 foot of sea level rise, a threshold likely to be reached by 2050.

4.3 Extent

The strength or magnitude of a flood varies based on meteorological, environmental, and geological factors, including latitude, altitude, topography, and atmospheric conditions. Flood is also affected by seasonal variation, storm characteristics, warning time, speed of onset, and duration. Most floods are preceded by a warning period that allows emergency managers to communicate the need to prepare for the event. A flood may last from minutes to days (O'Connor, Grant and Costa 2002).

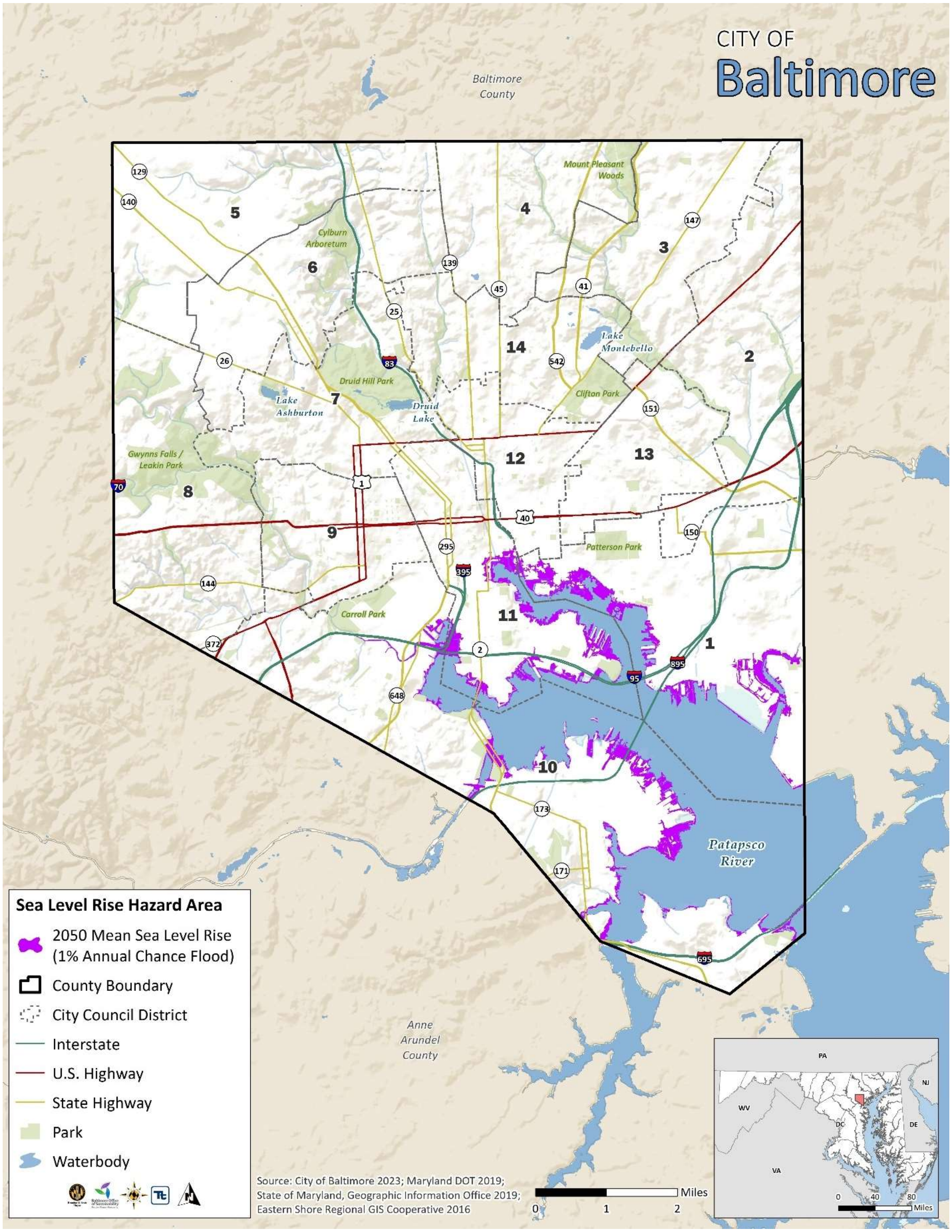
Warnings issued through official sources, such as the National Weather Service (NWS) and the Storm Prediction Center, provide the most reliable and timely preparedness information, but the exact flood location and depth depends on the amount, duration, and location of rainfall. Many floods, especially flash floods, occur outside of FEMA-designated flood zones.

In the case of riverine flood hazard, once a river reaches flood stage, the flood extent or severity categories used by the NWS include minor flooding, moderate flooding, and major flooding.

Flood Advisory Definitions

- Flood Advisory: Issued when flooding that is not considered a significant threat to life or property is expected or occurring (NWS 2017).
- Flash Flood Watch: Issued when conditions are favorable for flash flooding. It does not mean that flash flooding will occur, but it is possible (NWS 2017).
- Flash Flood Warning: Issued when flash flooding is imminent or occurring (NWS 2017).
- Flood Watch: Issued when conditions are favorable for flooding. It does not mean flooding will occur, but it is possible (NWS 2017).
- River Flood Watch: Issued when river flooding is possible at one or more forecast points along a river (NWS 2017).
- River Flood Warning: Issued when river flooding is occurring or imminent at one or more forecast points along a river (NWS 2017).

Figure 4-8. Projected 2050 Mean Sea Level Rise



Each NWS category has a definition based on property damage and public threat:

- Minor Flooding - minimal or no property damage, but possibly some public threat or inconvenience.
- Moderate Flooding - some inundation of structures and roads near streams. Some evacuations of people and/or transfer of property to higher elevations are necessary.
- Major Flooding - extensive inundation of structures and roads. Significant evacuations of people and/or transfer of property to higher elevations (NOAA 2021).

The severity of a flood depends not only on the amount of water that accumulates in a period of time, but also on the land's ability to manage this water. The size of rivers and streams in an area and infiltration rates are significant factors. When it rains, soil acts as a sponge. When the land is saturated or frozen, infiltration rates decrease and any more water that accumulates must flow as runoff (Harris 2001).

The frequency and severity of flooding are measured using a discharge probability, which is the probability that a certain river discharge (flow) level will be equaled or exceeded in a given year. Flood studies use historical records to determine the probability of occurrence for the different discharge levels. The flood frequency equals 100 divided by the discharge probability. For example, the 100-year discharge has a 1-percent chance of being equaled or exceeded in any given year. The "annual flood" is the greatest flood event expected to occur in a typical year. These measurements reflect statistical averages only; it is possible for two or more floods with a 100-year or higher recurrence interval to occur in a short time period. The same flood can have different recurrence intervals at different points on a river.

The extent of flooding associated with a 1-percent annual probability of occurrence (the base flood or 100-year flood) is used by the NFIP as the standard for floodplain management and to determine the need for flood insurance, as well as the regulatory flood boundary by many agencies. Also referred to as the Special Flood Hazard Area (SFHA), this boundary is a convenient tool for assessing vulnerability and risk in flood-prone communities. Many communities have maps that show the extent and likely depth of flooding for the base flood. Corresponding water-surface elevations describe the water elevation resulting from a given discharge level, which is one of the most important factors used in estimating flood damage. A structure located within a SFHA shown on a FIRM has a 26-percent chance of suffering flood damage during the term of a 30-year mortgage.

The term "500-year flood" is the flood that has a 0.2-percent chance of being equaled or exceeded each year. The 500-year flood could occur more than once in a relatively short period of time. Statistically, the 0.2-percent (500-year) flood has a 6-percent chance of occurring during a 30-year period of time, the length of many mortgages. The 500-year floodplain is referred to as Zone X500 for insurance purposes on FIRMs. Base flood elevations or depths are not shown within this zone and insurance purchase is not required in this zone (FEMA 2022).

4.3.1 Coastal and Nuisance Flooding

As relative sea level rises due to climate change, one of the most noticeable consequences is an increase in coastal flooding. Many coastal cities have defined "nuisance" flooding (also referred to as high tide flooding) thresholds. When water rises above this level, minor impacts from flooding typically occur in some streets, many storm drains become ineffective, and a coastal flood advisory may be issued. Recurrent coastal flooding can cause impacts such as frequent road closures, reduced stormwater drainage capacity, and deterioration of infrastructure not designed to withstand frequent inundation or exposure to salt water. Coastal flooding can also affect human health by increasing the risk that drinking water and wastewater infrastructure will fail, putting people at risk of being exposed to pathogens and harmful chemicals (EPA 2022).

Until recently, nuisance floods have occurred less than 10 days per year in Baltimore City. However, due to climate change and sea level rise, The National Oceanic and Atmospheric Administration (NOAA) predicts that Baltimore City will experience 15-25 nuisance flood events by 2030 and could see 50-160 events by 2050. In Baltimore City, there are several areas of concern when it comes to nuisance flood events. Lower Fells Point and areas along Inner Harbor have historically been the most impacted areas during nuisance floods. However, as sea levels continue to rise, other areas in Canton, Locust Point, Middle Branch, Port Covington, Westport, Fairfield, and Curtis Bay have been identified as vulnerable locations (Baltimore City Office of Sustainability 2020).

Coastal flooding can be categorized by the warnings, watches, and advisories issued by the National Weather Service (NWS). A coastal flood watch is issued when moderate-major coastal flooding is possible. A coastal flood warning is issued when moderate-major coastal flooding is actively occurring or imminent. A coastal flood advisory is issued when a minor or nuisance coastal flood is occurring or imminent for the area. In Baltimore City, coastal warning, watches, and advisories are issued along the Tidal Potomac River and along the Chesapeake Bay. All coastal flooding warnings, watches, and advisories have the potential to cause serious risk to both life and property for Baltimore City (NWS 2017). More information on coastal flooding and hazards related to coastal storms can be found in Section 6 (Coastal Hazards).

4.3.2 Sea Level Rise

Sea level is measured by two main methods: tide gauges and satellite laser altimeters. Tide gauge stations from around the world have measured the daily high and low tides for over a century. Using data from these stations, scientists can calculate a global average of change. Since the early 1990s, sea level has been measured from space using laser altimeters. This method determines the height of the sea surface by measuring the return speed and intensity of a laser pulse directed at the ocean. The higher the sea level, the faster and stronger the return signal (NASA Earth Observatory 2020).

Vertical land motion (VLM) throughout the Chesapeake Bay region is predominantly the result of glacial isostatic adjustment caused by rebounding of the land mass to the north that was once burdened by massive ice-age glaciers. Maryland is well south of the glaciated area, so the land is moving downward in compensation for the rebound in the north. Beyond the effects of negative VLM due to regional geological processes, sea-level rise at Baltimore is projected to be about 17-percent greater than for global mean sea-level rise in 2100. Projections have sea levels rising in the by up to 1.78 feet in 2050, 2.66 feet in 2070, and 4.25 feet in 2100 compared to current levels (University of Maryland 2023).

4.4 Previous Occurrences and Losses

Many sources provided historical information regarding previous occurrences and losses associated with flooding throughout Baltimore City. With so many sources reviewed for this plan update, loss and impact information for many events could vary. Therefore, the accuracy of monetary figures discussed is based only on the available information in cited sources.

Flooding in Baltimore City has caused loss of life; the flood of 1966 had 39 fatalities. There has also been loss of dwellings, factories, bridges, and farm animals.

The most severe storm on record in Baltimore City area was a hurricane that occurred in 1933. This hurricane hit the coast at a higher latitude than most tropical storms that affect the region and entered the Chesapeake Bay directly from the ocean. There was no loss of energy by passing overland. Damage from tidal flooding in Baltimore City area was estimated to be approximately $5 million. Wind velocities reached 60 miles per hour, and tides rose to a record height of 7.87 feet at Fort McHenry.

One of the most significant flooding events in recent years was Tropical Storm Isabel in September 2003. Isabel was a federally declared disaster, which caused over $8 million in damage in Maryland (FEMA 2018).

4.4.1 FEMA Major Disasters and Emergency Declarations

Between 1953 and 2022, Baltimore City was included in three (3) disaster (DR) or emergency (EM) declarations for flood-related events, identified in Table 4-4. Generally, these disasters cover a wide region of the State; therefore, they can impact many counties. However, not all counties were included in the disaster declarations as determined by FEMA (FEMA 2023).

Table 4-4. FEMA Flood Disaster Declarations in Baltimore City (1953 to 2022)

Date(s) of Event	Date of Declaration	Event Type	FEMA Declaration Number	Description
August 17, 1971	August 17, 1971	Flood	DR-309-MD	Maryland Severe Storms, Flooding
June 23, 1972	June 23, 1972	Flood	DR-341-MD	Maryland Tropical Storm Agnes
October 4, 1975	October 4, 1975	Flood	DR-489-MD	Maryland Heavy Rains, Flooding

Source: FEMA 2023

4.4.2 Previous Events

For the 2023 DP3 update, known flood events that impacted Baltimore City between 1996 and 2022 are discussed below in Table 4-5. Instances where narrative was not available on the NOAA National Centers for Environmental Information (NCEI) Storm Events Database are not included in Table 4-5.

Table 4-5. Flood Events in Baltimore City (1996 to 2022)

Date(s) of Event	Event Type	FEMA Declaration Number (if applicable)	City included in Declaration?	Location Impacted	Description
January 19, 1996	Flash Flood	N/A	N/A	Citywide	A deep snowpack was melted by warm temperatures. Streams quickly overflowed their banks, and water ponded quickly from clogged storm drains and saturated ground. Several water rescues were reported just south of Baltimore City, Interstate 695 was closed briefly. Baltimore City did not incur any property damage from this event.
June 17, 1996	Flash Flood	N/A	N/A	Northeast Portion of Baltimore City	Thunderstorms produced widespread flash flooding in Baltimore City. At least 20 persons were rescued from stranded automobiles. Many of the trapped motorists were on Loch Raven Blvd. and along federal highway 40. No injuries or deaths were reported. Hundreds of low-lying intersections and underpasses were flooded. Numerous basements and ground floors were flooded by a combination of heavy rainfall and clogged storm drains. The combination of high water, gusty winds, and lightning knocked out power to nearly 14 thousand City residents. Baltimore City incurred $100,000 in property damage from this event.
June 19, 1996	Flash Flood	N/A	N/A	Citywide	Baltimore City incurred $125,000 in property damage from this event.
July 30, 1998	Flood	N/A	N/A	Highlandtown	An isolated thunderstorm produced heavy rains; this, combined with poor drainage, caused sidewalk flooding in the Fells Point section of Baltimore City. At least two poorly draining intersections reported water "up to car windows" in the south portion of Baltimore City. Baltimore Gas and Electric reported 15,000 customers lost power during the storm. Baltimore City incurred $8,000 in property damage from this event.
August 26, 1999	Flash Flood	N/A	N/A	Citywide	A line of intense thunderstorms produced damaging winds and frequent lightning. Baltimore City reported major flash flooding; 4.77 inches of rain fell in less than 4 hours. Flooding closed sections of Interstate 83 in Baltimore. Water poured off Interstate 83 and reached a depth of 6 feet on Clipper Mill Road. Forty cars in the parking lot were damaged, and most of the cars were moved several yards by the force of the water.

Date(s) of Event	Event Type	FEMA Declaration Number (if applicable)	City included in Declaration?	Location Impacted	Description
					Several flights were delayed or cancelled at Baltimore Washington International Airport (BWI). Baltimore City reported numerous roads under water and several stalled vehicles and water rescues. So many streets flooded that officials asked drivers to stay put until the water receded. Over 17,000 residents of Baltimore City lost power as a direct result of the storm, and hundreds of basements flooded. The Northwest Ice Rink was inundated with water, and motorists near Camden yards waited on the roofs of their cars to be rescued from waist-high water. A building collapsed on Wicomico Street, and rushing water blasted a hole in another home. Rain and mud on railroad tracks and water in the Howard Street tunnel two miles south of Baltimore's Penn Station delayed MARC and Amtrack commuter trains between Washington D.C. and Baltimore City. It rained so hard that medevac helicopters from the Shock Trauma Center at University Hospital had to be grounded. Baltimore City incurred $100,000 in property damage from this event.
September 9, 1999	Flash Flood	N/A	N/A	Citywide	Thunderstorms producing damaging winds and very heavy rainfall moved across Central Maryland between 5:30 PM and 11:00 PM EDT. Jones Creek went out of its banks, and roads were flooded downtown. Baltimore City did not incur any property damage from this event.
September 16, 1999	Flash Flood	N/A	N/A	Citywide	Hurricane Floyd made landfall just east of Cape Fear, North Carolina in the early morning hours of the 16th and moved north-northeast across extreme southeast Virginia to near Ocean City, Maryland by evening on the 16th. Tidal flooding was reported along the Chesapeake Bay. Strong southerly winds ahead of the hurricane pushed tides 2 to 3 feet above normal, flooding several low-lying areas. 5.78 inches of rainfall was recorded at Baltimore/Washington International Airport.

Date(s) of Event	Event Type	FEMA Declaration Number (if applicable)	City included in Declaration?	Location Impacted	Description
					Jones Falls and Western Run overflowed, causing nearby residents to be evacuated. Baltimore City incurred $50,000 in property damage from this event.
July 14, 2000	Flash Flood	N/A	N/A	Citywide	A cold front moved across the region during the evening of the 14th. Thunderstorms that developed ahead and along this front produced very heavy rainfall, frequent lightning, large hail, and winds in excess of 55 MPH. In Baltimore City, flooding was concentrated between Back River and Middle River where some stranded motorists had to be rescued. Baltimore City did not incur any property damage from this event.
February 22-23, 2003	Flood	N/A	N/A	Citywide	A combination of 1.5 to 3 inches of rain that fell between the evening of the 21st and the morning of the 23rd and snowmelt from the massive snowstorm of 14-18 February led to widespread flooding. The Baltimore-Washington Parkway was closed by high water on the afternoon of the 23rd north of the Baltimore Beltway. In Baltimore City, 90 roads and 290 basements were flooded. Baltimore City did not incur any property damage from this event.
May 16, 2003	Flood	N/A	N/A	Citywide	A large area of showers and thunderstorms containing heavy downpours moved through the region between the afternoon of the 15th and the morning of the 16th. The system dropped between 2 and 4 inches of rain across western and central Maryland which caused several low-lying areas to flood. Baltimore City did not incur any property damage from this event.
June 12, 2003	Flash Flood	N/A	N/A	Citywide	Thunderstorms with very heavy rainfall, frequent lightning, and damaging winds moved through central Maryland during the afternoon and evening of the 12th. In Baltimore City, six roads were flooded. In addition, pea sized hail fell in Towson and Baltimore. Baltimore City did not incur any property damage from this event.

Date(s) of Event	Event Type	FEMA Declaration Number (if applicable)	City included in Declaration?	Location Impacted	Description
June 13, 2003	Flash Flood	N/A	N/A	Citywide	Thunderstorms with very heavy downpours and gusty winds moved through North Central Maryland. In Baltimore City, cars and homes were damaged after several streets were flooded by rapidly rising water. Motorists had to be rescued or swam to safety; the hardest hit areas included Hillen Road, 35th Street, and Aisquith Street near 25th Street. A woman was injured when she fell through a floor that was weakened by flooding. Baltimore City incurred $500,000 in property damage from this event.
June 21, 2003	Flash Flood	N/A	N/A	Citywide	Showers and thunderstorms with heavy downpours and hail moved through the Baltimore metropolitan area during the late afternoon and early evening hours of the 21st. In Baltimore City, some streets were flooded. High water was also reported on Interstate 95 in town. Baltimore City did not incur any property damage from this event.
November 19, 2003	Flash Flood	N/A	N/A	Citywide	Creeks and roads were flooded. There were four fatalities reported for this event, including an 11-year-old male. Baltimore City did not incur any property damage from this event.
December 11, 2003	Flood	N/A	N/A	Citywide	An area of low pressure moved across the region and produced some heavy rainfall late on the 10th and early on the 11th. This rain fell on top of snow-covered grounds and led to melting. The combination of the heavy rainfall and the melting snow produced widespread road flooding of over portions of Maryland during the morning and afternoon hours. Rainfall amounts averaged 2 to 3 inches. Baltimore City did not incur any property damage from this event.
February 6-7, 2004	Flood	N/A	N/A	Citywide	Heavy rainfall and melting snow produced some flooding across North Central Maryland and the Baltimore Metropolitan area. Radar estimates and rain gauge data indicated that two to three inches of rain fell over the region. Some roads were blocked after small streams came out of their banks. Baltimore City did not incur any property damage from this event.
July 7, 2004	Flash Flood	N/A	N/A	Woodberry	Scattered showers and thunderstorms developed and produced strong winds that downed trees and power lines, penny size hail,

Date(s) of Event	Event Type	FEMA Declaration Number (if applicable)	City included in Declaration?	Location Impacted	Description
					and flooding. In Baltimore City, stores and businesses along the Jones Falls closed early to allow clients, shoppers, and employees to get out before the waters started to rise. A portion of the historic Meadow Mill building in the Woodberry neighborhood was flooded, and nearly 30 cars in the parking lot were almost submerged. The Mount Washington neighborhood also witnessed some impressive flooding. The Meadow Hill Athletic Club reported a loss of 500,000 dollars in exercise equipment. A newly opened men clothing store reported damage around 400,000 dollars. Baltimore City incurred $1 million in property damage from this event.
July 27, 2004	Flash Flood	N/A	N/A	North Portion of Baltimore City	Two to five inches of rain produced by a slow-moving system caused widespread flash flooding. In Baltimore City, streets flooded with water covering roadways. Baltimore City did not incur any property damage from this event.
August 1, 2004	Flash Flood	N/A	N/A	West Portion of Baltimore City	A system produced over two inches of rain in a short time causing drainage problems in many areas. Several primary and secondary roads were closed due to high water. Baltimore City did not incur any property damage from this event.
September 28, 2004	Flash Flood	N/A	N/A	Citywide	A weather system caused a few roads to close due to high water. Baltimore City did not incur any property damage from this event.
April 2, 2005	Flood	N/A	N/A	Citywide	A strong cold front crossed the Mid Atlantic Saturday, April 2nd. This front brought severe thunderstorms that downed trees and power lines as well as heavy downpours that flooded rivers, streams, and roadways. After the front passed, strong winds downed trees and power lines mainly in the higher terrain of western Maryland. Baltimore City did not incur any property damage from this event.
October 8, 2005	Flood	N/A	N/A	Citywide	The remnants of Tropical Storm Tammy caused widespread heavy rainfall between 3 to 7 inches across the region. Numerous reports of flooded roads were received due to the prolonged rains.

Date(s) of Event	Event Type	FEMA Declaration Number (if applicable)	City included in Declaration?	Location Impacted	Description
					The Baltimore/Washington Airport measured 6.72 inches of rainfall. Baltimore City did not incur any property damage from this event.
June 1, 2006	Flash Flood	N/A	N/A	Citywide	Thunderstorms moved into the Washington/Baltimore corridor. Flash flooding was reported in the eastern portion of Baltimore City. Reports were received about water flowing across Belair Road near Interstate 695.
June 25-26, 2006	Flash Flood, Coastal Flood	N/A	N/A	Citywide	A slow-moving thunderstorm caused 4 to 7 inches across the Baltimore Metro, leading to extensive urban flooding on June 25 and June 26. The Water Treatment Plant reported that streams overflowed their banks across Baltimore City. Jones Falls topped its banks, flooding parts of Clipper Mill Road and Union Avenue. Thames Street in the Fells Point neighborhood flooded. Baltimore City did not incur any property damage from this event.
June 27-28, 2006	Coastal Flood	N/A	N/A	Citywide	Several storm systems moved into the region consecutively, causing double digit rainfall totals affected parts of the region through the five days. Winds produced by the systems caused abnormally high tidal departures in the Chesapeake Bay and Tidal Potomac River. Baltimore County Citizen Core Program reported tidal flooding near Bowley Bar with two roads along Middle River under water and impassable. Water was up on properties near Middle River and Bowley Bar. Rapid water rises and tidal flooding was reported near high tide. Baltimore City incurred $20,000 in property damage from this event.
November 16, 2006	Flash Flood, Coastal Flood	N/A	N/A	Citywide	Thunderstorms produced periods of heavier rainfall as well as gusty and isolated damaging winds. Although rain ended across the region during the midafternoon hours, some locations continued to experience flooding until just after midnight. Several roads in Baltimore City were closed due to flash flooding. Jones Falls flooded the bridge at Interstate 83 and 41st Street. Other roadways affected by flash flooding include Erdman Avenue on the east side of Baltimore City and Caroline and Fleet

Date(s) of Event	Event Type	FEMA Declaration Number (if applicable)	City included in Declaration?	Location Impacted	Description
					Streets near downtown. Baltimore City incurred $15,000 in property damage from this event.
April 15, 2007	Flood	N/A	N/A	Hampden	A Nor'easter brought heavy rains, causing flooding in the afternoon and evening. Winds from the storm downed trees and power lines across central and lower southern Maryland. There were reports of flooding in the Hampden area of Baltimore City. Baltimore City did not incur any property damage from this event.
July 23, 2008	Flash Flood	N/A	N/A	Mount Royal	Scattered showers and thunderstorms developed in the afternoon and evening hours. These storms produced heavy rainfall, and repeatedly moved over the same areas. This allowed flash flooding to occur across the Baltimore metro area, resulting in several road closures and water rescues. Local broadcast media reported a water rescue at Exeter Hall Avenue and Aisquith Street. Northbound ramps of the Jones Falls Expressway at President Street and Monument Street were closed. Baltimore City did not incur any property damage from this event.
September 27, 2008	Flash Flood	N/A	N/A	Roland Park	Thunderstorms with heavy rains occurred in Baltimore City in short periods of time, resulting in flash flooding. Jones Falls was out of its banks near Falls Road and Smith Avenue. Bridges were closed along Smith Avenue. Parking lots were under water. Baltimore City incurred $1,000 in property damage from this event.
January 25, 2010	Coastal Flood	N/A	N/A	Citywide	A persistent onshore wind led to areas of coastal flooding near the shore of the Chesapeake Bay. High water rescues were reported along Bay Drive on Millers Island. Baltimore City incurred $10,000 in property damage from this event.
March 13, 2010	Coastal Flood	N/A	N/A	Citywide	A persistent the onshore wind caused coastal flooding in southern Baltimore County near the Chesapeake Bay. A gage indicated that water levels surpassed thresholds for minor coastal flooding near the Chesapeake Bay in southern Baltimore County. Baltimore City did not incur any property damage from this event.

Date(s) of Event	Event Type	FEMA Declaration Number (if applicable)	City included in Declaration?	Location Impacted	Description
September 30, 2010	Coastal Flood	N/A	N/A	Citywide	Strong winds allowed water to pool in the Chesapeake Bay and be pushed onshore. Water was also pushed upstream the tidal Potomac River. Coastal flooding was observed along the lower tidal Potomac River and across the Chesapeake Bay. Baltimore City did not incur any property damage from this event.
March 10, 2011	Flash Flood, Coastal Flood	N/A	N/A	Citywide	Showers and thunderstorms produced locally heavy amounts of rain in a short period of time which led to flash flooding. Both the Meadow Mill and Jones Falls parking lots were closed due to flash flooding. Strong onshore wind caused water levels to be elevated which led to coastal flooding along areas near the western shore of the Chesapeake Bay and near the Tidal Potomac River. Both ends of Bay Drive were flooded. Community property was flooded up to the roadway. Baltimore City did not incur any property damage from this event.
April 16-17, 2011	Coastal Flood	N/A	N/A	Citywide	Elevated water levels due to the onshore wind caused areas of coastal flooding along the western shore of the Chesapeake Bay. High water was reported along Miller Highland Road and across North Point Road near Shallow Creek. Water was about a foot and a half deep along the intersection of Bay Drive and Chesapeake Road. There was also a report of water that was about one foot deep in the park across from the intersection of Bullneck Road and Longpoint Road in Dundalk. Baltimore City did not incur any property damage from this event.
July 7, 2011	Flash Flood	N/A	N/A	Camden	Showers and thunderstorms slowly moved through Baltimore City and caused flash flooding with rainfall rates of over 1 inch per hour occurring. The intersection of Washington Blvd and Monroe Street was closed due to flash flooding. Baltimore City did not incur any property damage from this event.
August 27, 2011	Flash Flood	N/A	N/A	Gardenville, Hillen, Clifford	Hurricane Irene tracked up the Mid-Atlantic Coast during the afternoon and evening hours of the 27th. Heavy rains associated with Irene and her rainbands fell over saturated soils of Maryland. Flash flooding resulted in some areas and flooding continued into the 28th as waters rose. Storm total rainfall from Irene reached 12.00 in spots.

Date(s) of Event	Event Type	FEMA Declaration Number (if applicable)	City included in Declaration?	Location Impacted	Description
					In Baltimore City, Harford Road near Montebello Terrace was closed due to flash flooding. A nearby rain gage tallied 4.59 inches; McElderry Street near North Patterson Park Avenue was closed due to flooding. A rain gage in downtown Baltimore measured 3.63 inches during the event; and the 600 Block of West Patapsco Avenue was closed due to flooding. A nearby rain gage tallied 3.34 inches. Baltimore City did not incur any property damage from this event.
September 7, 2011	Flash Flood	N/A	N/A	Westport	The remnants of Tropical Depression Lee merged with another weather system causing major flooding and flash flooding to occur. The ramp from Route 295 northbound to Interstate 95 was closed due to flash flooding. A nearby rain gauge measured 4.33 inches. Baltimore City did not incur any property damage from this event.
August 26, 2012	Flash Flood	N/A	N/A	Hillen, Roland Park, Crisp	Heavy rain and isolated thunderstorms produced damaging winds and lightning. Heavy rain caused evacuations on the 2300 block of East Monument Street due to flash flooding. Baltimore City did not incur any property damage from this event.
September 3, 2012	Flash Flood	N/A	N/A	Hampden, Roland Park	The remnants of Isaac caused heavy rains and localized strong winds over the Bay. The intersections of Roland Avenue at Wyndhurst Road and Falls Road and Clark Hill Road were closed due to flooding. Baltimore City did not incur any property damage from this event.
October 30, 2012	Coastal Flood	N/A	N/A	Citywide	Hurricane Sandy caused heavy rain and high winds over spread coastal regions and most of Maryland. Heavy rain caused flood and river flooding. As Sandy moved north of the Mid Atlantic, winds switched to southerly and coastal flooding occurred. Water reached the porch of a home on Wilson Point. Shore Rd and Middle river and other nearby streets were flooded. Water piled up on the steps of a business facing the harbor. Wolfe Street and Fells Point were flooded Thames and Aliceanna Streets. The end of Thames Street was also flooded. Baltimore City did not incur any property damage from this event.
June 10, 2013	Flash Flood	N/A	N/A	Camden	Heavy rains and damaging winds occurred in Baltimore City. There was water observed up to the hoods of cars in the 500

Date(s) of Event	Event Type	FEMA Declaration Number (if applicable)	City included in Declaration?	Location Impacted	Description
					block of South Charles Street. Baltimore City did not incur any property damage from this event.
April 30, 2014	Flash Flood	N/A	N/A	Mount Royal, Mount Winans	Showers and thunderstorms broke out across the area; heavy rain produced flash flooding and rapid rises on streams and creeks. Jones Falls was out of its banks. There was flooding reported at the Mount Washington Mill Complex and water moving across Clipper Mill Road. Water covered almost all the pedestrian bridge paralleling Water Street, and covered Water Street from the MD 4 Westbound exit ramps to Judges Street. There was a landslide near North Charles St and East 26th Street. Baltimore City did not incur any property damage from this event.
June 19, 2014	Flash Flood	N/A	N/A	Westport, Brooklyn, Clifford	Localized heavy rain led to flash flooding in Baltimore City. There was flooding blocking one lane of Maryland 295 near Waterview Avenue. There were multiple water rescues near the intersection of Patapsco Avenue and Magnolia Avenue. Baltimore City did not incur any property damage from this event.
August 12, 2014	Flash Flood	N/A	N/A	Mount Winans, Curtis Bay, Fairfield	Heavy rain produced flooding in parts of the Washington DC and Baltimore Metro Areas. Gwynns Falls exceeded its flood stage of 13 feet with minor overbank flooding occurring for about an hour near the Gwynns Falls Trail. It went above flood stage and peaked at 13.78 feet at 2:20 PM EDT. The outer loop of the Baltimore Beltway was flooded and completely closed at Quarantine Road; all traffic was diverted. The Baltimore Harbor Tunnel was closed due to flooding. Baltimore City did not incur any property damage from this event.
June 20-21, 2015	Flash Flood, Flood	N/A	N/A	Brooklyn, Clifford	Remnants of Tropical Storm Bill caused showers and thunderstorms, which led to heavy rain across the Interstate 95 corridor and flash flooding occurred. There was a car stranded in high water on East Patapsco Avenue between 6th and 7th Streets. Baltimore City incurred $10,000 in property damage from this event.

Date(s) of Event	Event Type	FEMA Declaration Number (if applicable)	City included in Declaration?	Location Impacted	Description
July 30, 2016	Flash Flood	N/A	N/A	Westport	Thunderstorms developed and led to very heavy rainfall, causing flash flooding. The stream gauge on Gwynn Falls at Washington Boulevard reached their flood stage of 13 feet; it peaked at 17.72 feet. Water covered the bike path alongside the stream and approached the end of Berlin Street. Baltimore City did not incur any property damage from this event.
July 29, 2017	Flash Flood	N/A	N/A	Clifford	Thunderstorms led to widespread flooding; the 3400 Block of Spelman Road flooded and closed due to torrential rainfall. Baltimore City did not incur any property damage from this event.
October 24, 2017	Coastal Flood	N/A	N/A	Citywide	A strong onshore flow led to moderate coastal flooding along portions of the western shore of the Chesapeake Bay. Water covered most piers and it proceeded into residence yards in the Bowley Bar Area. Water was about 6 inches deep. Baltimore City did not incur any property damage from this event.
May 27, 2018	Flash Flood	N/A	N/A	Catonsville, Frederick Road	Heavy rain trained to the northeast of Baltimore City early in the afternoon, causing flash flooding; the system stalled producing 6-12 inches of rain in a very short period. The stream gage on Gwynns Falls at Washington Boulevard in Baltimore City rapidly exceeded the 13-foot flood stage, flooding portions of Gwynns Falls Park; the peak level of 17.09 feet was the 4th highest on record. Several roads flooded in Baltimore City. More than 20 people were rescued from vehicle rooftops during heavy rains. Six people were displaced from their homes, and Frederick Avenue was damaged in the Beechfield neighborhood. Baltimore City incurred $3 million in property damage from this event.
July 21-22, 2018	Flash Flood	N/A	N/A	Walbrook, Loudon Park	Heavy rain caused rainfall totals of 3 to 6 inches, with isolated higher amounts, causing widespread flooding. The USGS stream gage on Gwynns Falls in Baltimore City rapidly exceeded the 13-foot flood stage during the indicated period; the peak level of 18.29 feet was observed on July 22nd. Gwynns Falls Park was flooded during this period. Baltimore City did not incur any property damage from this event.

Date(s) of Event	Event Type	FEMA Declaration Number (if applicable)	City included in Declaration?	Location Impacted	Description
July 25, 2018	Flood	N/A	N/A	Camden	Heavy rainfall fell in some areas, especially in Baltimore and Carroll Counties, with widespread flooding and flash flooding throughout the period. More than ten roads flooded and closed throughout Baltimore City. Baltimore City did not incur any property damage from this event.
July 27, 2018	Flash Flood	N/A	N/A	Catonsville Manor, Mount Royal	Heavy rain fell on saturated ground during the afternoon and evening of July 27th in the Baltimore metro area. One to three inches of rain was observed, along with numerous instances of flooding. US 40 flooded and closed due to torrential rain near the West Baltimore MARC station. Torrential rain forced cars to be stuck in high water on Falls Road, with nearby ramps to Interstate 83 also flooded, blocking traffic. Baltimore City did not incur any property damage from this event.
August 31, 2019	Flood	N/A	N/A	Mount Winans	Showers and thunderstorms developed around a stalled boundary. A slow storm motion combined with copious amounts of moisture led to heavy rain. The gauge at Gwynns Falls at Washington Boulevard surpassed flood stage of 13 feet, cresting at 14.11 feet. Water covered the bike path alongside the stream and approached the end of Berlin Street. Baltimore City did not incur any property damage from this event.
October 31, 2019	Flash Flood	N/A	N/A	Leahigh	Locally heavy rainfall caused West Strathmore Road to close due to flash flooding near the intersection with Cross Country Boulevard. Baltimore City did not incur any property damage from this event.
April 13, 2020	Coastal Flood	N/A	N/A	Citywide	A southerly wind led to moderate tidal flooding. Moderate flooding occurred due to the water level around Fort McHenry. Baltimore City did not incur any property damage from this event.
April 30, 2020	Coastal Flood	N/A	N/A	Citywide	A southerly wind led to elevated water levels, which caused moderate tidal flooding. Moderate flooding occurred due to the water level around Fort McHenry. Baltimore City did not incur any property damage from this event.
November 15, 2020	Coastal Flood	N/A	N/A	Citywide	A southerly wind led to elevated water levels. Fort McHenry Tidal Gage reached a peak of 3.88 feet. Baltimore City did not incur any property damage from this event.

Date(s) of Event	Event Type	FEMA Declaration Number (if applicable)	City included in Declaration?	Location Impacted	Description
December 25, 2020	Coastal Flood	N/A	N/A	Citywide	Onshore flow ahead of a storm led to some instances of moderate coastal flooding along the Chesapeake Bay. Fort McHenry Tidal Gage reached a peak of 3.85 feet. Baltimore City did not incur any property damage from this event.
September 1, 2021	Flood	N/A	N/A	Canton, Bay View	The remnants of Ida produced widespread flooding along with instances of flash flooding across the area. Rainfall amounts averaged around 1-3 near and east of Interstate 95, with amounts around 4 to 8 inches across portions of northern and central Maryland. Excess runoff from the heavy rainfall led to river flooding as well. Flooding reported at North Point Boulevard and Kane Street. Multiple roads flooded in Fells Point. Baltimore City did not incur any property damage from this event.
August 5, 2022	Flash Flood	N/A	N/A	Canton	Isolated instances of flooding and flash flooding occurred due to slow moving thunderstorms around Baltimore City. Flooding was reported along the Intersection of Orleans Street and North Lakewood Avenue. Baltimore City did not incur any property damage from this event.

Source: NOAA 2023; City of Baltimore 2018; FEMA 2023

May 27, 2018, Flash Flooding

Event Summary

On May 27, 2018, a heavy line of thunderstorms impacted portions of central Maryland, dropping 9-10 inches of rain in the western area of Baltimore City resulting in catastrophic urban flooding. The Frederick Avenue corridor was the epicenter of this flash flooding event. The intersection of Frederick and Beechfield was rapidly inundated with water in just a few minutes. First responders reported being able to carefully maneuver through flood waters on foot upon arriving on scene; however, after 10 minutes, the waters gained depth and swiftness, not being able to be traversed on foot or by vehicle.

Figure 4-9. FEMA Floodplain Along Frederick Avenue Culvert

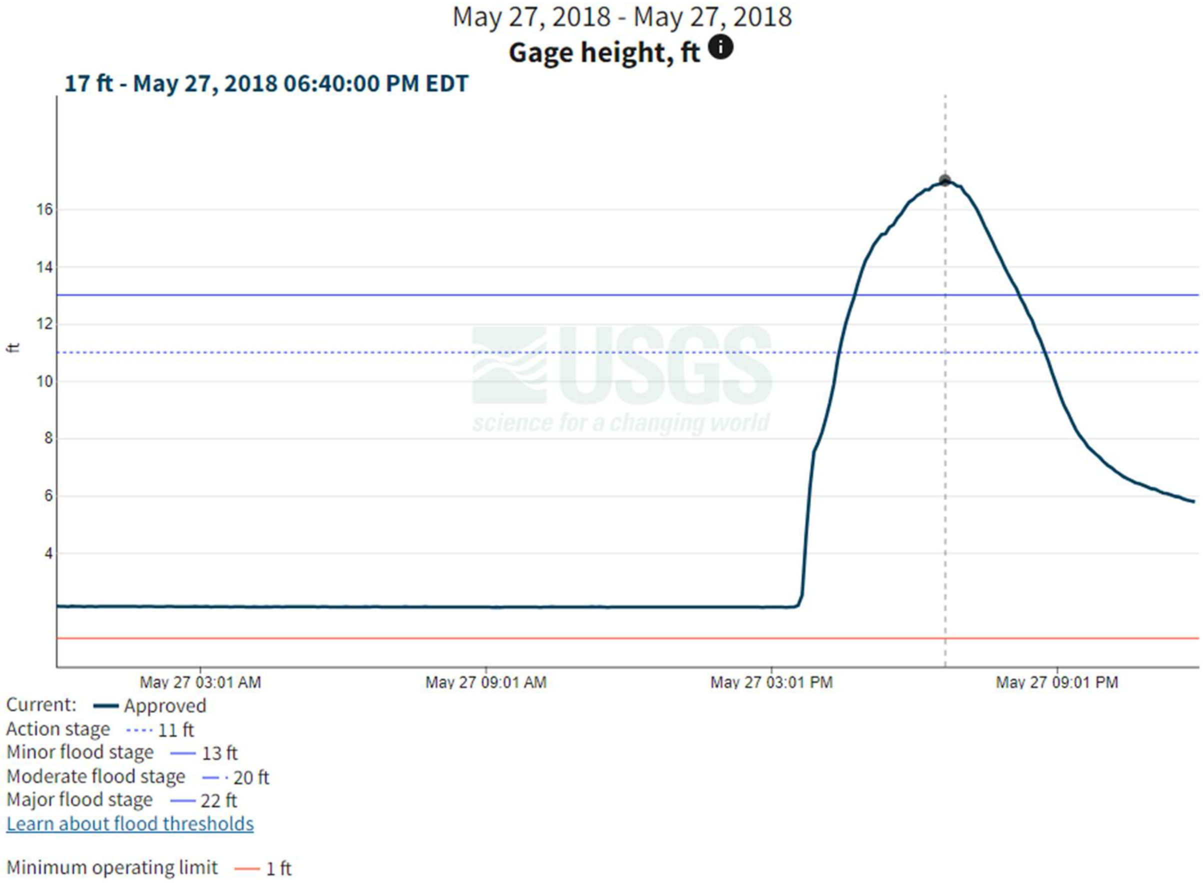
Source: FEMA 2023

Timeline of Events

Calls to 9-1-1 began around 3:00PM, with an uptick around 6:00PM; a total of 64 9-1-1 calls and 217 3-1-1 calls related to the flooding event were recorded, ranging from requesting a water rescue, reporting the flooding, identifying vehicles in water, and noting an electric hazard due to the flood waters.

The stream gage on Gwynns Falls at Washington Boulevard in Baltimore City rapidly exceeded the 13-foot flood stage, flooding portions of Gwynns Falls Park; the peak level of 17.09 feet was the 4th highest on record. See Figure 4-10 for the stream gage graph.

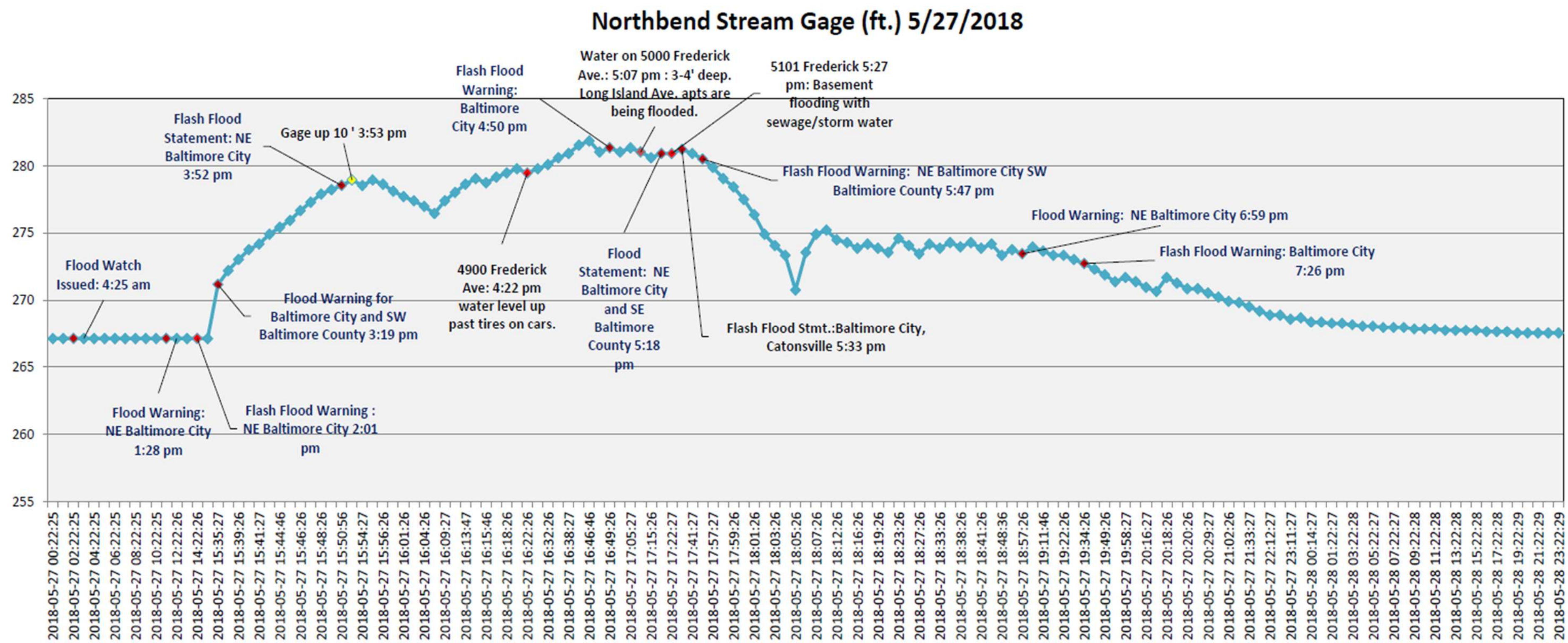
Figure 4-10. Gwynns Falls at Washington Blvd., Baltimore City



Source: USGS 2018

Figure 4-11 shows the North Bend Stream gage overlayed with key points during the event, including when flood watches, warnings, and statements were issued; stream gage readings; and reports from 9-1-1 and 3-1-1 calls. Zone AE is known as the special flood hazard area, where flooding occurs once in every 100 years. As displayed below, flood notifications were issued by the National Weather Service beginning at 425 a.m. the morning of May 27th. Flash flood notifications began later in the day at 2:01 p.m. when a flash flood warning was issued for Baltimore City. A statement regarding the flash flooding was made one minute before the Northbend Stream Gage reached 10 feet. Much of the activity for this flash flooding event coincided with peak gage readings at the Northbend Stream Gage, including water levels being above car tires, apartments being flood in 3 to 4 feet of water, and basement flooding with sewage and storm water. Despite the Northbend Stream Gage readings lowering around 6:00 p.m., flood and flash flood warnings continued to be issued for Baltimore City as the slow-moving system continued eastward, leaving pooling waters in its wake.

Figure 4-11. Northbend Stream Gage with Key Event Markers



Source: Baltimore City OEM 2018

Impacts

The Frederick Apartments had water pooled to the first level apartment balconies, where the water reached an estimated 7 feet in depth. Baltimore Gas and Electric (BGE) cut off utilities to a number of apartments in this apartment complex due to the depth of the water. Ground level apartments were submerged in water, houses in the area reported basement and first-floor flooding, destroying the contents in many basements.

City first responders performed 21 water rescues on Frederick Avenue, performed by rescue swimming tactics and the deployment of zodiac boats. A majority of the rescues were from an occupied Maryland Transit Administration (MTA) bus, which was floating in the floodwaters.

At the intersection of Frederick Avenue and North Bend, people were trapped in their vehicles. A woman exited her vehicle just as a sinkhole began to form underneath her vehicle. The woman was swept away and floated east bound on Frederick Avenue, where she became entangled in chain-link fence; miraculously, the woman survived the incident. No fatalities were reported from this flash flooding event, and the ages of individuals rescued ranged from infant to mid-60s.

Recovery

Recovery efforts are still ongoing for the Frederick Avenue community. In the days following the flood, recovery efforts began to clean-up debris and waste related to the incident. The American Red Cross (ARC) coordinated with Stillmeadow Community Fellowship to provide meals to residents, responders, and work crews. The ARC also assisted with providing medications, home clean-up kits, and operated a shelter in Stillmeadow Church. The ARC also conducted outreach to residents about mold remediation. Non-profit organizations Team Rubicon and Southern Baptist Convention mucked out houses and conducted mold remediation.

Stillmeadow outreach and preparedness event

Image provided by OEM.

The Stillmeadow Community Fellowship continues to assist Baltimore City by being a Resiliency Hub for Baltimore City. Community Resiliency Hubs are trusted, service-based non-profit community organizations with strong leadership. Stillmeadow Community Fellowship partners with Baltimore City and provides essential resources and community support during times of crisis. The Stillmeadow Community Fellowship serves as a space where vulnerable neighbors can gather in times of emergency; access reliable power for their essential devices;

receive supplies, food, and drinking water; and store medications sensitive to temperature, among other things. As a resiliency hub, the Stillmeadow Community Fellowship can also serve as community-based staging areas for emergency and recovery personnel as well as conduits for critical supply distribution to the community.

Following the flash flooding event, the following actions have taken place to mitigate future flood loss:

- Frederick Avenue was repaired after the flash flood event due to damage from the flood waters; no change was made to the road other than new asphalt.
- A large retaining wall was installed along the north side of the 5100 block of Frederick Avenue. During the 2018 flood a portion of the slope collapsed; the wall is to stabilize the slope.
- Since 2018, DPW crews have included the additional maintenance task of checking on storm drain inlets and culverts in advance of expected storms.
- A storm drain system survey, hydrology and hydraulics (H&H) model, and alternatives analysis were conducted for Baltimore City drainage area by the culvert where the deepest of the flooding occurred on Frederick Avenue.
- Due to the historic flooding in the Frederick Avenue corridor in the southwestern area of Baltimore City, the Maryland Silver Jackets team undertook an effort to raise awareness and provide technical assistance to reduce the flood risk through modeling, mapping, flood warning, flood proofing guidance and outreach. Baltimore City DPW is using this data, along with grant funding from FEMA, to implement risk reduction measures in this community.
- A stream geomorphic restoration project was completed at Beechfield Elementary and Mt. St. Joe's whose environmental benefits included stream/floodplain reconnection and daylighting approximately 200 feet of piped stream.

4.5 Probability of Future Hazard Events

For the 2023 DP3 update, the most up-to-date data was collected to calculate the probability of future occurrence of flood events for Baltimore City. Information from NOAA-NCEI storm events database and the 2018 Baltimore DP3 were used to identify the number of flood events that occurred between 1996 and 2022. Note that the numbers in the below table are probabilities. Data is taken from various sources to assess the likelihood of future events based on previous event records. Although a given hazard may have zero (0) previous occurrences, this event may have still occurred in the past without any records and may occur in the future. Table 4-6 presents the probability of future events for flood in Baltimore City.

Occurrences for sea level rise are incalculable due to the current inability to directly tie certain flooding events to sea level rise; however, studies show that the long-term impacts of sea level rise can exacerbate current flooding. The *2020 Baltimore City Nuisance Flood Plan* states that the NOAA tidal gauge at Fort McHenry has recorded a 12-inch increase in relative sea level since 1900 (Baltimore City Office of Sustainability 2020). While sea level rise may not be able to be tied directly to episodic events, it does contribute to increased flooding in the long-term. It can be assumed that sea level rise will cause an increase in the number of flooding events, as projections have sea levels rising by roughly 1.78 feet by 2050, 2.66 feet by

2070, and 4.25 feet by 2100 in Baltimore City compared to current levels (University of Maryland 2023).

Table 4-6. Probability of Future Flood Events

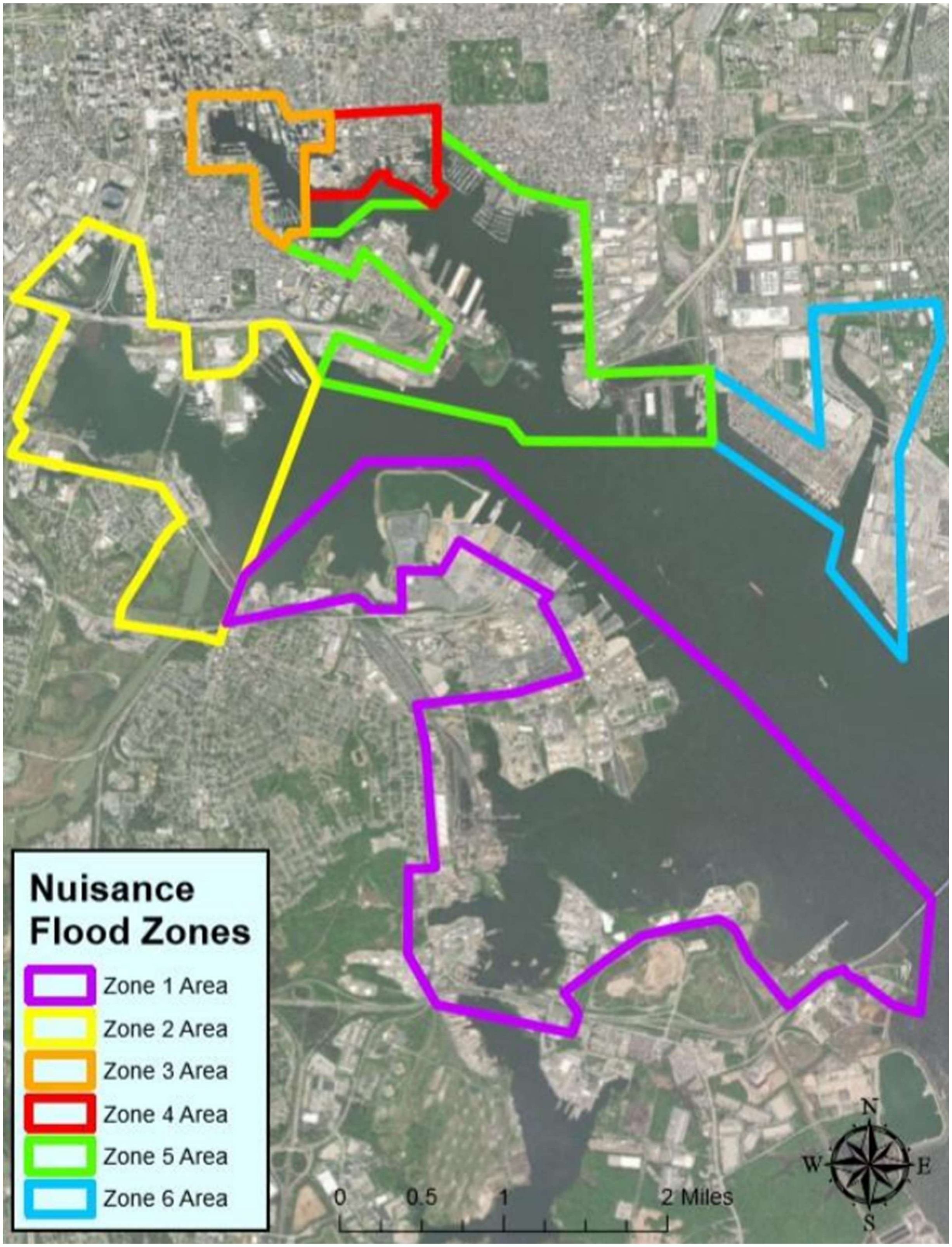
Hazard Type	Number of Occurrences Between 1996 and 2022	% Chance of Occurring in Any Given Year
Coastal Flooding	14	52%
Flash Flooding	38	100%
Nuisance Flooding [a]	17	63%
Riverine Flooding	14	52%
Sea Level Rise [b]	-	-
Stormwater/Urban Flooding [c]	-	-
Total	**71** [d]	**99%**

Sources: NOAA 2023; City of Baltimore 2018; NOAA 2022
Note: Disaster occurrences include federally declared disasters since the 1950 Federal Disaster Relief Act, and selected events since 1950. Due to limitations in data, not all flood events occurring between 1954 and 1996 are accounted for in the tally of occurrences. As a result, the number of hazard occurrences is underestimated.
a Since nuisance flooding is generally tied to high-tide occurrences, the number of high tide days are reported as the number of occurrences.
b Occurrences for Sea Level Rise are incalculable due to the current inability to directly tie certain flooding events to Sea Level Rise. It can be assumed that Sea Level Rise will cause an increase in the number of flooding events.
c There is no official reporting system for the collection of data related to stormwater/urban flooding. Although it is certain this type of flooding occurs, there is no determined number of occurrences.
d Includes the three (3) flood events from the FEMA disaster declarations.

There is no official reporting system for the collection of data related to stormwater/urban flooding. Although it is certain this type of flooding occurs, there is no determined number of occurrences. Projections for increased rain will contribute to the rise in frequency of stormwater/urban flooding. Baltimore City is projected to receive increased annual rainfall and more intense rainfall and severe storms. These increases will influence the occurrence of inland flooding, cause flash flooding, tremendous soil erosion, and impact stormwater systems as the influx of precipitation will likely not be able to be managed by the current drainage systems (University of Maryland 2023).

Baltimore City is in the midst of a trial period for utilizing the 3-1-1 Service the MyCoast Maryland application to collect reports of nuisance flooding. The flooding occurrence data received from each source will be validated based on location of the event and tide height data. Reports from this trial period are currently unavailable; the trial period runs from 2020 through 2025. Despite limited data on past occurrences, it can be assumed that nuisance flooding will continue to plague the coastal areas of Baltimore City. Baltimore City 2020 Nuisance Flood Plan lists projections for each Nuisance Flood Zone in Baltimore City. View Table 4-7 to see the projections for each Zone, which describes the total area in acres of land impacted by nuisance flooding. See Figure 4-12 for a map of the identified Nuisance Flood Zones (Baltimore City Office of Sustainability 2020).

Figure 4-12. Nuisance Flood Zones for Baltimore City



Source: Baltimore City Office of Sustainability 2020

Table 4-7. Predicted Estimations of Areas within the Nuisance Flood Zones Affected by Nuisance Flooding Based on Model Years

Zone	Model Year					
	2015		2050		2100	
	Area (Acres)	Overall Increase (%)	Area (Acres)	Overall Increase (%)	Area (Acres)	Overall Increase (%)
Zone 1	38	-	94	147 %	372	296 %
Zone 2	36	-	42	17 %	212	405 %
Zone 3	8	-	32	300 %	196	512 %
Zone 4	12	-	16	33 %	119	644 %
Zone 5	28	-	82	193 %	388	373 %
Zone 6	18	-	80	344 %	114	43 %

Source: Baltimore City Office of Sustainability 2020

4.6 Potential Impacts of Climate Change

Climate temperatures are rising due to high amounts of greenhouse gases in the atmosphere absorbing the sun's energy and warming the environment. The Intergovernmental Panel on Climate Change (IPCC) provides evidence for this phenomenon in the latest IPCC report on global warming. Global temperatures are expected to rise by 2.7 degrees Celsius by the end of the century. In fact, the seven warmest years on record have all occurred in the last decade. The year 2020 is the second warmest year, with 2016 being the warmest (IPCC 2021).

Although the climate is always changing, the rate at which global warming is taking place is unprecedented. As temperatures are rising so are sea levels. Sea level rise is a result of two phenomena, glacial ice melts and thermal expansion. Large land-based ice sheets and mountain glaciers are melting at alarming rates due to rising global temperatures. These permafrost areas store much of the Earths water and carbon through carbon sequestration. As these ice sheets melt, they add to the oceans volume of about 2 mm per year on average (NASA 2020). As well, glacial ice sheets are a natural form of carbon sequestration, and as a result, release greenhouse gases into the atmosphere when they melt (Wadham, et al. 2019). Another phenomenon contributing to sea level rise is thermal expansion. Thermal expansion is when water molecules expand due to a rise in temperature. Higher temperatures result in greater distance between water molecules as the cohesive forces holding them together expand. This thermal expansion contributes to an overall increase in global sea levels. In fact, approximately 1/3 of the global sea level rise recorded since 2004 has been caused by thermal expansion (NASA 2021).

Climate change will significantly impact flood hazard events. In fact, influence from sea level rise on flood hazard impacts can already be seen today when compared to historic records; shoreline erosion, deterioration of wetlands, saline contamination of low-lying areas, increased occurrences of nuisance flooding, and inland impacts from storm surge are all observations currently occurring in Baltimore City. The rate of sea level rise is anticipated to continue increasing even if humanity can scale back its impacts to global climate change, such as reducing its carbon footprint (UMCES 2018).

Riverine or inland flooding will increase in frequency due to climate change. Sea level rise and its influence on tidal rivers, as well as an increase in precipitation and ultimately soil saturation will increase flooding concerns. Not only is more rainfall projected, but heavy downpours are anticipated to increase, which leads to inland flooding. In Maryland, about 30% of rainstorms during the period 2007-2016 would have fallen into the top 1% of storm intensity had the storms occurred in the 1950s. This is at least in part due to the greater amount of water vapor now in the air (about 9% more than in 1950) (University of Maryland 2023).

Heavy rainfall can cause flash flooding and tremendous soil erosion in regions where stormwater is not carefully managed. With nowhere else to go, flood water will run outside of the floodplain and into urbanized areas. This will exacerbate flood damage already present in urban metropolitan areas. Soil erosion and the influx of additional flood waters into urbanized areas will cause disruption and potential damage to critical infrastructure, such as stormwater and sewer systems. When rain falls very fast in a downpour, runoff commonly leads to inland flooding, which is projected to increase by about 50% in Maryland by 2050. The devastating flood on Frederick Street in 2018 illustrates the severity of inland flooding from more intense rainstorms (University of Maryland 2023).

Climate change can impact stored water systems as well, as increased rainfall accumulations can cause reservoirs to overtop. Dams are designed using a hydrograph to evaluate dam safety issues for situations where the reservoir inflow peak discharge is greater than the maximum spillway capacity, the reservoir has large surcharge storage, and/or the reservoir has dedicated flood control space. Increased precipitation may result in overtopping, as the hydrographs are based off historical events (USBR 2003). The overtopping of a dam can lead areas downstream to become inundated with flood waters that would otherwise be safely stored.

4.7 Vulnerability Assessment

To understand risk, a community must evaluate what assets are exposed or vulnerable in the hazard area identified. The entire City has been identified as exposed to the flood hazard; however, the highest risk is in the mapped SFHA. Therefore, all assets in Baltimore City (population, structures, critical facilities, and lifelines), as described in the Section 3 (Risk Assessment), are exposed and potentially vulnerable to the 1-percent and 0.2-percent floodplains.

With a total population of 591,489, 1,767 residents are living in the 1-percent annual chance floodplain, or 0.3-percent of Baltimore City's total population; there are an estimated 4,982 residents living in the 0.2-percent annual chance floodplain, or 0.8-percent of Baltimore City's total population. 1,172 buildings in Baltimore City, approximately 0.5-percent of Baltimore City's total general building stock inventory, are located in the 1-percent annual chance flood boundary with an estimated $9 billion of replacement cost value (RCV). In addition, there are 2,759 buildings. Approximately 0.8-percent of Baltimore City's total general building stock inventory. located in the 0.2-percent annual chance flood boundary with an estimated $17.1 billion RCV. Of the 148 lifelines located in the 1-percent annual chance floodplain, and 204 lifelines located in the 0.2-percent annual chance floodplain.

There are an estimated 2,075 residents living in the projected 2050 mean sea level rise area, or 0.4-percent of Baltimore City's total population. 1,191 buildings in Baltimore City are located in the projected 2050 mean sea level rise area with an estimated $5.3 billion of replacement cost value; this represents approximately 0.5-percent of Baltimore City's total general building stock inventory.

4.7.1 Impacts on Population

The impact of flooding on life, health, and safety is dependent upon several factors including the severity of the event and whether adequate warning time is provided to residents. In instances of flash flooding, there is little to no warning time. This may lead to individuals becoming injured as a direct result of floodwaters, isolated, or displaced from their homes, creating dangerous situations. This may be exacerbated in instances where stormwater and urban flooding have caused roadways and evacuation routes to be impassable.

Flooding directly contributes to public health concerns as floodwaters may carry hazardous materials and waterborne illnesses through a community. If floodwaters are slow to recede, vector-borne diseases may increase as mosquitoes and other insects breed near stagnant waters. Additionally, water entering homes produces mold, which poses a threat to the health and safety of residents.

Exposure represents the population living in or near floodplain areas that could be impacted should a flood event occur. Additionally, exposure should not be limited to only those who reside in a defined hazard zone, but everyone who may be affected by the effects of a hazard event (e.g., people are at risk while traveling in flooded areas, or their access to emergency services is compromised during an event). The degree of that impact will vary and is not strictly measurable.

To estimate population exposure to the 1-percent- and 0.2-percent annual chance flood events, the DFIRM flood boundaries were used. Based on the spatial analysis, there are an estimated 1,767 residents living in the 1-percent annual chance floodplain, or 0.3-percent of Baltimore City's total population. There are an estimated 4,982 residents living in the 0.2-percent annual chance floodplain, or 0.8-percent of Baltimore City's total population. City Council District 1 has the greatest number of residents living in the 1-percent and 0.2-percent annual chance flood event hazard area with approximately 545 residents and 1,845 residents, respectively. Table 4-8 summarizes the population exposed to the flood hazard by City Council District.

To estimate population exposure to the sea level rise hazard, the projected 2050 mean sea level rise area was used. Based on the spatial analysis, there are an estimated 2,075 residents living in the projected 2050 mean sea level rise area, or 0.4-percent of Baltimore City's total population. City Council District 1 has the greatest number of residents living in projected 2050 mean sea level rise area with approximately 1,951 residents. Table 4-9 summarizes the population exposed to the flood hazard by jurisdiction.

Table 4-8. Estimated Number of Persons Living in the 1-percent and 0.2-percent Annual Chance Flood Event Hazard Areas

City Council District	Total Population (American Community Survey 2021)	Estimated Population Located in the Flood Hazard Areas			
		Number of Persons Located in the 1-percent Annual Chance Flood Event Hazard Area	Percent of Total	Number of Persons Located in the 0.2-percent Annual Chance Flood Event Hazard Area	Percent of Total
1	43,739	545	1.2%	1,845	4.2%
2	45,252	11	<0.1%	38	0.1%
3	42,257	40	0.1%	40	0.1%
4	45,027	35	0.1%	35	0.1%
5	43,601	92	0.2%	194	0.4%
6	41,604	3	<0.1%	18	<0.1%
7	39,638	155	0.4%	169	0.4%
8	46,396	453	1.0%	653	1.4%
9	35,869	0	0.0%	0	0.0%
10	41,521	94	0.2%	205	0.5%
11	48,022	276	0.6%	1,557	3.2%
12	37,130	44	0.1%	151	0.4%
13	38,768	0	0.0%	0	0.0%
14	42,664	20	<0.1%	77	0.2%
Baltimore City (Total)	**591,489**	**1,767**	**0.3%**	**4,982**	**0.8%**

Source: U.S. Census Bureau 2021, ACS; FEMA 2021

Table 4-9. Estimated Number of Persons Living in the Projected 2050 Mean Sea Level Rise Area

City Council Districts	Total Population (American Community Survey 2021)	Number of Persons Located in the projected 2050 Mean Sea Level Rise (1% Annual Chance Flood) Hazard Area	
		Number of Persons	Percent of Total
1	43,739	1,951	4.5%
2	45,252	0	0.0%
3	42,257	0	0.0%
4	45,027	0	0.0%
5	43,601	0	0.0%
6	41,604	0	0.0%
7	39,638	0	0.0%
8	46,396	0	0.0%
9	35,869	0	0.0%
10	41,521	0	0.0%
11	48,022	124	0.3%
12	37,130	0	0.0%
13	38,768	0	0.0%
14	42,664	0	0.0%
Baltimore City (Total)	**591,489**	**2,075**	**0.4%**

Source: U.S. Census Bureau 2021, ACS; ESRGC 2016

Impacts on Socially Vulnerable Populations and Underserved Communities

Socially vulnerable populations are most susceptible based on many factors, including their physical and financial ability to react or respond during a hazard and the location and construction quality of their housing. Economically disadvantaged populations are likely to evaluate their risk and make decisions based on the major economic impact on their family and may not have funds to evacuate. Vulnerable populations include homeless persons, elderly (over 65 years old), low income or linguistically isolated populations, people with life-threatening illnesses, and residents that may struggle to evacuate. These groups may require extra time to evacuate or need assistance to evacuate and are more likely to seek or need medical attention.

Homelessness in Baltimore City is a great concern, as the populations are significantly at risk from hazards due to their exposure and general lack of a structurally sound structure. The Point-in-Time (PIT) Count is federally mandated survey conducted annually that seeks to determine how many people are experiencing homelessness on any given night in Baltimore City. In 2022, the night of the PIT Count revealed a total of 1,597 people were counted in emergency shelters, transitional housing, and unsheltered spaces such as encampments. This is down from 2,193 people in 2020 and follows a four-year downward trend (Baltimore City 2022). The 2023 PIT occurred in January of 2023; however, the results have not yet been made public. Homelessness or population displacement following a flood event is plausible. Table 4-10 details the estimated population displaced or seeking short-term shelter following the 1-percent annual chance flood event. Using 2021 American Community Survey data, Hazus estimates 983 people may seek short-term sheltering, while 3,991 people may be displaced.

Table 4-10. Estimated Population Displaced or Seeking Short-Term Shelter from the 1-percent Annual Chance Flood Event

City Council District	Total Population (American Community Survey 2021)	1-Percent Annual Chance Flood Event	
		Displaced Population	Persons Seeking Short-Term Sheltering
1	43,739	955	124
2	45,252	174	59
3	42,257	106	17
4	45,027	111	53
5	43,601	303	117
6	41,604	413	161
7	39,638	105	14
8	46,396	751	145
9	35,869	19	15
10	41,521	120	30
11	48,022	332	41
12	37,130	246	144
13	38,768	7	3
14	42,664	349	60
Baltimore City (Total)	**591,489**	**3,991**	**983**

Source: Hazus v5.1; FEMA 2021; U.S. Census 2021, American Community Survey

Table 4-11 displays the total population data for Baltimore City by City Council District. According to the 2021 American Community Survey, there are roughly 84,000 persons (14.1-percent of the total population) over the age of 65; approximately 36,000 persons (6.2-percent of the total population) under the age of 5; just over 10,000 persons (1.7-percent of the total population) which do not speak English; an estimated 93,000 persons (15.7-percent of the total population) who have a disability; and about 116,000 persons (19.5-percent of the total population) living at or below the poverty level.

The aftermath of flooding presents numerous threats to public health and safety, including unsafe food; contaminated drinking and washing water and poor sanitation; mosquitoes and animals; mold and mildew; carbon monoxide poisoning; and mental stress and fatigue. In instances of longer recovery periods mental stress and fatigue may be exacerbated in communities and groups experiencing heighted social vulnerability. Current loss estimation models such as Hazus are not equipped to measure public health impacts. The best preparation for these effects includes awareness that they can occur, education of the public on prevention, and planning to deal with them during responses to flooding events.

4.7.2 Impacts on Structures

General Building Stock

After considering the population exposed and potentially vulnerable to the flood hazard, the built environment was evaluated. Exposure includes those buildings located in the flood hazard areas. Potential damage is the modeled loss that could occur to the exposed inventory, including structural and content replacement cost values.

Table 4-12 summarizes the number of structures located in the 1-percent and 0.2-percent annual chance flood events by City Council District. In summary, there are 1,172 buildings located in the 1-percent annual chance flood boundary with an estimated $9 billion of replacement cost value (i.e., building and content replacement costs). In total, this represents approximately 0.5-percent of Baltimore City's total general building stock inventory. In addition, there are 2,759 buildings located in the 0.2-percent annual chance flood boundary with an estimated $17.1 billion of building stock and contents exposed. This represents approximately 1.2-percent of Baltimore City's total general building stock inventory.

The Hazus flood model estimated potential damage to the buildings in Baltimore City at the structure level using the custom structure inventory developed for this DP3 and the depth grid generated using the effective DFIRM data. The potential damage estimated by Hazus to the general building stock inventory associated with the 1-percent annual chance flood is approximately $1.2 billion. City Council District 11 has the greatest amount of estimated building loss of approximately $363 million (i.e., 28.6-percent of the total replacement cost value). Refer to Table 4-13 for the estimated losses by jurisdiction.

Table 4-14 summarizes the number of structures located in the projected 2050 mean sea level rise by City Council District. In summary, there are 1,191 buildings located in the projected 2050 mean sea level rise area with an estimated $5.3 billion of replacement cost value (i.e., building and content replacement costs). In total, this represents approximately 0.5-percent of Baltimore City's total general building stock inventory. City Council District 1 has the largest number of structures within the project 2050 sea level rise with a total of 1,058, or 88-percent of the total number of buildings in the projected area.

Table 4-11. Baltimore City Total Population by City Council District

City Council District	Total Population (American Community Survey 2021)	Percent of City Total	American Community Survey 5-Year Population Estimates (2021)									
			Over 65	Percent of Jurisdiction Total	Under 5	Percent of Jurisdiction Total	Non-English Speaking	Percent of Jurisdiction Total	Disability	Percent of Jurisdiction Total	Poverty Level	Percent of Jurisdiction Total
1	43,739	7.4%	4,481	10.2%	3,344	7.6%	1,141	2.6%	4,200	9.6%	5,851	13.4%
2	45,252	7.7%	5,528	12.2%	3,009	6.6%	1,376	3.0%	5,394	11.9%	6,530	14.4%
3	42,257	7.1%	5,988	14.2%	1,669	4.0%	470	1.1%	5,485	13.0%	3,539	8.4%
4	45,027	7.6%	6,401	14.2%	3,113	6.9%	371	0.8%	5,601	12.4%	6,218	13.8%
5	43,601	7.4%	8,122	18.6%	3,762	8.6%	1,176	2.7%	6,613	15.2%	7,155	16.4%
6	41,604	7.0%	8,355	20.1%	2,356	5.7%	546	1.3%	7,741	18.6%	7,910	19.0%
7	39,638	6.7%	6,177	15.6%	1,895	4.8%	349	0.9%	7,764	19.6%	9,082	22.9%
8	46,396	7.8%	7,799	16.8%	2,947	6.4%	392	0.8%	8,376	18.1%	8,014	17.3%
9	35,869	6.1%	4,927	13.7%	2,024	5.6%	641	1.8%	8,523	23.8%	11,821	33.0%
10	41,521	7.0%	4,755	11.5%	3,468	8.4%	1,054	2.5%	7,685	18.5%	12,283	29.6%
11	48,022	8.1%	5,774	12.0%	2,182	4.5%	907	1.9%	6,231	13.0%	8,651	18.0%
12	37,130	6.3%	4,203	11.3%	1,690	4.6%	575	1.5%	6,388	17.2%	9,815	26.4%
13	38,768	6.6%	4,701	12.1%	2,684	6.9%	582	1.5%	6,814	17.6%	11,673	30.1%
14	42,664	7.2%	6,316	14.8%	2,324	5.4%	702	1.6%	5,891	13.8%	7,086	16.6%
Baltimore City (Total)	**591,489**	**100.0%**	**83,527**	**14.1%**	**36,468**	**6.2%**	**10,283**	**1.7%**	**92,707**	**15.7%**	**115,625**	**19.5%**

Table 4-12. Estimated General Building Stock Located in the 1- and 0.2-Percent Annual Chance Flood Event

City Council District	Total Number of Buildings	Total Replacement Cost Value (RCV)	Estimated Building Stock Located in the Flood Hazard Area							
			Number of Buildings Located in the 1-percent Annual Chance Flood Event Hazard Area	Percent of Total	Total Replacement Cost of Buildings in the 1-percent Annual Chance Flood Event Hazard Area	Percent of Total	Number of Buildings Located in the 0.2-percent Annual Chance Flood Event Hazard Area	Percent of Total	Total Replacement Cost of Buildings in the 0.2-percent Annual Chance Flood Event Hazard Area	Percent of Total
1	22,781	$42,726,169,218	355	1.6%	$2,372,968,741	5.6%	1,118	4.9%	$6,418,069,021	15.0%
2	12,746	$19,773,061,274	34	0.3%	$300,652,743	1.5%	61	0.5%	$682,509,700	3.5%
3	14,274	$14,195,099,773	14	0.1%	$13,592,422	0.1%	14	0.1%	$13,592,422	0.1%
4	14,536	$12,686,748,697	12	0.1%	$20,062,527	0.2%	12	0.1%	$20,062,527	0.2%
5	12,637	$18,575,913,421	69	0.5%	$611,011,446	3.3%	106	0.8%	$710,241,382	3.8%
6	15,009	$19,159,968,457	9	0.1%	$102,676,305	0.5%	18	0.1%	$185,144,919	1.0%
7	17,409	$18,007,600,793	87	0.5%	$294,741,816	1.6%	113	0.6%	$525,443,214	2.9%
8	14,350	$14,208,439,442	140	1.0%	$123,507,485	0.9%	203	1.4%	$169,432,640	1.2%
9	21,371	$21,990,875,897	9	0.0%	$118,076,220	0.5%	12	0.1%	$180,701,840	0.8%
10	16,334	$33,621,448,750	112	0.7%	$1,036,363,378	3.1%	226	1.4%	$2,097,828,285	6.2%
11	17,184	$62,344,674,213	260	1.5%	$3,339,495,321	5.4%	715	4.2%	$4,895,998,388	7.9%
12	15,436	$33,041,741,651	62	0.4%	$715,051,723	2.2%	129	0.8%	$1,128,850,670	3.4%
13	18,095	$19,432,245,395	0	0.0%	$0	0.0%	0	0.0%	$0	0.0%
14	15,694	$17,744,799,580	9	0.1%	$32,687,979	0.2%	32	0.2%	$78,395,700	0.4%
Baltimore City (Total)	**227,856**	**$347,508,786,561**	**1,172**	**0.5%**	**$9,080,888,105**	**2.6%**	**2,759**	**1.2%**	**$17,106,270,708**	**4.9%**

Source: Maryland Department of Planning 2020, 2022; RS Means 2023; FEMA 2021

Table 4-13. Estimated General Building Stock Potential Loss to the 1-Percent Annual Chance Flood Event

General Building Stock						
City Council District	Total Replacement Cost Value (RCV)	Estimated Loss for All Occupancies	Percent of Total	Estimated Loss for Residential Properties	Estimated Loss for Commercial Properties	Estimated Loss for All Other Occupancies
1	$42,726,169,218	$156,478,807	0.37%	$17,071,269	$138,795,241	$612,298
2	$19,773,061,274	$71,831,570	0.36%	$2,741,919	$61,036,839	$8,052,812
3	$14,195,099,773	$5,103,267	0.04%	$1,190,770	$3,912,497	$0
4	$12,686,748,697	$6,529,930	0.05%	$5,860,791	$669,139	$0
5	$18,575,913,421	$214,138,421	1.15%	$3,141,002	$183,878,276	$27,119,143
6	$19,159,968,457	$18,913,298	0.10%	$46,600	$12,917,581	$5,949,116
7	$18,007,600,793	$122,240,557	0.68%	$7,681,118	$99,208,623	$15,350,816
8	$14,208,439,442	$18,914,975	0.13%	$11,902,111	$1,614,876	$5,397,988
9	$21,990,875,897	$57,338,888	0.26%	$0	$51,550,960	$5,787,929
10	$33,621,448,750	$127,847,009	0.38%	$3,977,792	$113,955,151	$9,914,066
11	$62,344,674,213	$363,173,341	0.58%	$26,989,938	$281,864,344	$54,319,059
12	$33,041,741,651	$102,470,543	0.31%	$11,591,104	$84,389,441	$6,489,998
13	$19,432,245,395	$0	0.00%	$0	$0	$0
14	$17,744,799,580	$4,367,390	0.02%	$1,114,146	$3,253,244	$0
Baltimore City (Total)	**$347,508,786,561**	**$1,269,347,995**	**0.37%**	**$93,308,560**	**$1,037,046,210**	**$138,993,224**

Source: Hazus v5.1; FEMA 2021; RS Means 2022

Table 4-14. Estimated General Building Stock Located in the Projected 2050 Mean Sea Level Rise Area

City Council District	Total Number of Buildings	Total Replacement Cost Value (RCV)	Number of Buildings and Total Replacement Cost Value of Structures Located in the projected 2050 Mean Sea Level Rise (1% Annual Chance Flood) Hazard Area			
			Number of Buildings	Percent of Total	Total Replacement Cost Value	Percent of Total
1	22,781	$42,726,169,218	1,058	4.6%	$3,619,324,649	8.5%
2	12,746	$19,773,061,274	0	0.0%	$0	0.0%
3	14,274	$14,195,099,773	0	0.0%	$0	0.0%
4	14,536	$12,686,748,697	0	0.0%	$0	0.0%
5	12,637	$18,575,913,421	0	0.0%	$0	0.0%
6	15,009	$19,159,968,457	0	0.0%	$0	0.0%
7	17,409	$18,007,600,793	0	0.0%	$0	0.0%
8	14,350	$14,208,439,442	0	0.0%	$0	0.0%
9	21,371	$21,990,875,897	0	0.0%	$0	0.0%
10	16,334	$33,621,448,750	27	0.2%	$322,480,395	1.0%
11	17,184	$62,344,674,213	106	0.6%	$1,456,617,837	2.3%
12	15,436	$33,041,741,651	0	0.0%	$0	0.0%
13	18,095	$19,432,245,395	0	0.0%	$0	0.0%
14	15,694	$17,744,799,580	0	0.0%	$0	0.0%
Baltimore City (Total)	**227,856**	**$347,508,786,561**	**1,191**	**0.5%**	**$5,398,422,881**	**1.6%**

Source: Maryland Department of Planning 2020, 2022; RS Means 2022; ESRGC 2016
Notes: ESRGC (Eastern Shore Regional GIS Cooperative)

Critical Facilities

All critical facilities in Baltimore City are exposed to the flood hazard. Impacts on critical facilities buildings will experience similar issues as described above for general building stock. Additionally, it is essential that critical facilities remain operational during natural hazard events.

In areas that are directly flooded, renovations of commercial and industrial buildings may be necessary, disrupting associated services. Refer to the 'Impact on General Building Stock' subsection earlier which discusses direct impacts to buildings in Baltimore City. Other economic components such as loss of facility use, functional downtime and socio-economic factors are less measurable with a high degree of certainty.

Debris management may also be a large expense after a flood event. Hazus estimates the amount of debris generated from the 1-percent annual chance event. The model breaks down debris into three categories: (1) finishes (dry wall, insulation, etc.); (2) structural (wood, brick, etc.) and (3) foundations (concrete slab and block, rebar, etc.). The distinction is made because of the different types of equipment needed to handle the debris. Table 4-15 summarizes the debris Hazus estimates for these events. As a result of the 1-percent annual chance event, Hazus estimates approximately 50,680 tons of debris will be generated in total.

Table 4-15. Estimated Debris Generated from the 1-percent Annual Chance Flood Event

City Council District	1-Percent Annual Chance Flood Event			
	Total (tons)	Finish (tons)	Structure (tons)	Foundation (tons)
1	2,522	2,507	19	6
2	555	520	40	15
3	704	397	281	167
4	331	311	9	15
5	5,536	1,509	4,703	1,677
6	23,738	3,195	26,431	7,327
7	2,008	1,094	993	417
8	2,726	2,082	599	342
9	5,092	674	4,796	2,020
10	2,200	956	1,340	574
11	3,805	2,738	1,292	421
12	769	754	18	6
13	86	3	86	40
14	609	447	184	69
Baltimore City (Total)	**50,680**	**17,187**	**40,792**	**13,096**

Source: Hazus v5.1; FEMA 2021

Critical Infrastructure

It is important to determine the critical infrastructure that may be at risk from flooding, and who may be impacted should damage occur. Critical services during and after a flood event may not be available if critical infrastructure is directly damaged. Roads that are blocked or damaged can isolate residents and can prevent access throughout Baltimore City to many service providers needing to reach vulnerable populations or to make repairs.

Flooding can cause extensive damage to public utilities and disruptions to delivery of services. Loss of power and communications may occur, and drinking water and wastewater treatment facilities may be temporarily out of operation.

Community Lifelines

Community lifeline exposure to the flood hazard was examined. Table 4-16 lists the number of lifelines within the 1-percent and 0.2-percent annual chance flood boundaries. Of the 148 lifelines located in the 1-percent annual chance flood event boundary, the greatest number are health and medical facilities. Additionally, there are 204 lifelines located in the 0.2-percent annual chance flood event boundary, 132 of which are transportation facilities.

Table 4-16. Lifelines Located in the 1-Percent and 0.2-Percent Annual Chance Event Floodplain

FEMA Lifeline Category	Number of Lifelines	Number of Lifelines Located in the 1-percent Annual Chance Flood Event Hazard Area	Number of Lifelines Located in the 0.2-percent Annual Chance Flood Event Hazard Area
Communications	307	11	22
Energy	70	9	17
Food, Hydration, and Shelter	127	4	9
Hazardous Materials	0	0	0
Health and Medical	802	14	17
Safety and Security	290	5	7
Transportation	446	105	132
Baltimore City (Total)	**2,042**	**148**	**204**

Source: City of Baltimore 2023; Maryland Department of Transportation (MDOT) 2023; Baltimore City Department of Public Works 2023; HILFD 2018, 2021, 2022

In cases where short-term functionality is impacted by flooding, other facilities of neighboring jurisdictions may need to increase support response functions during a disaster event. Mitigation planning should consider means to reduce flood impacts to lifelines and ensure sufficient emergency and school services remain when a significant event occurs.

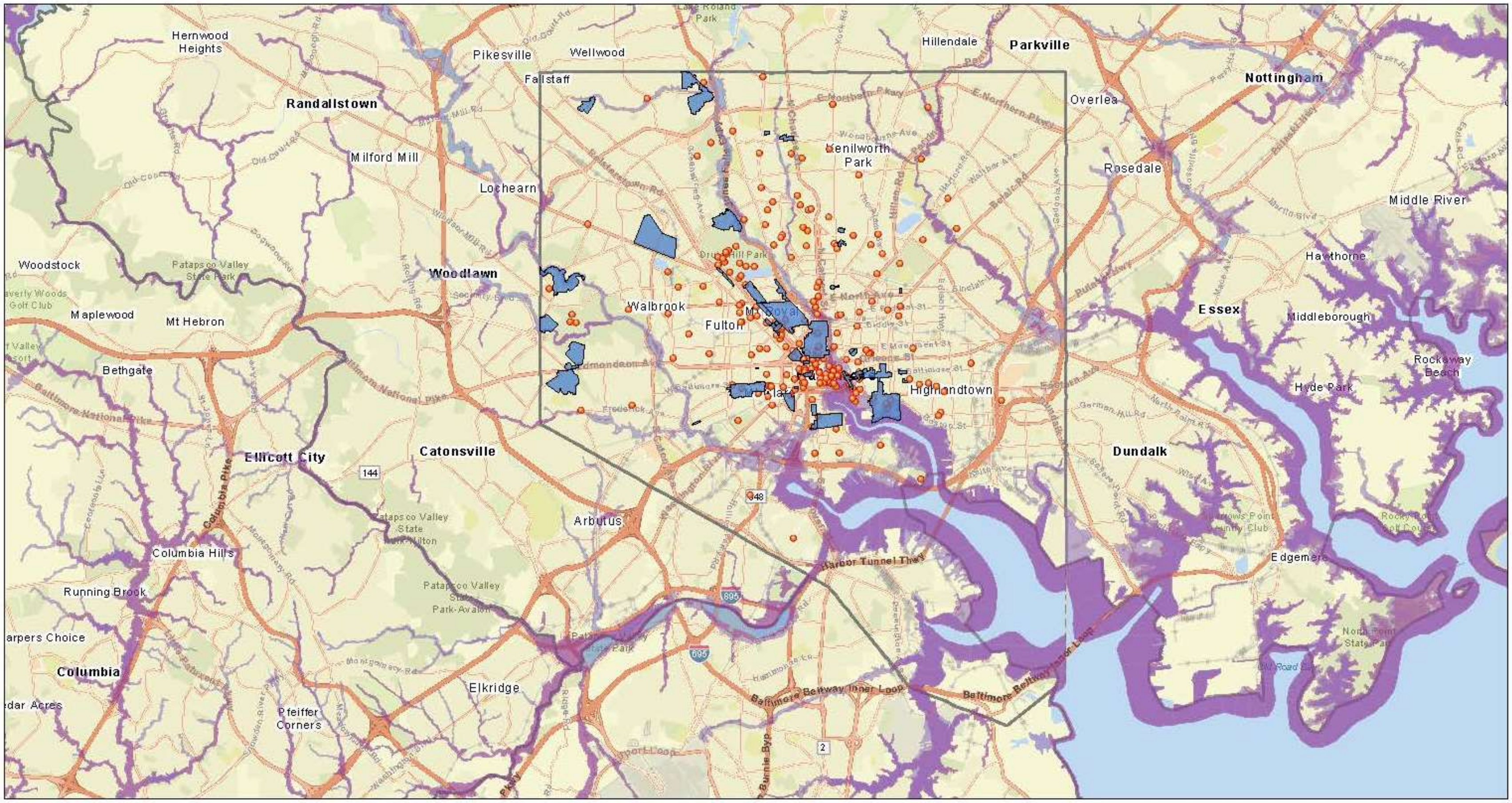
4.7.3 Impacts on Natural, Historic, and Cultural Resources

Flood events will inevitably impact Baltimore City's natural and local environment. Severe flooding not only influences the habitat of these natural land areas, but it can also be disruptive to species that reside in these natural habitats. Flooding could lead to loss of critical habitat and further stresses on some threatened and endangered species (Kopp et al 2019). Heavy rainfall and flash flooding can cause habitat damage through soil loss. Runoff can cause damage to aquatic systems through overloading of sediment and chemicals from non-point source pollution. Flooding could cause the release of environmentally damaging pollutants from facilities such as septage facilities, solid landfills, and yard waste facilities.

Further, residents living in and around areas which flood may be at increased risk of future due to changes in the natural landscape. Flood events can cause erosion to river and stream beds and the shoreline, causing them to expand and potentially encroach and damage properties.

The historic Fells Point neighborhood in Baltimore City is extremely susceptible to impacts from flooding and a guide was published to assist property owners with mitigation these impacts (*Fells Point Flood Mitigation Guidelines*). Other historic and cultural areas prone to flooding in Baltimore City, include historic mills along the Jones Falls, the historic district neighborhoods of Mount Vernon, Jonestown, Mt. Royale Terrace Woodberry, and Mounty Washington, and cultural resources such as the National Aquarium at the Inner Harbor. Historic landmarks and districts are shown in Figure 4-13.

Figure 4-13. Designated Historic Landmarks and Districts in Flood Prone Areas



11/28/2023, 3:29:18 PM

County Boundaries (click on county for data on 22 CRCI Indicators)

CHAP_Historic_Districts

Designated_Landmarks

Flood Hazard (zoom to activate)

0.2% Annual Chance Flood Hazard

1% Annual Chance Flood Hazard

Future Conditions 1% Annual Chance Flood Hazard

Regulatory Floodway

1:144,448

0 1.25 2.5 5 mi

0 2.25 4.5 9 km

City of Baltimore, Baltimore County Government, VGIN, Esri, HERE, Garmin, SafeGraph, GeoTechnologies, Inc, METI/NASA, USGS, EPA, NPS, USDA

Resilience Analysis and Planning Tool

City of Baltimore, Baltimore County Government, VGIN, Esri, HERE, Garmin, SafeGraph, GeoTechnologies, Inc, METI/NASA, USGS, EPA, NPS, USDA | NOAA/NWS/SPC | NOAA/NWS/CPC and NOAA/NWS/WPC | NOAA/NWS/WPC | National Weather Service | NOAA Office for Coastal Management | NOAA/NWS/

4.8 Cascading and Compounding Impacts

4.8.1 Public Health

Cascading impacts may also include exposure to pathogens such as mold. After flood events, excess moisture and standing water contribute to the growth of mold in buildings. Mold may present a health risk to building occupants, especially those with already compromised immune systems such as infants, children, the elderly and pregnant women. The degree of impact will vary and is not strictly measurable. Mold spores can grow in as short a period as 24-48 hours in wet and damaged areas of buildings that have not been properly cleaned. Very small mold spores can easily be inhaled, creating the potential for allergic reactions, asthma episodes, and other respiratory problems. Buildings should be properly cleaned and dried out to safely prevent mold growth (CDC 2020).

Molds and mildews are not the only public health risk associated with flooding. Floodwaters can be contaminated by pollutants such as sewage, human and animal feces, pesticides, fertilizers, oil, asbestos, and rusting building materials. Common public health risks associated with flood events also include:

- Unsafe food
- Contaminated drinking and washing water and poor sanitation
- Mosquitos and animals
- Carbon monoxide poisoning
- Secondary hazards associated with re-entering/cleaning flooded structures
- Mental stress and fatigue (FEMA 2022)

Current loss estimation models such as Hazus are not equipped to measure public health impacts. The best level of mitigation for these impacts is to be aware that they can occur, educate the public on prevention, and be prepared to deal with these vulnerabilities in responding to flood events.

4.8.2 Utility Disruption

Floods of any type have the potential to impact water and power utilities which may impact public and private use, as well as cause disruption to critical infrastructure. Refer to the list below to view flooding's harmful effects on the water supply:

- Water Supply Contamination: Excess floodwater can contaminate private drinking water sources, such as wells and springs. Floodwater picks up debris, increasing the number of bacteria, sewage, and other industrial waste and chemicals into the water source or leaky pipes. Excess water also makes it more difficult for water treatment plants to treat the water efficiently and effectively. If there is a contamination at any step of the water flow process, this puts consumers at risk of exposure to dangerous toxins that could result in serious harm, such as wound infections, skin rashes, gastrointestinal illnesses, and tetanus; in extreme cases, death may occur.
- Disruption to Clean Drinking and Cooking Water: In the event of only having access to contaminated water, consumers are unable to cook or clean in their home the water is certified as safe. Depending on the severity of the flood and the storm, this could

take days, weeks, months and in some cases even years. Without access to clean drinking and cooking water, consumers ultimately become reliant on bottled water. In impoverished communities, this reality is even more detrimental because those affected may not have the economic means to “stock up” on bottled water. Moreover, in a flood, retail locations are often inaccessible and/or low on water supply (Andrew 2021).

Floodwaters can also cause damage to power utilities. In particular, flooded buildings may have the utilities disrupted if the service panel, generator, meter, etc. are not elevated above the flood protection level. Oversaturated soils from periods of heavy rain and flooding may cause utility poles to tip over or fall completely, interrupting the power grid for a potentially large area, especially if the transformer is impacted.

4.9 Future Changes that May Impact Vulnerability

Understanding future changes that impact vulnerability in Baltimore City can assist in planning for future development and ensuring that appropriate mitigation, planning, and preparedness measures are in place.

4.9.1 Changes in Land Use and Development

Baltimore City participates in the NFIP and has flood damage prevention regulations in place that regulate how development can occur in mapped SFHAs. Future development in these areas will require adherence to flood damage prevention standards. If new development occurs in areas that currently support natural and beneficial floodplain functions, such as in conservation areas, impacts to flooding may be seen throughout the associated locations.

An increase in development, particularly in low-lying and coastal areas, will worsen flooding. Paved surfaces, such as roads and parking lots, contribute significantly to urban and stormwater flooding. When this urban flooding occurs in areas where the water table is high, water has nowhere to go but up, creating localized flooding across the region. To address stormwater management related to new development while also mitigating the impacts of flooding and sea level rise, communities can consider nature-based and environmentally sound solutions such as rain gardens, bioswales, and permeable paving.

As the population increases, so may the number of people exposed to flood risk. To limit the number of residents impacted by flooding in the future, communities can consider planning and zoning solutions such as expanded regulatory floodplains, increased freeboard requirements, buyouts of vulnerable residential areas, and identification of growth areas outside of hazard-prone areas.

4.9.2 Changes in Population

Baltimore has experienced a decrease in its population since 2010. According to the U.S. Census Bureau, Baltimore City’s population decreased by approximately 4.75 percent between 2010 and 2021 (U.S. Census 2021). Estimated population projections provided by the Maryland Department of Planning indicate that Baltimore City’s population will begin to increase going into 2030, reaching a total population of approximately 596,390 persons and continue to increase into 2040 to a population of 599,220 (Maryland Department of Planning 2020).

The overall anticipated increase in population for Baltimore City will heighten the threat of the flood hazard and its impact on life. As the population continues to grow, Baltimore City may need to increase its residential areas and construct apartment buildings and rezone areas for residential purposes. The groups most vulnerable to the hazard will likely increase, especially if variances are given to build in floodplains. The geographic and topographic areas most vulnerable to the flood hazard will remain the same, but the population exposed will increase.

4.9.3 Climate Change

As discussed above, most studies project that Baltimore City will see an increase in average annual temperatures and precipitation. It is anticipated that Baltimore City will continue to experience direct and indirect impacts of flooding events annually that may induce secondary hazards such as infrastructure deterioration or failure, utility failures, power outages, water quality and supply concerns, and transportation delays, accidents, and inconveniences.

4.9.4 Change in Vulnerability Since 2018 DP3

Since the 2018 DP3 was drafted, updated inventory data has become available to assess additional flood hazard areas in Baltimore City. This data includes the 5-Year 2021 American Community Survey population estimates, 2022 general building stock data provided by Baltimore City, 2022 RS Means for building stock replacement cost valuation, and updated critical facility data provided by Baltimore City. Hazus v5.1 was also used to assess the losses in Baltimore City to the overall risk from 1-percent and 0.2-percent flood risk. Overall, this vulnerability assessment uses a more accurate and updated asset inventory which provides more accurate estimated exposure to the flood hazard.

Section 5. Dam Failure

Key changes reflected in the 2023 DP3 update:

- Dam failure created into separate section to expand on hazard description, extent, risk, and probability.
- Inclusion of climate impacts to dam failures.

5.1 Description

A dam is an artificial barrier allowing storage of water, wastewater, or liquid-borne materials for many reasons (flood control, human water supply, irrigation, livestock water supply, energy generation, containment of mine tailings, recreation, or pollution control). Many dams fulfill a combination of these stated functions (Association of State Dam Safety Officials 2022). Dams are an important resource in the United States.

Constructed dams can be classified according to type of construction material used; methods applied in construction, slope, or cross-section of the dam; how a dam resists forces of water pressure behind it; means used to control seepage; and purpose of the dam. The materials used for construction of dams include earth, rock, tailings from mining or milling, concrete, masonry, steel, timber, miscellaneous materials (such as plastic or rubber), and any combination of these materials.

Dams require regular maintenance to retain their level of protection. Over time, dams decay and require maintenance. More than a third of the country's dams are 53 or more years old. Approximately 15,600 of those dams pose a significant hazard to life and property if failure occurs. About 2,000 unsafe dams are dispersed throughout the United States in almost every state (FEMA 2021). When dams fail or overtop, they can cause catastrophic impacts and lead to major flooding and impacts (Association of State Dam Safety Officials 2023).

Dam failures occur when the dam is damaged, destroyed, or when the spillway is inadequate and excess flow overtops the dam. Internal erosion, known as piping, through the dam or foundation can also lead to dam failures. When these things happen, water or other liquid stored behind the dam is released. Complete failure occurs if internal erosion or overtopping results in a complete structural breach, releasing a high-velocity wall of debris-filled water that rushes downstream, damaging or destroying anything in its path (Federal Emergency Management Agency [FEMA] 2015).

A catastrophic failure is characterized by the sudden, rapid, and uncontrolled release of water from a dammed impoundment. Seepages in earthen dams usually develop gradually, and if detected early, downstream residents have anywhere from a few hours to a few days to evacuate. Overtopping of a dam normally gives enough time for evacuation.

Throughout history, hundreds of dams have failed in the United States, causing property and environmental damage, injuries, and fatalities. According to the Association of State Dam Safety Officials, dam failures are most likely to occur as a result of the one or a combination of the following (Association of State Dam Safety Officials 2021):

- Overtopping caused by water spilling over the top of a dam

- Foundation defects, including settlement and slope instability
- Cracking caused by movement
- Inadequate maintenance and upkeep
- Seepage through a dam that is not properly filtered so that soil particles form sinkholes in the dam

Dam failures usually occur as a secondary effect of massive rainfall and flooding, causing too much water to enter the spillway system. This type of failure occurs with little to no warning. Spring thaws, severe thunderstorms, and heavy rainfall are also contributing factors. Depending on the size of the body of water where the dam is constructed, additional water may come from distant upstream locations.

The Dam Safety Program within MDE ensures all dams are designed, constructed, operated, and maintained safely to prevent failures and the resulting consequences. MDE's responsibilities include conducting safety inspections of dams based on their hazard classification, evaluating downstream hazard conditions, issuing permits for new construction and repairs to existing structures; and conducting construction inspections. MDE also works with dam owners and emergency management professionals to develop and exercise an "Emergency Action Plan" for dams to be used in the event of imminent dam failure. (MDE n.d.)

Despite efforts to provide sufficient structural integrity and to perform inspection and maintenance, problems can develop that lead to failure. While most dams have storage volumes small enough that failures would have little or no consequences, dams with large storage amounts could cause significant flooding downstream (FEMA 2013).

Lake Montebello Reservoir

Source: WBALTV11 2020

5.1.1 Regulatory Oversight of Dams

Potential for catastrophic flooding caused by dam failures led to enactment of the National Dam Safety Act (Public Law 92-367), which for 50 years has protected Americans from dam failures. The National Dam Safety Program is a partnership among states, federal agencies, and other stakeholders that encourages individual and community responsibility for dam safety. Under FEMA's leadership, state assistance funds have allowed all participating states to improve their programs through increased inspections, emergency action planning, and purchases of needed equipment. FEMA has also expanded existing and initiated new training programs. Grant assistance from FEMA provides support for improvement of dam safety programs that regulate most dams in the United States (FEMA 2013).

5.1.2 U.S. Army Corps of Engineers Dam Safety Program

The U.S. Army Corps of Engineers (USACE) is responsible for safety inspections of some federal and non-federal dams in the United States that meet the size and storage limitations specified in the National Dam Safety Act. USACE has inventoried dams and has surveyed each state and federal agency's capabilities, practices, and regulations regarding design, construction, operation, and maintenance of the dams. USACE has also developed guidelines for inspection and evaluation of dam safety (USACE 2017). The USACE National Inventory of Dams (NID) provides the most recent dates of inspection of dams within Baltimore City.

5.1.3 Maryland Department of the Environment

MDE holds responsibility for dam safety as called for in the Code of Maryland Environmental Article. MDE is responsible for adequately preserving public safety and promoting the general public welfare by implementing a comprehensive Dam Safety program. MDE classifies dams based on *FEMA 333: Hazard Potential Classification System for Dams* as described in section 5.3. A permit is required for any activity to construct, reconstruct, repair, or alter a dam or reservoir in the State of Maryland. Normal maintenance activities at dams and reservoirs is encouraged. MDE keeps dam owners and operators informed through newsletters, an annual dam owners' workshop, inspections, and other outreach activities.

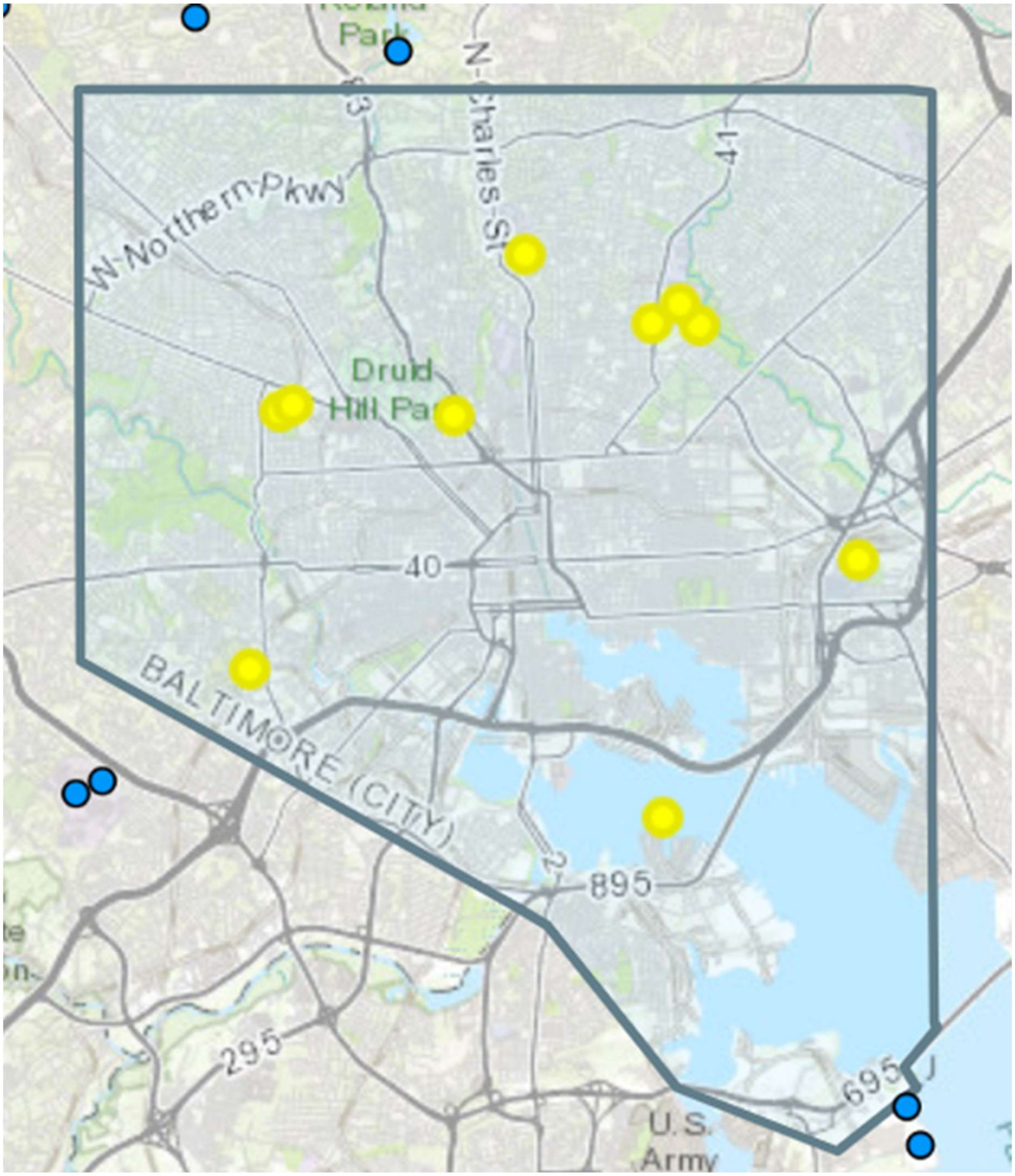
In preparing this hazard profile, dam inundation data was provided by MDE. These inundation areas were used to identify the area, population, buildings, critical facilities, and other assets in areas vulnerable to dam failures.

5.2 Location

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 the City's dams are earthen (one is earthen with rockfill), and all but one are considered off-stream dams (City of Baltimore 2018).

The "inundation zone" is the area downstream of the dam that would be flooded in the event of a failure or uncontrolled release of water and is generally much larger than the area for the normal river or stream flood event. Downstream development increases the potential consequences of a dam's failure. Any dam has the potential to adversely affect downstream areas and lives, and many dams, should they fail, can also affect the delivery of essential utilities or flood control (FEMA 2013). Figure 5-1**Error! Reference source not found.** shows the locations of the 10 dams identified to be in the City by the USACE NID; according to the USACE National Inventory of Levees, there are no known levees in the City. Each yellow dot represents a dam located within the jurisdictional boundary; blue dots indicate dams located outside of the City limits.

Figure 5-1. Dams Located in Baltimore City



Source: USACE 2023

Note: Each yellow dot represents a dam located within the jurisdictional boundary; blue dots indicate dams located outside of the City limits.

5.3 Extent

Flood control structures can significantly alter the extent of flooding in an area. Major flood control structures in the City include dams and levees. The following provides information regarding dams located in the City.

Dams are classified based on the downstream damage that would result if the dam were to fail. The hazard classification has no relationship to the condition of the dam, its structural integrity, operational status, or flood storage capability. In general accordance with dam safety practices nationally, Maryland uses three categories to classify dams: High, Significant, and Low Hazard (MDE 2015):

- High Hazard Dam: Failure would likely result in loss of human life, extensive property damage to homes and other structures, or cause flooding of major highways such as State roads or interstates. High Hazard dams are referred to as “Category I” dams in the Code of Maryland Regulations (COMAR 26.17.04.05) and “Class C” ponds by the US Natural Resources Conservation Service (NRCS).
- Significant Hazard Dam: Failure could possibly result in loss of life or increase flood risks to roads and buildings, with no more than 2 houses impacted and less than six lives in jeopardy. These are referred to as “Category II” dams in COMAR and “Class B” by NRCS.
- Low Hazard Dam: Failure is unlikely to result in loss of life, and only minor increases to existing flood levels at roads and buildings are expected. These structures are referred to as “Category III” dams in COMAR and “Class A” by NRCS.

In addition to the classifications described above, USACE also developed a classification of hazard potentials of dam failures, based only on potential consequences of dam failure (see Table 5-1). This classification does not consider probability of failure. According to the USACE, there are 10 dams in the City (see Table 5-2). Of the 10 dams, six are classified as high hazard, of which two have a poor condition assessment (USACE 2023).

The risk a dam poses to communities can be split into the following three components of the total risk (FEMA 2020):

- **Incremental Risk:** The risk (likelihood and consequences) to the pool area and downstream floodplain occupants that can be attributed to the presence of the dam should the dam breach prior or subsequent to overtopping, or undergo component malfunction or misoperation, where the consequences considered are over and above those that would occur without dam breach. The consequences typically are due to downstream inundation, but loss of the pool can result in significant consequences in the pool area upstream of the dam.

- **Non-Breach Risk:** The risk in the reservoir pool area and affected downstream floodplain due to normal operation of the dam (e.g., large spillway flows within the design capacity that exceed channel capacity) or “overtopping of the dam without breaching” scenarios.

- **Residual Risk:** The risk that remains after all mitigation actions and risk reduction actions have been completed. With respect to dams, FEMA defines residual risk as "risk remaining at any time" (FEMA 2015). It is the risk that remains after decisions related to a specific dam safety issue are made, and prudent actions have been taken to address the risk. It is the remote risk associated with a condition that was judged to not be a credible dam safety issue.

Table 5-1. USACE Dam Hazard Potential Classification

Hazard Category[1]	Direct Loss of Life[2]	Lifeline Losses[3]	Property Losses[4]	Environmental Losses[5]
Low	None (rural location, no permanent structures for human habitation)	No disruption of services (cosmetic or rapidly repairable damage)	Private agricultural lands, equipment, and isolated buildings	Minimal incremental damage
Significant	Rural location, only transient or day-use facilities	Disruption of essential facilities and access	Major public and private facilities	Major mitigation required
High	Certain (one or more) extensive residential, commercial, or industrial development	Disruption of essential facilities and access	Extensive public and private facilities	Extensive mitigation cost or impossible to mitigate

Source: USACE 2023

1. *Categories are assigned to overall projects, not individual structures at a project.*
2. *Loss-of-life potential is based on inundation mapping of area downstream of the project. Analysis of loss-of-life potential should consider the population at risk, time of flood wave travel, and warning time.*
3. *Lifeline losses include indirect threats to life caused by the interruption of lifeline services from project failure or operational disruption; for example, loss of critical medical facilities or access to them.*
4. *Property losses include damage to project facilities and downstream property and indirect impact from loss of project services, such as impact from loss of a dam and navigation pool or impact from loss of water or power supply.*
5. *Environmental impact downstream caused by the incremental flood wave produced by the project failure, beyond what would normally be expected for the magnitude flood event under which the failure occurs.*

Table 5-2. Dams Located in Baltimore City

Dam Name	Dam Owner	Year Constructed	Date of Last Inspection	Hazard Potential Classification	Condition Assessment	EAP
Druid Hill Lake Reservoir and Storage Tanks	Baltimore City DPW Bureau of Water and Wastewater	1871	December 03, 2021	High	Poor	Yes
Pecks Branch Dam (Ashburton)	Baltimore City DPW Bureau of Water and Wastewater	1956	December 03, 2021	High	Fair	Yes
Lake Ashburton Reservoir and Storage Tanks	Baltimore City DPW Bureau of Water and Wastewater	1910	December 03, 2021	High	Poor	Yes

Dam Name	Dam Owner	Year Constructed	Date of Last Inspection	Hazard Potential Classification	Condition Assessment	EAP
Hillen Road Water Supply Tank	Baltimore City DPW Bureau of Water and Wastewater	1920	December 08, 2021	High	Satisfactory	Yes
Guilford Reservoir and Storage Tanks	Baltimore City DPW Bureau of Water and Wastewater	1893	December 08, 2021	High	Satisfactory	Yes
Lake Montebello	Baltimore City DPW Bureau of Water and Wastewater	1880	December 15, 2021	High	Fair	Yes
Amtrak Railroad Culvert 100.18	Amtrak	1888	April 08, 2019	Significant	Fair	No
Johns Hopkins Bayview Campus Stormwater Pond	FSK Land Corporation	2004	July 20, 2021	Significant	Fair	Yes
Montebello Wastewater Lake	Baltimore City DPW Bureau of Water and Wastewater	1915	August 12, 2019	Low	Not Rated	Not Required
Masonville Dredged Material Containment Facility	MDOT – Maryland Port Administration	2005	July 30, 2018	Low	Satisfactory	Not Required

Source: USACE 2023

The communities downstream are at the greatest risk for dam failure. Flooding is the most common secondary effect of dam failure. If the dam failure is severe, a large amount of water will enter the downstream body of water and overflow the stream banks for miles. Environmental vulnerability is dependent on the contents of the water and the path it takes. The Vulnerability Assessment section of this hazard profile provides information on the areas, people, buildings, critical facilities, and other resources at risk from dam failures in Baltimore City.

The majority of dams in Baltimore City function as reservoirs for drinking water. In recent years, DPW has undertaken projects to eliminate these reservoirs and utilize underground tanks as storage for drinking water. In 2017, DPW began the Druid Lake Tank Project which is scheduled to be completed in December 2023. The project consists of installing two underground tanks to store 52 million gallons of water, which is currently held in the Druid Hill Lake Reservoir. Additional reservoirs have been converted to underground storage including Lake Ashburton Reservoir, Guilford Reservoir, and Montebello.

During the update of the DP3 no additional information was made available regarding the condition or deficiencies of dams. Information regarding the condition of dams is available from the NID and available in Table 5-2.

5.4 Previous and Future Occurrences

There have been no reports of previous dam failure events or dam failure related losses within Baltimore City. Maryland has had 24 dam failure events as of 2018 (Stanford University 2018). No fatalities have been reported in relation to a dam failure in Maryland (ASDSO 2023).

5.5 Probability of Future Hazard Events

Minor dam failures can occur frequently across the country; however, they often have minimal impact and cause little or no harm to the general population. Significant dam failures occur much less frequently. Dam failures are often a secondary effect, resulting from another hazard, such as heavy rainfall from a hurricane or tropical storm.

Given certain circumstances, a dam failure can occur at any time. However, the probability of future occurrence can be reduced through proper design, construction, and maintenance measures. Without proper maintenance, the age of a dam can increase the potential for failures. Further documentation of dams and their failures will, over time, provide more information on this hazard.

Based on Risk Factor Methodology Probability Criteria (further defined in Section 3), and assuming regular maintenance and inspections of the dams in the City, dam failures are considered unlikely in Baltimore City.

5.6 Potential Impacts of Climate Change

Climate temperatures are rising due to high amounts of greenhouse gases in the atmosphere absorbing the sun's energy and warming the environment. The Intergovernmental Panel on Climate Change (IPCC) provides evidence for this phenomenon in the latest IPCC report on global warming. Global temperatures are expected to rise by 2.7°C by the end of the century. The seven warmest years on record have all occurred in the last decade: 2020 was the second warmest year on record; 2016 was the warmest year on record. (IPCC 2021).

Increased precipitation will occur in the form of heavy rainfalls, which have the potential to increase the risk of dam failures. Increases in precipitation may stress the dam wall. Existing dams may not be able to retain and manage increases in water flow from more frequent, heavy rainfall events. Heavy rainfalls may result in more frequent overtopping of these dams and flooding of the county's assets in adjacent inundation areas. However, the probable maximum flood used to design each dam may be able to accommodate changes in climate.

5.7 Vulnerability Assessment

To assess Baltimore City's risk to dam failure, a quantitative exposure analysis was implemented referencing the digitized inundation areas for all dams in Baltimore City, as shown in Figure 5-2.

5.7.1 Impacts on Population

The entire population residing within the dam inundation area is considered exposed and vulnerable. Risk and vulnerability are dependent upon the population density, critical infrastructure, and mitigation actions and plans implemented within these areas. Populations without adequate warning of the event are highly vulnerable to this hazard.

Within Baltimore City Council Districts 1, 7, and 11 have the highest concentration of people living within the dam inundation area. See Table 5-3 for a breakdown of the total population within the dam inundation area in Baltimore City. Evacuation plans are pertinent to protect the population of these communities. Additionally, maintenance and enhancement of infrastructure is important to reduce the risk of downstream flooding and impact on structures within the affected communities.

Figure 5-2. Dam Inundation Areas in Baltimore City

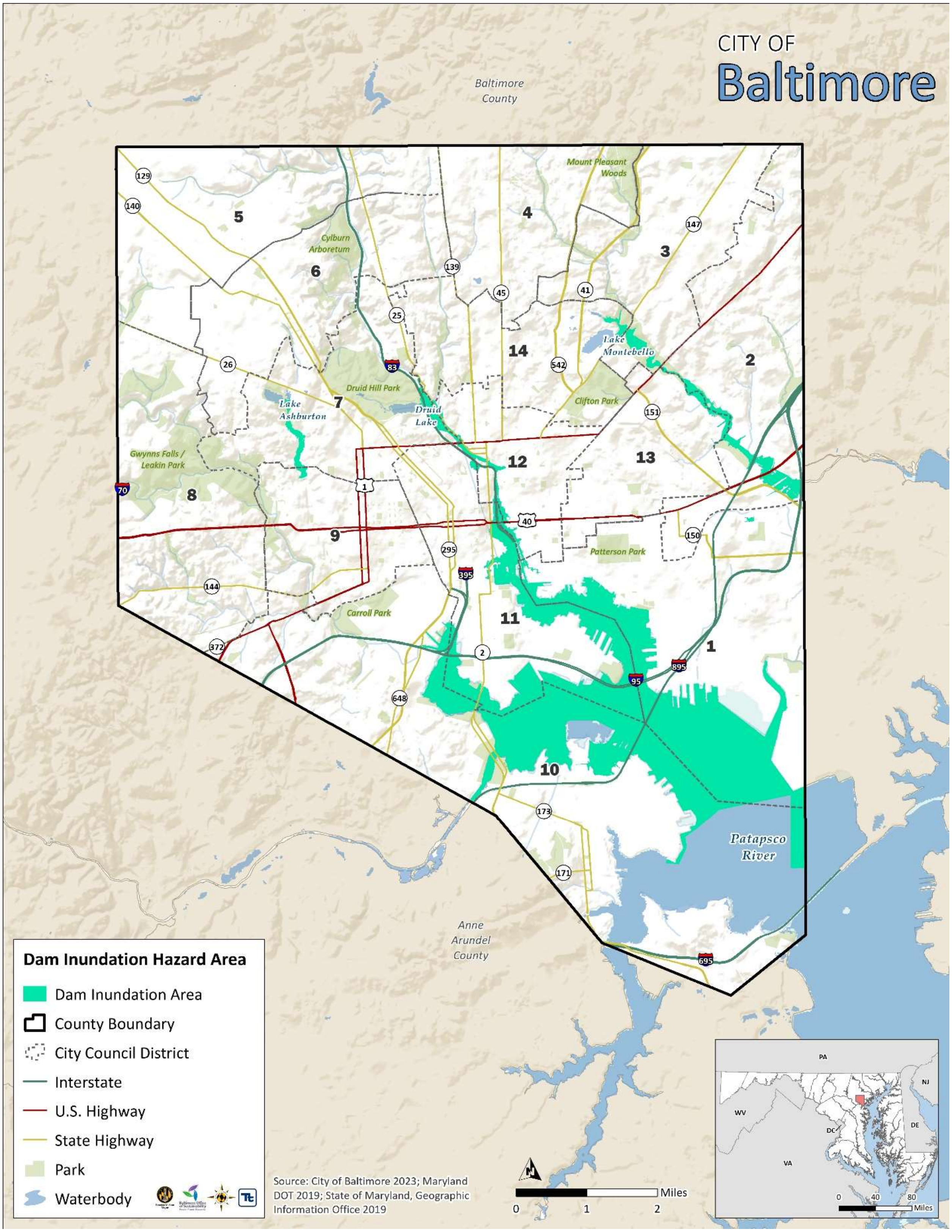


Table 5-3. Total Population within Dam Inundation Area in Baltimore City

City Council Districts	Total Population (American Community Survey 2021)	Number of Persons Located in the Dam Inundation Hazard Area	
		Number of Persons	Percent of Total
1	43,739	326	0.7%
2	45,252	0	0.0%
3	42,257	3	0.0%
4	45,027	0	0.0%
5	43,601	0	0.0%
6	41,604	0	0.0%
7	39,638	727	1.8%
8	46,396	0	0.0%
9	35,869	66	0.2%
10	41,521	0	0.0%
11	48,022	280	0.6%
12	37,130	5	0.0%
13	38,768	0	0.0%
14	42,664	0	0.0%
Baltimore City (Total)	591,489	1,407	0.2%

Source: U.S. Census Bureau 2021, ACS; City of Baltimore
Notes: Dam Inundation Areas are an aggregated dataset of all 'Sunny Day' Dam Inundation Areas; with the exception of JH Bayview Dam being a 'Brim Full' scenario.

Impacts on Socially Vulnerable Populations and Underserved Communities

Of the population exposed, the economically disadvantaged and the population over the age of 65 are the most vulnerable. Economically disadvantaged populations are more vulnerable because they may be unable to evacuate their homes due to a lack of transportation, lack of a safe place to which to evacuate, or lack of financial resources (e.g., cannot afford temporary lodging). The population over the age of 65 is also highly vulnerable because they are more likely to seek or need medical attention that may not be available because of isolation during a flood event, and they may have more difficulty evacuating. Over 14% of Baltimore City's 2022 population were persons 65 years or older (Census 2022).

5.7.2 Impacts on Structures

General Building Stock

Dam failure can result in significant damage to structures in the dam inundation area, due to the flooding associated with failures. In some cases, intense flooding may require restorative measures. City Council Districts 7, 11, and 1 have the highest number of structures in the dam inundation area, but City Council Districts 11, 2, and 7 would experience the highest dollar amount of losses. See Table 5-4 for a breakdown of the number of structures and the replacement cost value of those structures in the dam inundation area.

Table 5-4. Total Number and Total Replacement Cost Value of Structures within the Dam Inundation Area in Baltimore City

City Council District	Number of Buildings and Total Replacement Cost Value of Structures Located in the Dam Inundation Hazard Area			
	Number of Buildings	Percent of Total	Total Replacement Cost Value	Percent of Total
1	168	0.7%	$292,217,420	0.7%
2	53	0.4%	$605,559,280	3.1%
3	1	<0.1%	$321,910	<0.1%
4	0	0.0%	$0	0.0%
5	0	0.0%	$0	0.0%
6	0	0.0%	$0	0.0%
7	315	1.8%	$219,624,197	1.2%
8	0	0.0%	$0	0.0%
9	41	0.2%	$138,337,913	0.6%
10	8	<0.1%	$103,259,940	0.3%
11	232	1.4%	$2,991,039,631	4.8%
12	51	0.3%	$750,911,167	2.3%
13	1	<0.1%	$3,335,684	<0.1%
14	3	0.1%	$13,669,480	0.1%
Baltimore City (Total)	**873**	**0.4%**	**$5,118,276,622**	**1.5%**

Source: Maryland Department of Planning 2020, 2022; RS Means 2022; City of Baltimore
Notes: Dam Inundation Areas are an aggregated dataset of all 'Sunny Day' Dam Inundation Areas; with the exception of JH Bayview Dam being a 'Brim Full' scenario.

Dam failure can cause severe downstream flooding and may transport large volumes of sediment and debris, depending on the magnitude of the event. Widespread damage to buildings and infrastructure affected by an event would result in large costs to repair these locations. In addition to physical damage costs, businesses can be closed while flood waters retreat and utilities are returned to a functioning state.

Critical Facilities

Critical facilities are those which have high significance to the daily lives, health, and wellbeing of those located within Baltimore City. These facilities are critical for maintaining a safe environment. The lack of access to or function of these critical facilities can have the potential to result in loss of life during and after hazard events. For the purpose of this DP3, the critical facilities that were highlighted in the plan include: medical facilities; police stations; fire stations; schools; and emergency operation centers. Impacts from dam failures can result in damage to these facilities resulting in the inability to perform and provide help to people during and after a hazard event.

Dam failures may also impact critical facilities and infrastructure located in the inundation areas. Consequentially, dam failure can cut evacuation routes, limit emergency access, and/or create isolation issues. Further, utilities such as overhead power lines, cable lines, and phone lines could also be vulnerable. Loss of these utilities could create additional isolation issues for the inundation areas

Critical Infrastructure

Damage to critical infrastructure is both dangerous and costly. Dam failures have the potential to damage or even cause total destruction to many of Baltimore City's critical infrastructure. Some critical infrastructure could include residential structures, commercial structures, stormwater systems, and other structures that are vital to the health of the community.

Community Lifelines

Community lifelines can be identified as any structure which is critical to the safety of the people within Baltimore City during and after a hazard event. This could include transportation measures such as major highways, ports, and railways; it could also include communication systems such as phone towers, satellites, radios, and mass notification systems. When a community lifeline is down, risk to the hazard event is increased. Impacts from dam failures have the potential to damage or interrupt a community lifeline from functioning properly and increase Baltimore City's overall risk from the hazard during and after an event.

Table 5-5 provides a breakdown of community lifelines within the dam inundation area. Transportation accounts for the highest number of community lifelines within the dam inundation area followed by health and medical, communications, and safety and security.

Table 5-5. Community Lifelines in Dam Inundation Area in Baltimore City

FEMA Lifeline Category	Number of Lifelines	Number of Lifelines Located in the Dam Inundation Hazard Area
Communications	307	7
Energy	70	4
Food, Hydration, and Shelter	127	5
Hazardous Materials	0	0
Health and Medical	802	13
Safety and Security	290	6
Transportation	446	36
Baltimore City (Total)	**2,042**	**71**

Source: City of Baltimore 2023; Maryland Department of Transportation (MDOT) 2023; Baltimore City Department of Public Works 2023; HILFD 2018, 2021, 2022
Notes:
HIFLD (Homeland Infrastructure Foundation-Level Data)
Dam Inundation Areas are an aggregated dataset of all 'Sunny Day' Dam Inundation Areas; with the exception of JH Bayview Dam being a 'Brim Full' scenario.

5.7.3 Impacts on the Economy

Severe flooding that follows a dam failure can cause extensive structural damage and withhold essential services. The cost to recover from flood damage after a surge will vary depending on the hazard risk of each dam.

5.7.4 Impacts on Natural, Historic, and Cultural Resources

The environmental impacts of a dam failure can include significant water quality and debris disposal issues or severe erosion that can impact local ecosystems. Flood waters can back up sanitary sewer systems and inundate wastewater treatment plants, causing raw sewage to contaminate residential and commercial buildings and the flooded waterway. The contents of unsecured containers of oil, fertilizers, pesticides, and other chemicals may be added to flood waters. Hazardous materials may be released and distributed widely across the floodplain. Water supply and wastewater treatment facilities could be offline for weeks. After the flood waters subside, contaminated and flood-damaged building materials and contents must be properly disposed of. Contaminated sediment must be removed from buildings, yards, and properties.

The impacts on historic landmarks and historic districts from dam failure would largely mirror the same impacts from flooding within the mapped SFHA. Historic districts within the dam inundation area include Mt. Royal Terrace, Bolton Hill, Mount Vernon, and Jonestown. Several historic landmarks concentrated within the downtown/Inner Harbor area would be impacted by dam failures such as the War Memorial, St. Vincent De Paul Church, and Shot Tower.

5.8 Cascading and Compounding Impacts

Dam failure events are frequently associated with other natural hazard events such as earthquakes, landslides, or severe weather, which limits their predictability and compounds the hazard. The shaking associated with earthquakes may weaken the structure of a dam, particularly earthen dams, causing them to fail. Landslides can directly impact a dam, causing damage or failure. Likewise, landslides of the ground around a dam may weaken the ground on which the dam exists, causing the potential for the dam structure to fail. Landslides into the water being impounded by the dam can cause a wave to travel the length of the dam's impoundment area, ultimately crashing on the dam itself. Severe weather can result in large quantities of rain upstream of the dam that will ultimately be impounded by the dam, which could raise water levels behind the dam, resulting in overtopping of the dam and/or flooding of properties upstream of the dam itself.

5.9 Future Changes that May Impact Vulnerability

It is important to understand future projections that may impact Baltimore City's overall vulnerability to dam failure. This understanding could benefit the future development planning efforts within Baltimore City and ensure that sound mitigation and preparedness measures are in place.

5.9.1 Changes in Land Use and Development

Updates to building codes and regulations may help to lessen risk to development in areas within the dam inundation area. The continuation of high-rise building development in urban areas near the shoreline, such as in Downtown Baltimore, may increase the vulnerability to dam failures as this area is still within the dam inundation area. Any areas of growth could be potentially impacted by a dam failure event if the structures are located within the flood protection area, and mitigation measures are not considered.

5.9.2 Changes in Population

According to the U.S. Census Bureau, Baltimore City has a population of 569,931 in 2022. The Maryland Department of Planning projects these estimates to increase going into 2040. Such increase in population and an influx in tourism along the Chesapeake Bay increases Baltimore City's economy, but also the overall risk Baltimore City faces to dam failures. Since dam inundation areas overlap flood hazard areas, if more people move into flood hazard areas, there will be an increase in the population vulnerable to dam failure events. Careful planning and mitigation actions, such as warning systems, can significantly benefit the growing population and lower the overall vulnerability Baltimore City has dam failures.

5.9.3 Change in Vulnerability Since 2018 DP3

Baltimore City continues to be vulnerable to dam failures. Updated population and building stock statistics were used in the current risk assessment. Further, exposure for both the population and critical facilities was analyzed. These updated datasets provide a more accurate exposure analysis for the hazard.

Section 6. Coastal Hazards

Key Changes from 2018 DP3:

- The 2018 DP3 included tropical storms and hurricanes, sea level change, and tsunamis under the Coastal Hazards profile. This hazard now includes tropical cyclones (including tropical storms and hurricanes), Nor'easter (previously located in the Precipitation Variability profile in the 2018 DP3), and storm surge (previously located in the Flooding profile in the 2018 DP3).
- The discussion on the hazard description, including location, extent, previous occurrences and losses, and future probability, has been updated.
- Discussion of the potential impacts of climate change impacts on the coastal hazards has been included.
- The 2023 update includes a vulnerability assessment combined with the hazard description. The vulnerability assessment includes discussions on the impacts to population, structures, and natural/historic/cultural resources.
- Integration of cascading and compounding impacts.
- Discussion on future changes that may impact vulnerability.

6.1 Description

Coastal hazards impact the safety of residents and economic activity of Baltimore City. Hurricane Isabel in 2003, brought extensive flooding and high storm surges which cost Baltimore City over $4.8 million in damage and resulted in 70 thousand people without power; in 2006 Tropical Storm Ernesto produced approximately 10 inches of rain, and storm tides up to 6 feet along the Chesapeake Bay (BOS n.d.).

Although coastal storm hazards originate along the coast, this hazard affects more than just the areas located in floodplains of major waterways, such as the Patapsco River. In the case of severe coastal storm events residents located in coastal communities may be evacuated to ensure safety, as inland residents are warned to prepare and seek shelter. MDEM identifies evacuation areas in the Know Your Zone tool available to residents in Baltimore City (MDEM 2023). This tool is increasingly important to the community as climate change impacts, such as sea level rise and

Key Terms

- Tropical Cyclones— Rotating, organized systems of clouds and thunderstorms that originate over tropical or subtropical waters, with organized deep convection and a closed surface wind circulation about a well-defined center (NHC n.d.).
- Tropical Storms— Are tropical cyclones that have a maximum sustained surface wind speed ranging from 39 to 73 mph. (NHC n.d.).
- Hurricanes— Are tropical cyclones that have maximum sustained surface winds exceeding 74 mph or higher (NHC n.d.).
- Nor'easter— Storms that occur along the East Coast of North America. This hazard can take place at any time of the year but is most extreme between September and April (NWS n.d.).
- Storm Surge—The abnormal rise of water generated by a coastal storm, over and above predicted astronomical tides (NHC n.d.).

tidal flooding, exacerbate coastal hazards. Additional information on sea level rise and tidal flooding can be found in Section 4 (Flooding).

For the purpose of the DP3, and as deemed appropriate by the CPT, tropical cyclones, Nor'easters, and storm surge have been identified as the main coastal hazards of concern for Baltimore City. These hazard types are further discussed below.

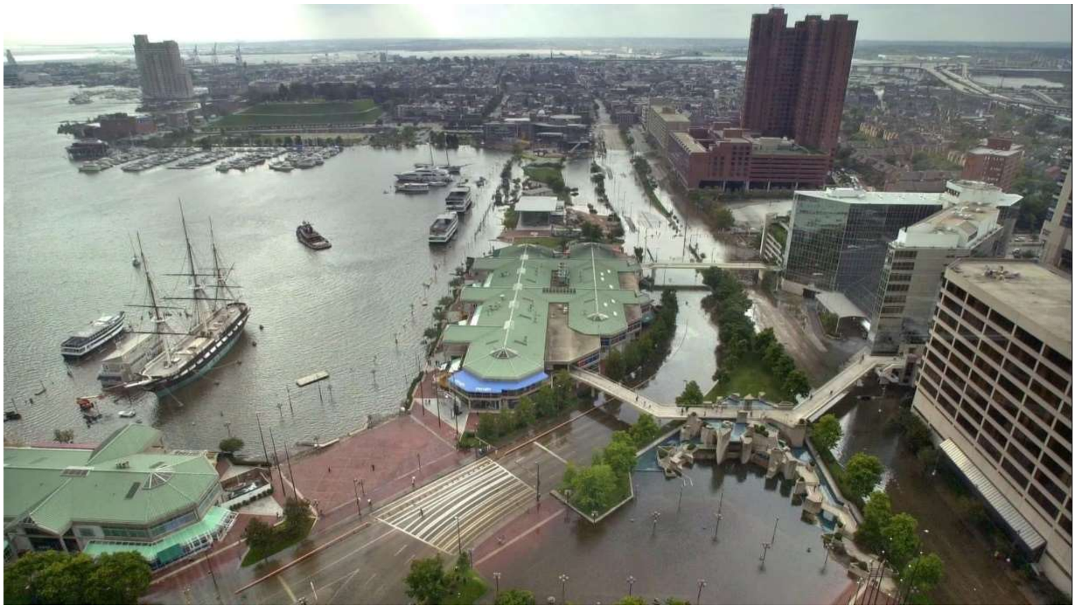
6.1.1 Tropical Cyclone

Tropical cyclones are an organized system of clouds and thunderstorms originating in tropical or subtropical waters. Tropical cyclones consist of heavy rainfall, surface winds and tornadoes, and storm surge. Tropical cyclones are classified based on wind speeds (NHC n.d.):

- Tropical depressions have maximum sustained winds of 38 mph or less
- Tropical storms have maximum sustained winds of 39 to 73 mph
- Hurricanes have maximum sustained winds of 74 to 110 mph
- Major hurricanes have maximum sustained winds of 111 mph or greater

Tropical systems can develop in the Atlantic between the Lesser Antilles and the African coast or in the warm tropical waters of the Caribbean Sea and Gulf of Mexico. These storms can move up the Atlantic coast of the United States, impacting the eastern seaboard, or move into the United States through the states along the Gulf Coast, bringing wind and rain as far north as New England before moving eastward offshore) (NHC n.d.).

Tropical cyclones form when cold, unstable air passes over warm humid air, causing the warm air to rise rapidly as the cool air drops. This results in a pressure gradient between the two air masses creating a swirling low pressure system. A hurricane often has a central 'eye' which is the area the low pressure rotates around, often containing little to no wind or rain. Figure 6-1 illustrates the formation of a tropical cyclone.



Inner Harbor and Light Street flooded during Hurricane Isabel

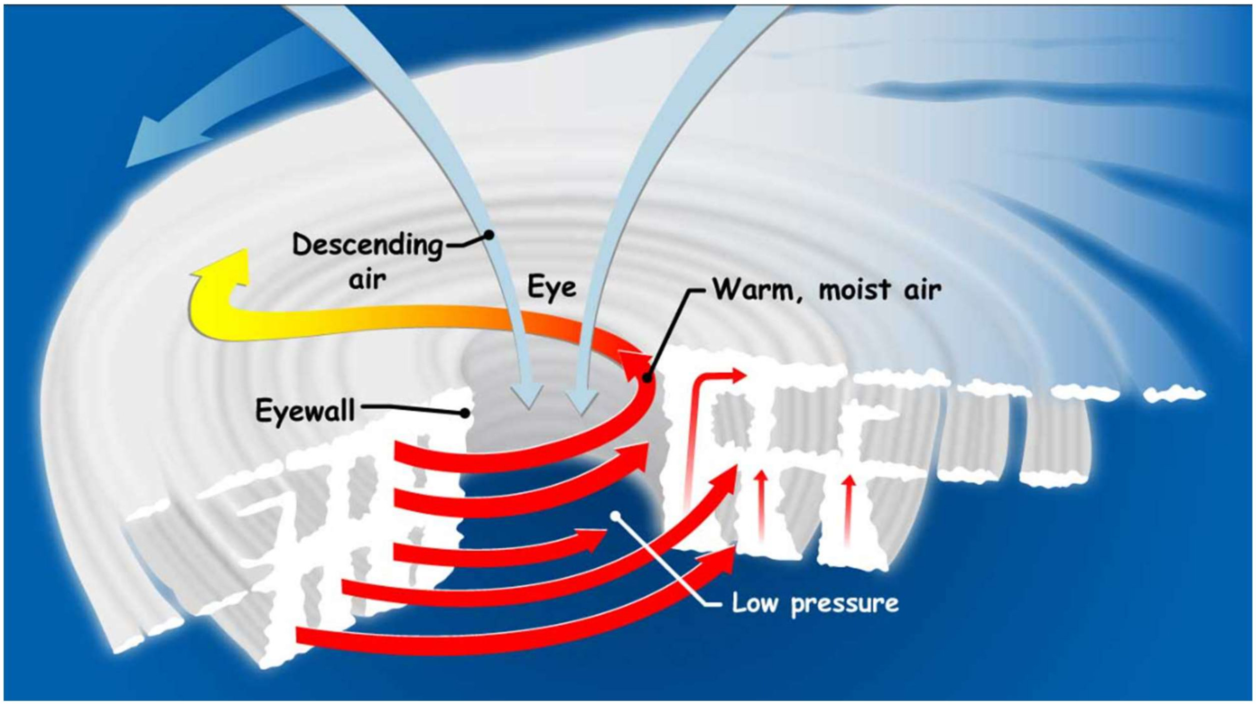
Source: The Baltimore Sun 2018

6.1.2 Nor'easter

A Nor'easter is an extratropical cyclone storm that typically brings wind, snow, rain, and flooding to a region. It forms along the east coast of North America and is named after the direction of the strongest winds, which generally blow over the northeast region. Nor'easters form within 100 miles of the coast between New Jersey and Georgia as shown in Figure 6-2. The polar jet stream blows cold air southward to Canada and eastward towards the warm Atlantic Ocean. When the cold air meets with the warm water, a low-pressure system forms. This low-pressure system results in the formation of clouds in which a Nor'easter storm starts to develop (NOAA, NOAA SciJinks 2023).

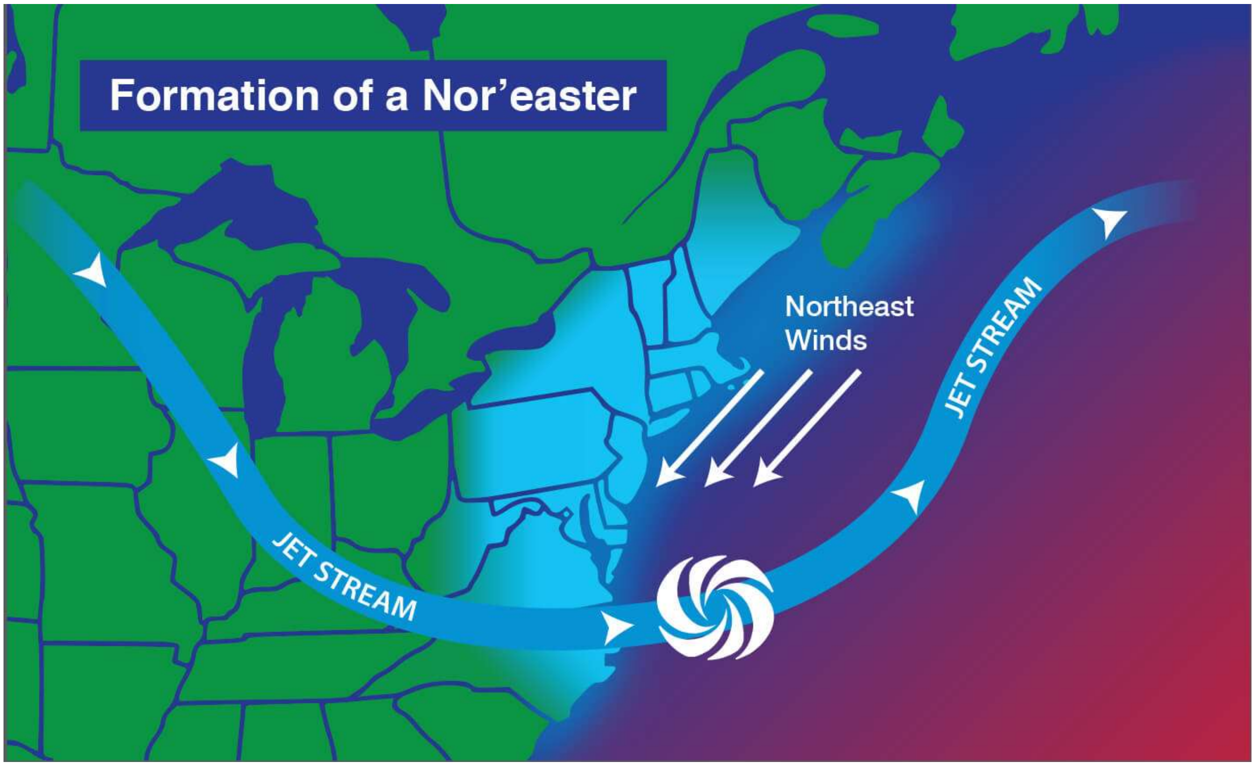
Nor'easters are typically more severe during the winter months. They can produce extremely heavy snow and blizzards, in addition to rain and flooding. These hazards cause coastal erosion and severe damage to structures. Wind gusts are also common during a Nor'easter and sometimes can rival that of a tropical cyclone (NOAA 2023). Nor'easters can stall off the mid-Atlantic coast resulting in prolonged episodes of precipitation, coastal flooding, and high winds.

Figure 6-1. Formation of a Tropical Cyclone



Source: NASA 2023

Figure 6-2. Formation of a Nor'easter



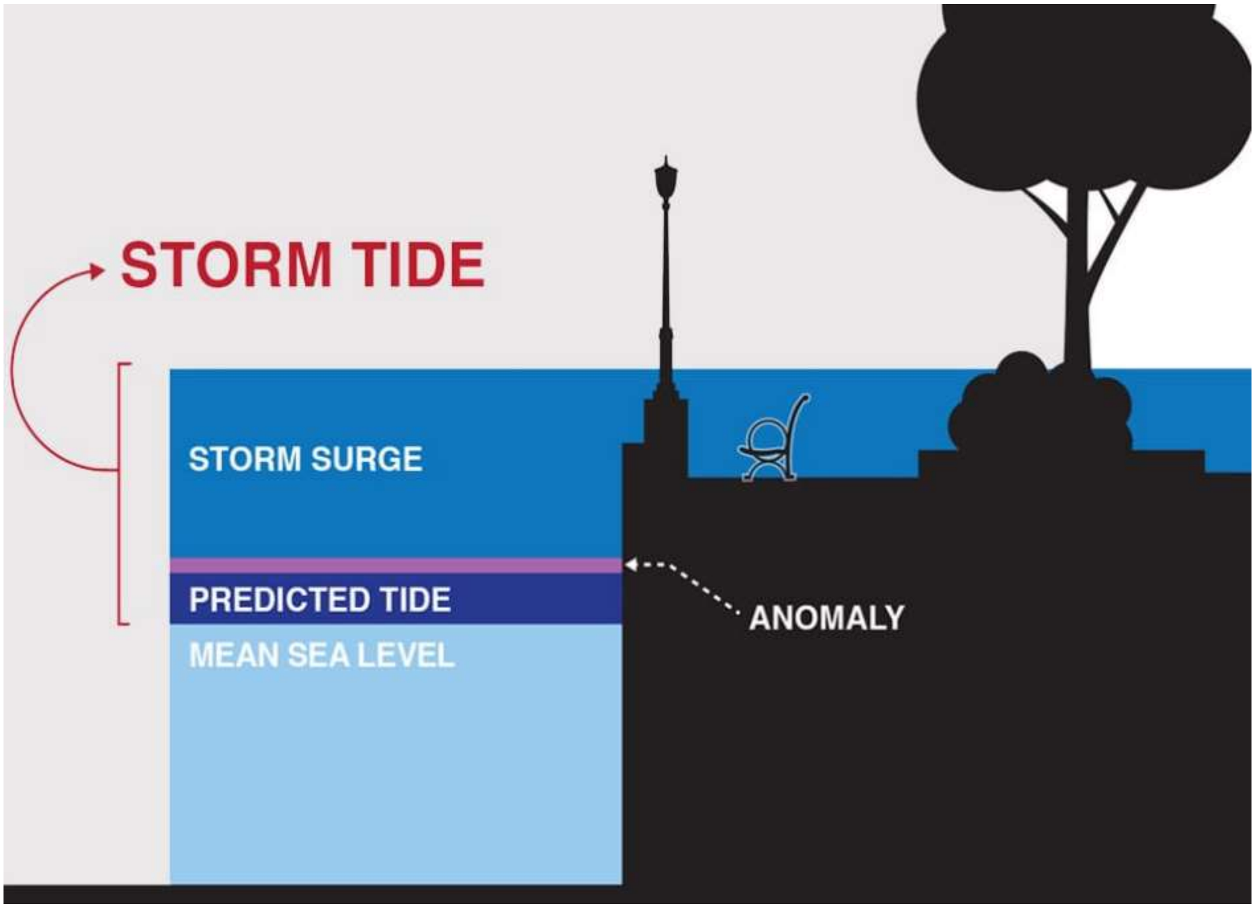
Source: NOAA/SciJinks 2023

Nor'easters and tropical cyclones can be mistaken as the same type of storm. They are similar in that they are both types of cyclone storm events with spiraling winds around a central pressure zone. However, while tropical cyclones gain their strength from warm, moist air from tropical waters, Nor'easters are cold-core systems that do not rely on warm sea surface temperatures (NOAA, NOAA SciJinks 2023). Nor'easters can occur any time of the year but are generally common around the months of September and April.

6.1.3 Storm Surge

Tropical cyclones and Nor'easters can result in storm surge events. A storm surge is water pushed towards the shoreline by strong winds and wave action, increasing coastal water surface elevations. It is measured as the height of the water above the normal predicted astronomical tide. The size of the storm surge is dependent on a variety of factors including storm track, storm intensity, storm size, and local bathymetry and topography. The combination of astronomical tide and a storm surge is known as the storm tide (see Figure 6-3). The occurrence of storm surge can cause extreme coastal flooding, especially when coinciding with astronomical high tides. Storm tides may reach up to 20 feet or more depending upon the factors listed above. During Hurricane Isabel in 2003, storm surge reached more than 8 feet throughout the Chesapeake Bay region (NHC n.d.).

Figure 6-3. Storm Tide Diagram



Source: NOAA 2023

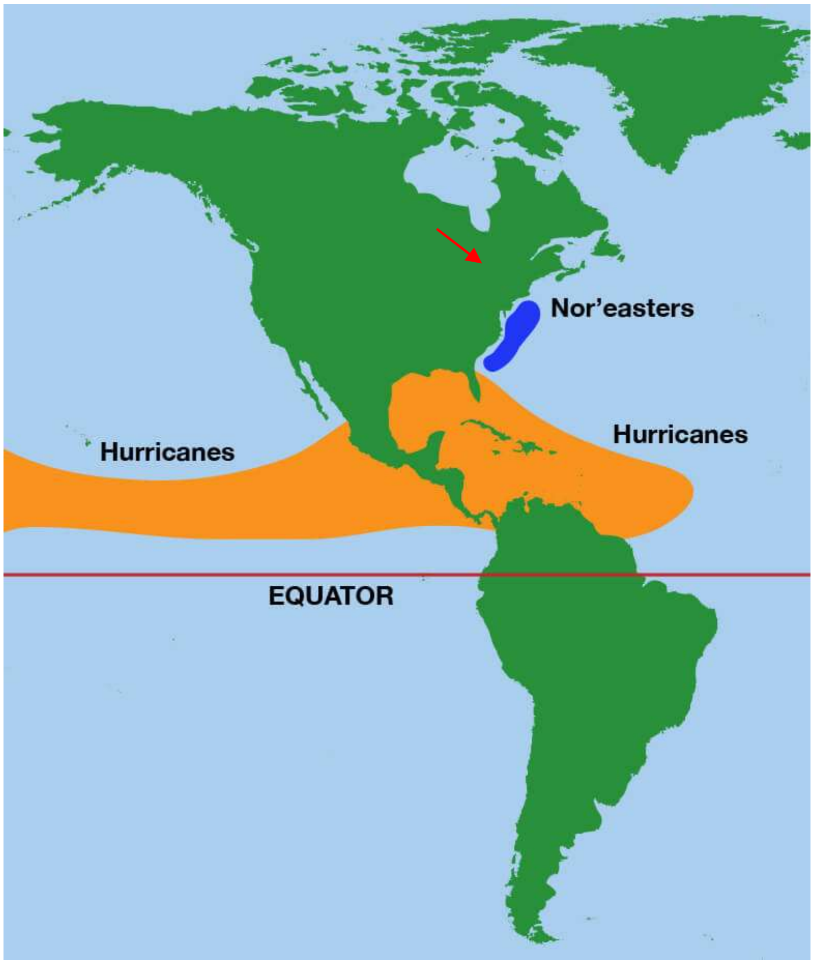
6.2 Location

Coastal hazards can have both a direct or indirect impact on the entirety of Baltimore City, and even the State of Maryland as a whole. Those areas most directly affected by coastal hazards are the communities adjacent to large coastal waters, such as the Chesapeake Bay and the Potomac River. Communities located near or adjacent to the bay and river systems, such as Downtown Baltimore, should take careful consideration in planning for and mitigating against coastal storm impacts.

The entire City is vulnerable to the damaging impacts of tropical cyclones and Nor'easters. While coastal communities within Baltimore City are more susceptible to damage resulting from strong winds and storm surge, some inland communities are susceptible to flash flooding from heavy rainfall in coastal storm events. Refer to Section 4 (Flooding), for more information on flash flooding and coastal flooding.

Figure 6-4 illustrates the typical formation locations of tropical cyclones and Nor'easters. The red arrow on the figure indicates the approximate location of Baltimore City. Unlike tropical cyclones which form over warm, tropical waters, nor'easters originate farther north near the eastern coast of the U.S.

Figure 6-4. Location of Nor'easters Vs. Tropical Cyclones/Hurricanes

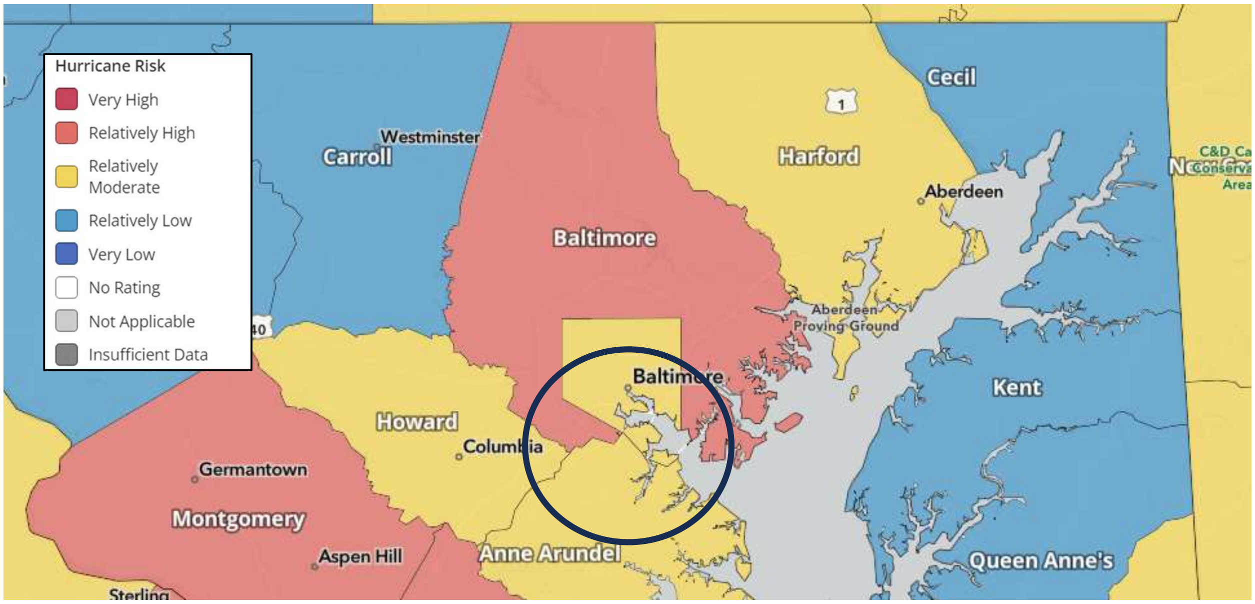


Source: NOAA/SciJinks 2023

6.2.1 Tropical Cyclone

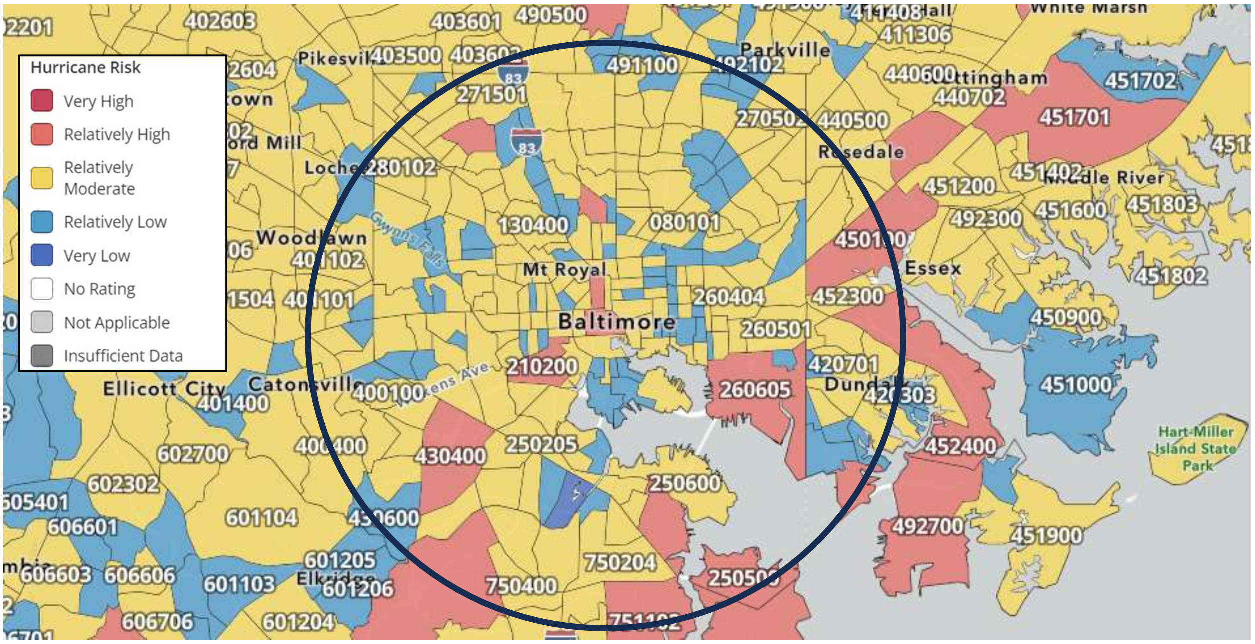
Figure 6-5 shows the Hurricane Risk Index for the United States (the black circle is representative of Baltimore City vicinity). This helps to understand the susceptibility of Baltimore City to hurricanes. According to the National Risk Index, on the county scale, Baltimore City as a whole has a relatively moderate risk to hurricanes; on the census tract scale, Baltimore City ranges from relatively high to moderate risk (see Figure 6-6).

Figure 6-5. National Risk Index, Hurricane Risk Index Score Using the County Scale



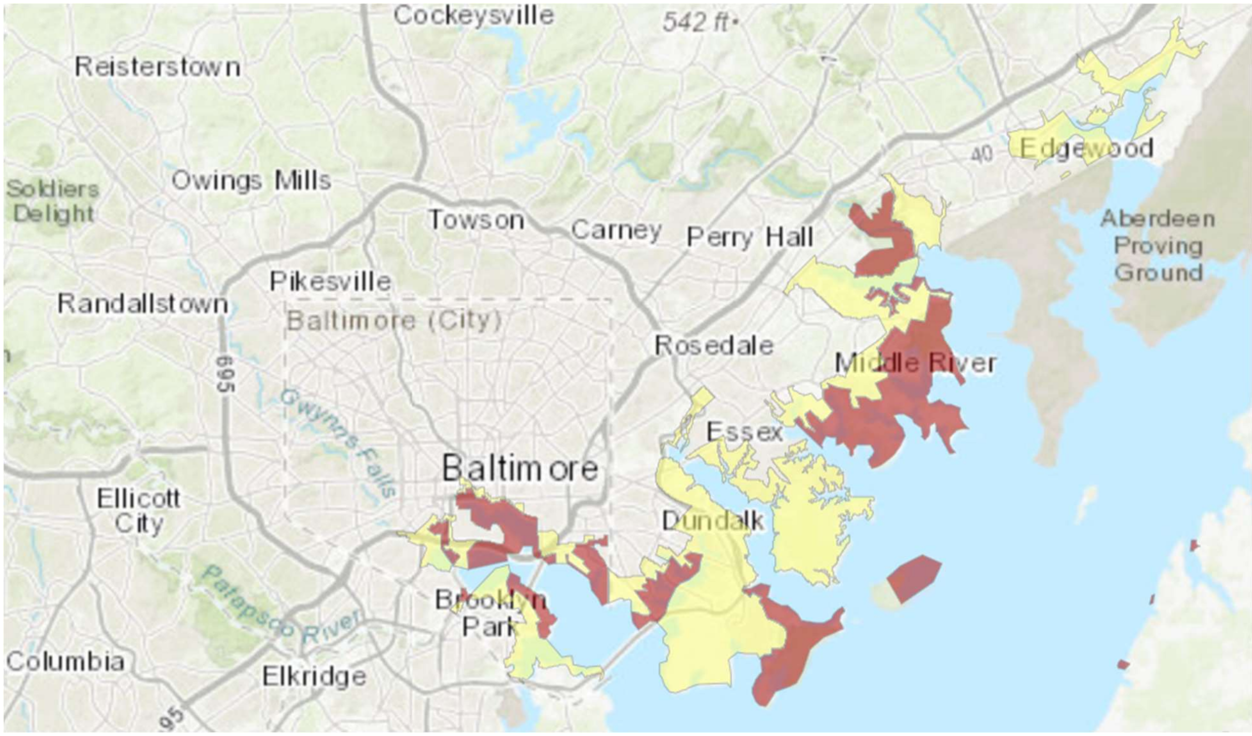
Source: FEMA 2023
Note: The vicinity of Baltimore City is within the black circle

Figure 6-6. National Risk Index, Hurricane Risk Index Score Using the Census Tract Scale



MDEM's Know Your Zone tool can be used as an indicator for potential impact areas of hurricanes. Figure 6-7 shows the Know Your Zone flood map for Baltimore City and neighboring communities. Each color is a designated evacuation zone which aids in emergency evacuation and response communications (MDEM 2023). The public is notified of the need to evacuate and take other emergency precautions based on their designated zones; zone A is red, zone B is blue, and zone C is yellow.

Figure 6-7. Know Your Zone



Source: MDEM 2023
Note: Each color is a designated evacuation zone which aids in emergency evacuation and response communications. The public is notified of the need to evacuate and take other emergency precautions based on their designated zones; zone A is red, zone B is blue, and zone C is yellow.

6.2.2 Nor’easter

The entire City is susceptible to the effects of Nor’easters; however, coastal areas along the Patapsco River and other low-lying areas are particularly vulnerable. Nor’easters usually form off the east cost between Georgia and New Jersey, as shown previously in as shown in Figure 6-2, and then follow a track northward along the coast until they blow out to sea. Although Baltimore City is inland in comparison to other parts of Maryland, Baltimore City is in close proximity to the Chesapeake Bay and other major water bodies. Therefore, Baltimore City is exposed to the direct and indirect impacts of a Nor’easter including rain, snow, wind, and coastal flooding.

6.2.3 Storm Surge

Storm surge occurs along coastal waterbodies. The reach of storm surge is dependent on the elevation of the land and the height of the storm tide. Inland communities are also vulnerable to storm surge events has rising water levels can also affect river systems, causing storm surges to travel upstream resulting in the flooding of inland areas (NOAA, NOAA SciJinks- Storm Surge 2023). The coastal areas of Baltimore City bordering the Patapsco River are the most susceptible to occurrences of storm surge.

6.3 Extent

Coastal hazards have the power to cause drastic impacts to Baltimore City and can impact large areas of the community in one event. In the case of a tropical cyclone, a large portion of Baltimore City, and even neighboring communities, may experience power outages and flooding. Critical infrastructure such as stormwater systems and culverts may not be equipped to manage such hazard events on a large scale. The entire City is susceptible to coastal hazards, but impacts depend on the track of storm events.

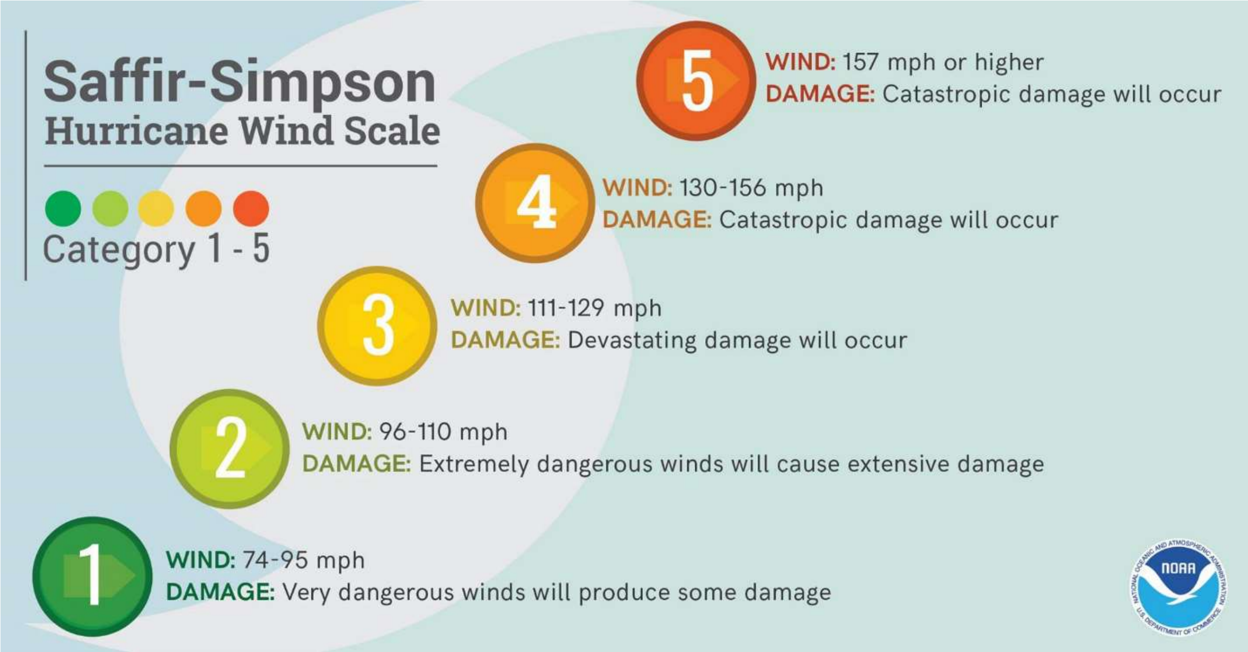
6.3.1 Tropical Cyclone

Tropical cyclones are a hazard which require Baltimore City to take proactive actions such as preparing, planning, and evacuating. The NWS issues watches and warnings when tropical cyclones approach the coastline:

- A Tropical Storm Watch is issued when winds up to 70 mph are possible along a specific coastal area within a 48-hour period of time.
- A Tropical Storm Warning is issued when winds up to 70 mph are expected in a specific coastal area within a 36-hour period of time or less.
- A Hurricane Watch is issued when sustained winds of 74 mph or higher are possible within the specified coastal area. Because hurricane preparedness activities become difficult once winds reach tropical storm force, the Watch is issued 48 hours in advance of the onset of tropical storm force winds.
- A Hurricane Warning is issued when sustained winds of 74 mph or higher are expected somewhere within the specified coastal area. Because hurricane preparedness activities become difficult once winds reach tropical storm force, the Warning is issued 36 hours in advance of the onset of tropical storm force winds. (NWS, Tropical Definitions 2023).

Hurricanes are categorized by the Saffir-Simpson Hurricane Wind Scale, as shown in Figure 6-8. The Saffir-Simpson Scale is a 1 to 5 rating system based solely on a hurricane's maximum sustained wind speeds. It is important to note that this scale does not take into account other potential hazards such as storm surge, or coastal flooding. Although all hurricanes produce severe winds that can be life-threatening to Baltimore City, hurricanes rated category 3 or higher fall under the "major" storm event category (NHC 2023). These storms will cause devastating to catastrophic wind damage and potential loss of life in Baltimore City due to the sheer strength of severe winds within the hurricane system.

Figure 6-8. The Saffir-Simpson Scale



Source: NOAA 2020

6.3.2 Nor'easter

The magnitude or severity of a Nor'easter depends on several factors including a region's climatological susceptibility to snowstorms, snowfall amounts, snowfall rates, wind speeds, temperatures, visibility, storm duration, topography, and time of occurrence during the day (e.g., weekday versus weekend), and time of season.

The extent of a Nor'easter can be classified by meteorological measurements and by evaluating its societal impacts. The Regional Snowfall Index (RSI), produced by NOAA's National Centers for Environmental Information can be used to assess the extent of significant snowstorms that impact the eastern two-thirds of the U.S. The RSI ranks snowstorm impacts on a scale from 1 to 5. It is based on the spatial extent of the storm, the amount of snowfall, and the interaction of the extent and snowfall totals with population (based on the 2000 Census). The NCEI has analyzed and assigned RSI values to over 500 storms since 1900 (NCEI n.d.). Table 6-1 presents the five RSI ranking categories.

Table 6-1. RSI Ranking Criteria

Category	RSI Value	Description
1	1-3	Notable
2	3-6	Significant
3	6-10	Major
4	10-18	Crippling
5	18.0+	Extreme

Source: NCEI n.d.

6.3.3 Storm Surge

The Sea, Lake, and Overland Surges from Hurricanes (SLOSH) model is used to assess the extent of storm surge. SLOSH is a computerized numerical model developed by the NWS to estimate storm surge heights resulting from historical, hypothetical, or predicted hurricanes by considering the atmospheric pressure, size, forward speed, and track data. These parameters are used to create a model of the wind field which drives the storm surge. It is important to note the model does not consider the effects of wave action. The SLOSH model includes the potential storm surge resulting in a Category 1 through 4 hurricanes. The SLOSH model for Baltimore City is shown in Figure 6-9.

Storm surge can be categorized by the warnings and watches issued by the National Hurricane Center (NHC). The advisories help the public to visualize areas most at risk from life-threatening surge. The advisories are issued based on the forecasted storm track, intensity, size of the storm, and the SLOSH model.

A storm surge warning is issued when there is danger of life-threatening inundation from rising water moving inland from the shoreline anywhere within the specified area, generally within 36 hours (NHC n.d.). The warning may be issued earlier when other conditions, such as the onset of tropical storm-force winds, are expected to limit the time available to take protective actions for surge (e.g., evacuations). The warning may also be issued for locations not expected to receive life-threatening inundation, but which could potentially be isolated by inundation in adjacent areas.

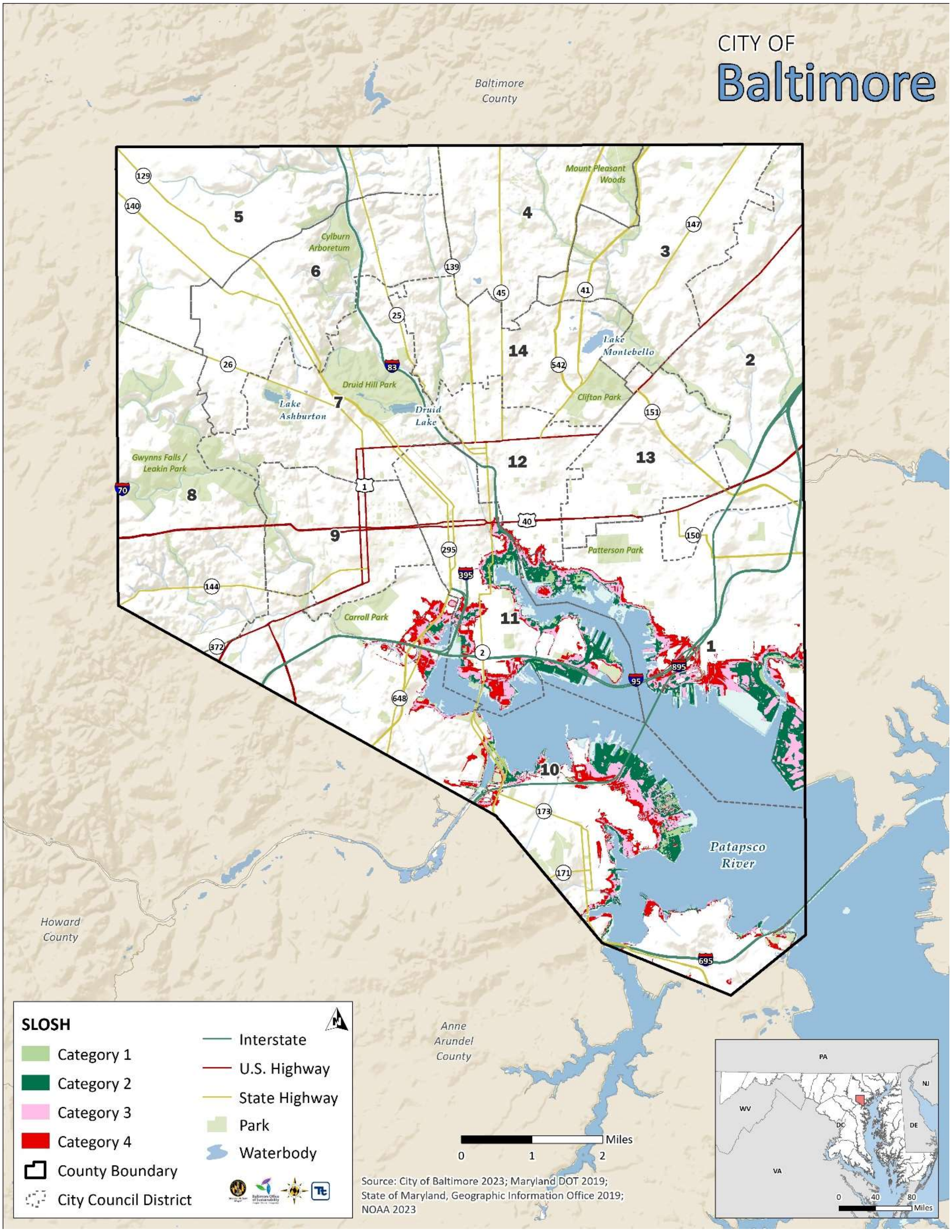
A storm surge watch is issued when there is the possibility of life-threatening inundation from rising water moving inland from the shoreline somewhere within the specified area, generally within 48 hours (NHC n.d.). The watch may be issued earlier when other conditions, such as the onset of tropical storm-force winds, are expected to limit the time available to take protective actions for surge (e.g., evacuations). The watch may also be issued for locations not expected to receive life-threatening inundation, but which could potentially be isolated by inundation in adjacent areas.

6.4 Previous Occurrences and Losses

Many sources provided historical information regarding previous occurrences and losses associated with coastal hazards throughout Baltimore City. With so many sources reviewed for this plan update, loss and impact information for many events could vary. Therefore, the accuracy of monetary figures discussed is based only on the available information in cited sources.

The most severe storm of record in Baltimore City area was a hurricane that occurred in 1933, referred to as the 1933 Chesapeake-Potomac Hurricane. This hurricane hit the coast at a higher latitude than most tropical storms that affect the region and entered the Chesapeake Bay directly from the ocean. The hurricane did not lose its energy while passing overland. Damage from tidal flooding in Baltimore City area was estimated to be approximately $5 million. Wind velocities reached 60 miles per hour, and tides rose to a record height of 7.87 feet at Fort McHenry.

Figure 6-9. SLOSH Model for Baltimore City



One of the most significant flooding events in recent years was Tropical Storm Isabel in September 2003. Isabel was a federally declared disaster, which caused over $8 million in damage in Maryland (FEMA 2018).

6.4.1 FEMA Major Disaster and Emergency Declarations

Between 1953 and 2022, the State of Maryland received nine disaster (DR) or emergency (EM) declaration for coastal related events; Baltimore City was included in six. Generally, these disasters cover a wide region of the State; therefore, they can impact many counties. However, not all counties were included in the disaster declarations as determined by FEMA (FEMA 2023). Table 6-2 lists the major FEMA declarations related to coastal storm events from 2011 to 2005.

Table 6-2. FEMA Coastal Storm Disaster and Emergency Declarations in Baltimore City (1953 to 2022)

Date(s) of Event	Date of Declaration	Event Type	FEMA Declaration Number	Description
September 16 – 20, 1999	September 24, 1999	Hurricane	DR-1303-MD	Maryland Hurricane Floyd
September 18 – 29, 2003	September 19, 2003	Hurricane	DR-1492-MD	Maryland Hurricane Isabel
August 20 – October 1, 2005	September 13, 2005	Hurricane	EM-3251-MD	Maryland Hurricane Katrina Evacuation
August 26 – September 5, 2011	August 27, 2011	Hurricane	EM-3335-MD	Maryland Hurricane Irene
August 24 – September 5, 2011	September 16, 2011	Hurricane	DR-4034-MD	Maryland Hurricane Irene
October 26 – November 8, 2012	October 28, 2012	Hurricane	EM-3349-MD	Maryland Hurricane Sandy
October 26 – November 4, 2012	November 20, 2012	Hurricane	DR-4091-MD	Maryland Hurricane Sandy

Source: FEMA 2023

6.4.2 Previous Events

For the 2023 DP3 update, known coastal hazard events that impacted Baltimore City between 1950 and 2022 are discussed below in Table 6-3. Instances where narrative was not available on the NOAA NECI Storm Events Database are not included in the table.

Table 6-3. Coastal Storm Events, 1950-2022

Date(s) of Event	Event Type	FEMA Declaration Number (if applicable)	Baltimore City Included in Declaration?	Location Impacted	Description
September 5, 1999	Storm Surge/Tide	N/A	N/A	N/A	Due to inclement weather remnants of Hurricane Dennis, water rose over a seawall into Harbor Place promenade at Inner Harbor.
September 16, 1999	Storm Surge/Tide; Tropical cyclone	N/A	N/A	N/A	Hurricane Floyd hit causing a tropical cyclone in Baltimore City. The tide rose 2 feet above normal ranges.
September 18, 2003	Tropical cyclone	N/A	N/A	N/A	Hurricane Isabella made landfall causing a tropical cyclone in Baltimore City. A huge wind field piled up the water on the Chesapeake Bay.
September 19, 2003	Hurricane	DR-1492-MD	N/A	N/A	N/A
September 13, 2003	Hurricane	EM-3251-MD	N/A	N/A	N/A
June 27, 2006	Coastal Flood	N/A	N/A	N/A	Prolonged onshore winds caused abnormally high tides in the Chesapeake Bay and Tidal Potomac River. Baltimore County Citizen Core Program reported tidal flooding and water was up to properties near Middle River and Bowley Bar.
June 28, 2006	Coastal Flood	N/A	N/A	N/A	Prolonged onshore winds caused abnormally high tides in the Chesapeake Bay and Tidal Potomac River. Rapid water rises and tidal flooding were reported at high tide.
November 16, 2006	Coastal Flood	N/A	N/A	N/A	Tidal flooding occurred in several communities, including Bowley Bar, Bowley Quarters, Millers Island, and Middle River. Up to 18 inches of water was reported covering roadways. Coastal flooding was also reported at shopping facilities located at the

Date(s) of Event	Event Type	FEMA Declaration Number (if applicable)	Baltimore City Included in Declaration?	Location Impacted	Description
					Baltimore Inner Harbor. Up to $15,000 in damage costs were reported.
January 25, 2010	Coastal Flood	N/A	N/A	N/A	Onshore winds caused coastal flooding near the Chesapeake Bay area. High water rescues took place along Bay Drive on Millers Island. Up to $10,000 in damage costs were reported.
March 13, 2010	Coastal Flood	N/A	N/A	N/A	Onshore winds caused coastal flooding in Southern Baltimore City near the Chesapeake Bay. Water levels passed thresholds for minor coastal flooding.
September 30, 2010	Coastal Flood	N/A	N/A	N/A	Strong southerly winds resulted in water to pool in the Chesapeake Bay. Water was also pushed upstream the Tidal Potomac River. Coastal Flooding was observed along the lower portion of the river and across the bay.
March 10, 2011	Coastal Flood	N/A	N/A	N/A	Strong onshore winds caused water levels to rise near the western shore of the Chesapeake Bay and along the Tidal Potomac River. Bay Drive was flooded along with community properties.
April 16, 2011	Coastal Flood	N/A	N/A	N/A	Onshore winds caused coastal flooding along the western portion of the Chesapeake Bay. High waters were reported along Miller Highland Road to North Point Road. Water levels were recorded at a foot and a half along the road intersections.
August 27, 2011	Hurricane; Tropical cyclone	EM-3335-MD	N/A	N/A	Hurricane Irene hit causing tropical cyclone conditions. Worst conditions were seen near the Chesapeake Bay. Total damage costs were over $10 million.
September 16, 2011	Hurricane	DR-4034-MD	N/A	N/A	N/A

Date(s) of Event	Event Type	FEMA Declaration Number (if applicable)	Baltimore City Included in Declaration?	Location Impacted	Description
October 28, 2012	Hurricane	EM-3349-MD	N/A	N/A	N/A
October 30, 2012	Coastal Flood	N/A	N/A	N/A	Coastal flooding as a result from Hurricane Sandy. Water reached many homes in the area, and streets were inundated.
November 20, 2012	Hurricane	DR-4091-MD	N/A	N/A	N/A
October 24, 2017	Coastal Flood	N/A	N/A	N/A	Strong onshore winds caused moderate coastal flooding along western portions of the Chesapeake Bay. Water was seen covering most piers and into resident yards. Inundation was measured approximately 6 inches in depth.
April 13, 2020	Coastal Flood	N/A	N/A	N/A	Southerly winds caused moderate tidal flooding.
April 30, 2020	Coastal Flood	N/A	N/A	N/A	Southerly winds caused moderate tidal flooding.
November 15, 2020	Coastal Flood	N/A	N/A	N/A	Strong southerly winds caused moderate flooding for Bowley's Quarters. Levels were recorded at a peak of 3.88 feet.
December 25, 2020	Coastal Flood	N/A	N/A	N/A	Onshore winds caused moderate coastal flooding along the Chesapeake Bay. Levels were recorded at a peak of 3.85 feet in Bowley's Quarters.

Source: NOAA NCEI 2023, FEMA, 2023
Note: With so many sources reviewed for this plan update, loss and impact information for many events could vary. Therefore, the accuracy of monetary figures discussed is based only on the available information in cited sources in relation to Baltimore City specifically.

6.5 Probability of Future Hazard Events

Based on historic and recent events, it is highly likely that coastal storm events will continue to occur in Baltimore City. In addition, as climate continues to change, the probability for future events such as tropical cyclones, hurricanes, storm surge, etc. may likely increase in quantity and severity. It is likely that events such as these will occur in varied severity for both the State and City. It is anticipated that the communities within Baltimore City will continue to experience direct and indirect impacts from coastal storm events into the future. Table 6-4 lists the probability of future occurrences of coastal storm events in Baltimore City. The probability of these hazards occurring in Baltimore City within any given year is 19.4% chance for coastal flood; 4.2% for tropical cyclones; and 2.8% chance for storm surge/tide events.

Table 6-4. Occurrence of Coastal Storm Events

Title	Number of Occurrences (1950-2022)	% Chance of Occurrence in Any Given Year
Tropical storm	3	4.2%
Hurricane	6	8.2%
Storm Surge/Tide	2	2.8%
Total	19	26.03%

Source: NCEI 2023
Note: With so many sources reviewed for this plan update, loss and impact information for many events could vary. Therefore, the accuracy of monetary figures discussed is based only on the available information in cited sources in relation to Baltimore City specifically.

6.6 Potential Impacts of Climate Change

Climate temperatures are rising due to high amounts of greenhouse gases in the atmosphere absorbing the sun's energy and warming the environment. The IPCC provides evidence for this phenomenon in the latest IPCC report on global warming (IPCC I. P., Climate Change 2021: Physical Science Basis, 2021). Global temperatures are expected to rise by 2.7° C by the end of the century. In fact, the seven warmest years on record have all occurred in the last decade. The year 2020 is the second warmest year, with 2016 being the warmest.

Although the climate is always changing, the rate at which global warming is taking place is unprecedented. As temperatures are rising so are sea levels. Sea Level rise is a result of two phenomena, glacial ice melts and thermal expansion. Large land-based ice sheets and mountain glaciers are melting at alarming rates due to rising global temperatures. These permafrost areas store much of the Earths water and carbon through carbon sequestration. As these ice sheets melt, they add to the ocean's volume of about 2 mm per year on average (NASA, 2023). Also, glacial ice sheets are a natural form of carbon sequestration, and as a result, release greenhouse gases into the atmosphere when they melt (Wadham, 2019). Another phenomenon contributing to sea level rise is thermal expansion. Thermal expansion is when water molecules expand due to a rise in temperature. Higher temperatures result in greater distance between water molecules as the cohesive forces holding them together expand. This thermal expansion contributes to an overall increase in global sea levels. In fact, approximately 1/3 of the global sea level rise recorded since 2004 has been caused by thermal expansion (NASA, Understanding Sea Level - Thermal Expansion, 2023).

Climate change, such as rising global temperatures and sea levels, have a direct effect on Coastal hazards. These changes exacerbate coastal storm hazards, causing higher frequency storms, and an overall increase in the severity of each event. Rising sea levels can impact the severity of coastal and tidal flooding, as flood waters will reach farther inland than previously seen. This will not only raise impacts seen in Baltimore's coastal communities on the Chesapeake Bay, but also result in impacts to inland communities as well. These inland communities who rarely experience coastal storm hazards may not be equipped to mitigate and respond to such coastal hazards.

6.7 Vulnerability Assessment

6.7.1 Impacts on Population

The entire population of Baltimore City is vulnerable to coastal storm events; especially those communities located on or near the Chesapeake Bay. Risk and vulnerability are dependent upon the population density, critical infrastructure, and mitigation actions and plans implemented within these coastal communities. The metropolitan areas of Baltimore, such as downtown Baltimore, are most vulnerable to coastal storm events due to its high population density and critical infrastructure near the bay. Hurricanes, tropical cyclones, coastal and tidal flooding, and more can severely impact the daily lives and overall safety of the people in downtown Baltimore and other coastal communities of Baltimore City. Table 6-5 lists the number of people locating within each storm category for the SLOSH area.

Impacts on Socially Vulnerable Populations and Underserved Communities

Socially vulnerable populations within Baltimore City have a higher vulnerability to coastal storm events. Groups such as those 65 and older, economically disadvantaged, or those with medical conditions are just some examples of socially vulnerable populations that are all at risk from impacts from coastal storm related hazards. Safe evacuation, access to shelter or necessary medical supplies, are all factors which can be severely impacted by such hazard events. Over 14% of Baltimore City's 2022 population were persons 65 years or older (Census 2022). This percentage of the population is highly vulnerable to coastal storm impacts, which can be life threatening. In addition to this, approximately 12% of Baltimore City's 2022 population have medical conditions (Census 2022). This population is highly vulnerable to Coastal hazards as medical supplies and assistance can be limited or inaccessible during these hazard events. It is important for Baltimore City to incorporate socially vulnerable populations into their mitigation efforts, to lessen the overall risk to present and future coastal storm hazards.

Table 6-5. Population Located in the SLOSH AREA

City Council District	Total Population (American Community Survey 2021)	Number of Persons Located in the SLOSH Category 1 Storm Surge Hazard Area		Number of Persons Located in the SLOSH Category 2 Storm Surge Hazard Area		Number of Persons Located in the SLOSH Category 3 Storm Surge Hazard Area		Number of Persons Located in the SLOSH Category 4 Storm Surge Hazard Area	
		Number of Persons	Percent of Total	Number of Persons	Percent of Total	Number of Persons	Percent of Total	Number of Persons	Percent of Total
1	43,739	577	1.3%	2,662	6.1%	4,483	10.2%	5,481	12.5%
2	45,252	0	0.0%	0	0.0%	0	0.0%	0	0.0%
3	42,257	0	0.0%	0	0.0%	0	0.0%	0	0.0%
4	45,027	0	0.0%	0	0.0%	0	0.0%	0	0.0%
5	43,601	0	0.0%	0	0.0%	0	0.0%	0	0.0%
6	41,604	0	0.0%	0	0.0%	0	0.0%	0	0.0%
7	39,638	0	0.0%	0	0.0%	0	0.0%	0	0.0%
8	46,396	0	0.0%	0	0.0%	0	0.0%	0	0.0%
9	35,869	0	0.0%	0	0.0%	0	0.0%	0	0.0%
10	41,521	0	0.0%	9	<0.1%	70	0.2%	310	0.7%
11	48,022	3	<0.1%	55	0.1%	1,309	2.7%	3,387	7.1%
12	37,130	0	0.0%	0	0.0%	25	0.1%	354	1.0%
13	38,768	0	0.0%	0	0.0%	0	0.0%	0	0.0%
14	42,664	0	0.0%	0	0.0%	0	0.0%	0	0.0%
Baltimore City (Total)	**591,489**	**580**	**0.1%**	**2,726**	**0.5%**	**5,886**	**1.0%**	**9,532**	**1.6%**

Source: U.S. Census Bureau 2021, ACS; NOAA 2023
Notes: ACS (American Community Survey); NOAA (National Oceanic and Atmospheric Administration)

6.7.2 Impacts on Structures

General Building Stock

Coastal hazards, such as hurricanes and storm surges, generally cause substantial damage or destruction to buildings along the shoreline. In some cases, such as intense tidal flooding scenarios, inland buildings and infrastructure may also be impacted and require restorative measures. For the purpose of this DP3 update, the general building stock was categorized in four major occupancy classes: residential (single and multi-family dwellings); commercial buildings; industrial buildings; government, religion, agricultural, and education buildings.

Table 6-6 shows the severity of expected damage for the total buildings within each occupancy class, based on a 100-year hurricane storm event, which happens 1 percent of the time. Residential dwellings have the highest total number within Baltimore City and are the only occupancy class which has a moderate severity of expected damage from the 100-year hurricane. All other occupancy classes are within the minor severity of expected damage.

Table 6-6. Total Buildings in Severity of Expected Damage for a 100-Year Hurricane

Occupancy Class	Total Number of Buildings Assessed in Occupancy	Total Number of Buildings in “Minor” Severity of Expected Damage	Total Number of Buildings in “Moderate” Severity of Expected Damage
Residential Exposure (Single and Multi-Family Dwellings)	211,043	52	1
Commercial Buildings	13,970	51	0
Industrial Buildings	746	3	0
Government, Religion, Agricultural, and Education Buildings	2,096	3	0

Source: Hazus v5.1

Critical Facilities

Critical facilities are those which have high significance to the daily lives, health, and wellbeing of those located within Baltimore City. These facilities are critical for maintaining a safe environment. The lack of access to or function of these critical facilities can have the potential to result in loss of life during and after hazard events. For the purpose of this DP3, the critical facilities that were highlighted in the plan include: medical facilities; police stations; fire stations; schools; and emergency operation centers. Coastal storm impacts from hurricanes, storm surges, tidal flooding, and more can result in damage to these facilities resulting in the inability to perform and provide help to people during and after a hazard event.

Table 6-7 shows the percent of damage probability for critical facilities from a 100-year hurricane event. Fire stations had the highest damage severity rating with a 0.01% probability of sustaining moderate damage from a 100-year hurricane event. The next highest were police stations and emergency operation centers with up to 0.5% probability of sustaining minor damage.

Table 6-7. Probability Critical Facilities Sustaining Damage for a 100-Year Hurricane

Facility Type	% Probability of Sustaining Damage - Minor	% Probability of Sustaining Damage - Moderate
Medical Facilities	0.1% - 0.2%	0%
Police Stations	0.3% - 0.4%	0%
Fire Stations	0.2% - 0.3%	0% - 0.01%
Schools	0.1% - 0.3%	0%
Emergency Operation Centers (EOC)	0.4% - 0.5%	0%

Source: Hazus v5.1

Critical Infrastructure

Damage to critical infrastructure is both dangerous and costly. Coastal hazards have the potential to damage or even cause total destruction to many of Baltimore City's critical infrastructure. Some critical infrastructure could include residential structures, commercial structures, stormwater systems, and other structures that are vital to the health of the community.

Table 6-8 shows the estimated building losses in US dollars by Baltimore City Council District for a 100-year hurricane event. District 11 has the highest total building loss at over $2.4 million in damage. District 12 has the highest total residential building loss at over $800 in damage. Again, District 11 has the highest total commercial building loss at close to $2 thousand in damage. For all other critical infrastructures, District 1 had the highest total building loss at over $1.6 million in damage. For Baltimore City as whole, a total of $12,335,121 is estimated for building losses during a 100-year hurricane event.

Table 6-8. Estimated Building Costs for a 100-Year Hurricane

City Council District	Estimated Building Losses	Estimated Building Losses for Residential Structures Only	Estimated Building Losses for Commercial Structures Only	Estimated Building Losses for All Other Occupancies Structures Only
1	$1,602,618	$284	$1,187	$1,601,147
2	$513,073	$103	$329	$512,641
3	$362,405	$85	$202	$362,118
4	$307,144	$128	$124	$306,891
5	$266,126	$199	$35	$265,893
6	$824,247	$512	$280	$823,455
7	$602,695	$525	$59	$602,111
8	$44,944	$45	$0	$44,900
9	$765,194	$765	$0	$764,428
10	$541,074	$97	$335	$540,641
11	$2,490,706	$549	$1,843	$2,488,313
12	$1,959,486	$816	$1,047	$1,957,622
13	$1,061,635	$556	$431	$1,060,648
14	$993,775	$582	$347	$992,847
Baltimore City (Total)	**$12,335,121**	**$5,247**	**$6,220**	**$12,323,655**

Source: Hazus v5.1

Community Lifelines

Community lifelines can be identified as any structure which is critical to the safety of the people within Baltimore City during and after a hazard event. This could include transportation measures such as major highways, ports, and railways; it could also include communication systems such as phone towers, satellites, radios, and mass notification systems. When a community lifeline is down, risk to the hazard event is increased. Coastal storm impacts have the potential to damage or interrupt a community lifeline from functioning properly and increasing Baltimore City's overall risk to the hazard during and after an event.

Some ways in which community lifelines can be affected by coastal storm events is due to substantial debris impeding the functionality of the lifeline. Whether from intense wind gusts of hurricanes, or flash flooding due to storm surges, debris from buildings and the environment can impede community lifelines such as roadways, highways, railways, power lines, phones lines, and more.

Table 6-9 shows the estimated debris that can occur during a 100-year hurricane wind event and is broken up by City council districts. District 10 has the highest eligible tree volume at close to 2,500 cubic yards. Subsequently, District 10 also has the highest estimated tree debris potential of about 534 tons of debris. District 1 has the highest potential of brick and wood debris at over 300 tons of debris. The total tons of debris potential for Baltimore City is 1,810 tons for brick and wood, and 2,163 tons for tree debris, as a result of a 100-year hurricane wind event.

Table 6-9. Estimated Debris Created During a 100-Year Hurricane Wind Event

City Council District	Brick and Wood (Tons)	Tree (Tons)	Eligible Tree Volume (Cubic Yards)
1	313	61	294
2	194	296	2,268
3	192	274	2,322
4	194	245	2,027
5	7	111	971
6	15	116	980
7	54	59	481
8	0	70	497
9	0	54	433
10	99	534	2,448
11	202	10	98
12	183	30	224
13	186	138	854
14	171	166	1,227
Baltimore City (Total)	**1,810**	**2,163**	**15,123**

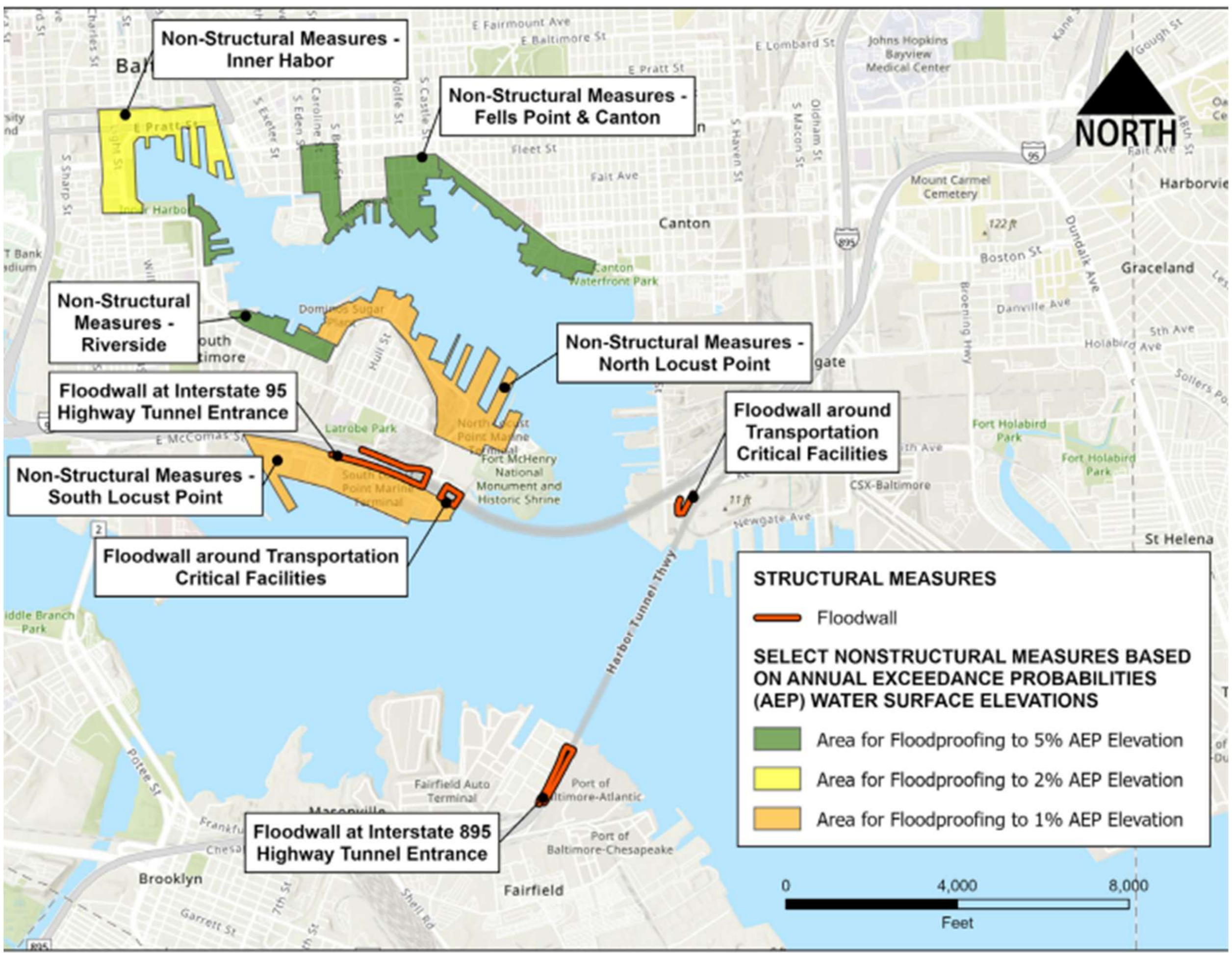
Source: Hazus v5.1

6.7.3 Impacts on the Economy

Coastal storm events have significant economic impacts by resulting in substantial damage costs and interruption to daily business activity. According to the Hazus results, the total cost of economic building loss to a 100-year hurricane event is over $12 million. Baltimore City in partnership with USACE conducted a Baltimore Coastal Storm Risk Management Feasibility Study, which evaluated project areas along the coastline of the Chesapeake Bay and included critical infrastructure frequently damaged by Coastal hazards. Critical infrastructure evaluated in this feasibility study included I-95 and I-895 tunnels, ventilation buildings, and nonstructural measures such as floodwalls, along the coast.

Figure 6-10 illustrates the study area for the feasibility study, and highlights the critical infrastructure evaluated for economic analysis. According to the feasibility study, the total economic cost to restore these critical structures and facilities totaled over $138 million (Campbell 2022). Other economic costs include annual maintenance which totaled $4.6 million (Campbell 2022). Although these are high costs, projects to restore critical structures such as these still have a relatively high benefit cost ratio due to their importance to Baltimore City's functions.

Figure 6-10. Critical Infrastructure included in the Study Area



6.7.4 Impacts on Natural, Historic, and Cultural Resources

Coastal storms can impact the environment because they can cause severe coastal erosion, through damaging winds and tidal flooding. Coastal erosion can negatively impact the environment by causing destruction to critical habitat for coastal species, especially nesting grounds which are critical for many coastal bird species (U.S. Climate Resileince Toolkit 2021). Additionally, tidal flooding can negatively impact the environment by causing pollutants to enter the nearby waterbodies and damage critical habitat. Tropical cyclones that result in hurricanes produce damaging winds that can cause mass destruction of Baltimore City's historical infrastructure. Many of the historical buildings and homes are not built to withstand such high winds, and are more vulnerable than other infrastructure, to hurricane events.

Tree canopy is also affected by coastal storm events such as tropical cyclones or derechos. Impacts such as high winds and inundation can cause downing of trees or damaging foliage; resulting in the overall decrease of shade area available for Baltimore City, further exacerbating other hazards such as extreme temperature (refer to section 9).

Coastal historic and cultural resources of significance located on the coastline in Baltimore City include Ft. McHenry and the Robert Long House.

6.8 Cascading and Compounding Impacts

Coastal storm events have the potential to occur simultaneously and/or cause the occurrence of each other. For example, both nor'easter and Coastal hazards normally cause coastal flooding in the impacted areas. Refer to Section 4 (Flooding), for more information on flooding events.

Since coastal storm events do not stay within jurisdictional boundaries, and often evolve into other systems along the coast, hazards in other states have the potential to impact the State of Maryland as well. In many cases, hurricanes that occur in neighboring states can be seen to affect the State of Maryland as a tropical cyclone. As well, hurricanes which occur in the state can lead to storm surge along coastal areas, which exacerbates flooding conditions already occurring due to the hazard event.

6.9 Future Changes that May Impact Vulnerability

It is important to understand future projections that may impact Baltimore City's overall vulnerability to severe storms. This understanding could benefit the future development planning efforts within Baltimore City and ensure that sound mitigation and preparedness measures are in place.

6.9.1 Changes in Land Use and Development

The majority of land use and development areas within Baltimore City are at risk from coastal storm events, especially the coastal neighborhoods near the Chesapeake Bay. Southeast Baltimore, South Baltimore, Federal Hill, Highlandtown, Downtown Baltimore, Westport, Cherry Hill, Brooklyn, Curtis Bay, and Hawkins Point, are just some of the coastal neighborhoods in Baltimore City that are located on or near the Chesapeake Bay. Updates to building codes and regulations may help to lessen risk to development in these neighborhoods. As well, these coastal neighborhoods within the City should consider incorporating response action plans or integrative technology into their planning efforts to lessen impacts from coastal storm events. Aging stormwater infrastructure also makes areas additionally vulnerable to coastal hazards. The continuation of high-rise building development in urban areas near the bay, such as in Downtown Baltimore, may increase the vulnerability to such hazards. Additionally, as development continues, there is an increase in impervious surfaces.

6.9.2 Changes in Population

According to the U.S. Census Bureau, Baltimore City has a population of 569,931 in 2022. The Maryland Department of Planning projects these estimates to increase going into 2040. Such increase in population and an influx in tourism along the Chesapeake Bay increases Baltimore City's economy, but also the overall risk Baltimore City faces to coastal storm events. Careful planning and mitigation actions, such as warning systems and safety shelters, can significantly benefit the growing population and lowering the overall vulnerability Baltimore City has to Coastal hazards.

6.9.3 Change in Vulnerability Since 2018 DP3

Baltimore City continues to be vulnerable to coastal storm hazards. Updated population and building stock statistics were used in the current risk assessment. Further, exposure for both the population and critical facilities was analyzed. These updated datasets provide a more accurate exposure analysis for the hazard.

Section 7. Severe Storms

Key Changes from 2018 DP3:

- Thunderstorm and winter storm hazards were previously included in the Precipitation Variability hazard for the 2018 DP3 Plan. They are both included in the Severe Storms section of the 2023 DP3 Update.
- Derecho and tornado hazard events were previously included in Chapter 3, Wind for the 2018 DP3 Plan. They are both included in the Severe Storms section of the 2023 DP3 Update.
- Extreme wind was included in its own section in the 2018 DP3 Plan (Chapter 3, Wind). Extreme wind is included in the Severe Storms section of the 2023 DP3 Update.

7.1 Description

Severe storms can occur anywhere in Baltimore City at any time. It is critical for the community to prepare and be aware of forecasts in their local jurisdictions.

The NWS Baltimore/Washington Forecast Office is an excellent resource for the community to receive updated forecast information on all severe storm events that can occur in Baltimore City. The different types of severe storms that were identified as impacting Baltimore City are further described below.

Key Terms

- Winter Storms— Is a combination of heavy snow, blowing snow, and dangerous wind chills. Winter storms can be life-threatening (NOAA n.d.).
- Thunderstorms— A localized storm produced by a cumulonimbus cloud and accompanied by lightning and thunder (NHC 2023).
- Extreme Wind Events— Include straight-line winds, downburst winds, micro- macro-burst winds, derechos, and more. Extreme wind events occur when there is a large pressure gradient in the atmosphere.
- Derecho— Widespread, long-lived windstorm that is associated with a band of rapidly moving showers and thunderstorms (NOAA n.d.).
- Tornado— A violent rotating column of air extending from the base of a thunderstorm to the ground (NOAA n.d.).

7.1.1 Winter Storm

A winter storm is a weather event in which the main types of precipitation are snow, sleet, or freezing rain. They can be a combination of heavy snow, blowing snow, and dangerous wind chills. The three basic components needed to make a winter storm include (NOAA n.d.):

- Cold Air: Below-freezing temperatures (cold air) in the clouds and near the ground to make snow and ice.
- Lift: The moist air near the Earth's surface must rise to form clouds and cause precipitation, such as warm air colliding with cold air and being forced to rise over the cold dome or air flowing up a mountainside.

- Moisture: Water is needed to form clouds and precipitation, such as air blowing across a large lake or the ocean.

Some winter storms are large enough to immobilize an entire region while others might only affect a single community. Winter storms typically are accompanied by low temperatures, high winds, freezing rain or sleet, and heavy snowfall. The aftermath of a winter storm can have an impact on a community or region for days, weeks, or even months; potentially causing cold temperatures, flooding, closed and blocked roadways, downed utility lines, and power outages.

Winter storms have the potential to be life-threatening and can severely impact the daily activities in Baltimore City. In the last 10 years, Baltimore City has experienced strong winter storm events that have disrupted daily activities and caused several automobile accidents. Power outages are also an impact felt by the community following a winter storm event. Baltimore City receives an average of approximately 21.1 inches of snowfall annually (BOEM 2023). For these severe winter storms, the amount of snowfall received was significantly more than the average.

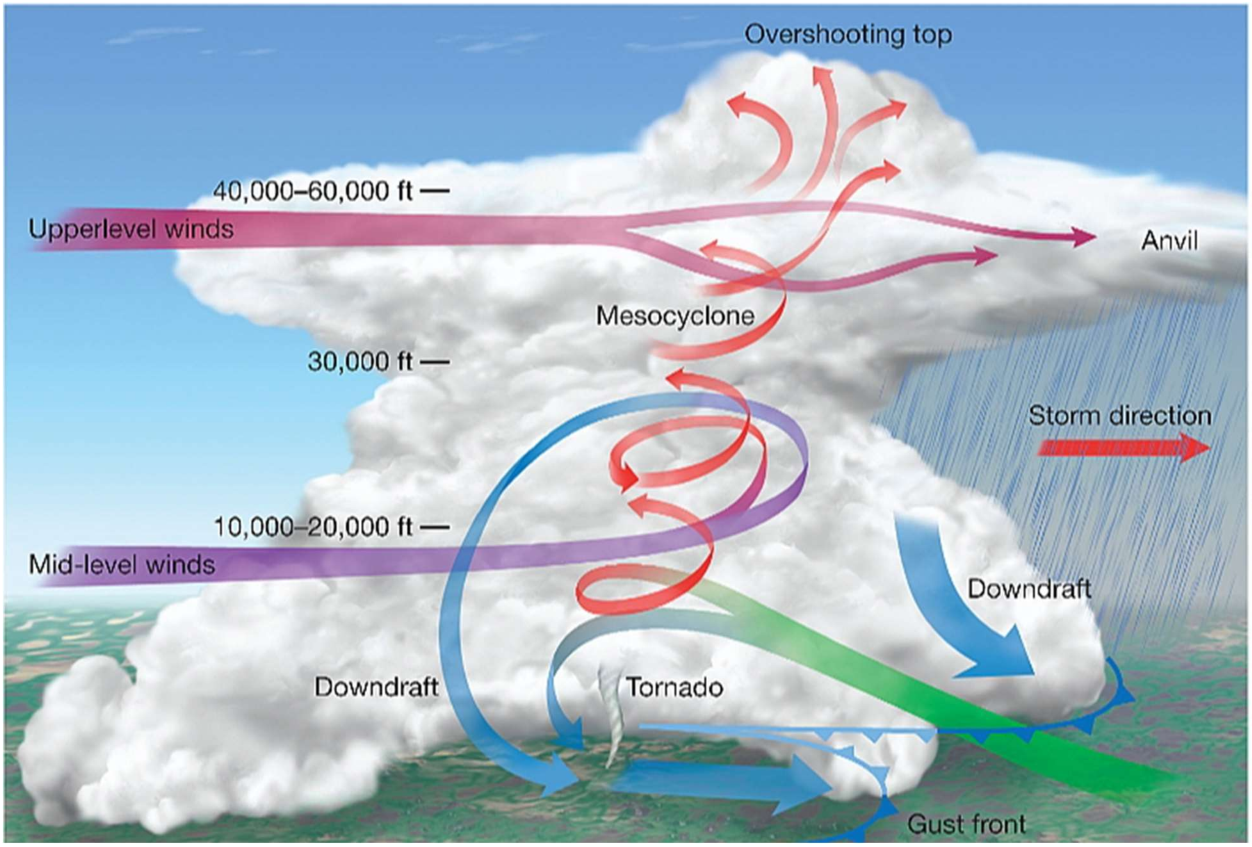
7.1.2 Thunderstorm

Although thunderstorms generally affect a small area when they occur, they have the potential to become dangerous due to their ability in generating tornadoes, hailstorms, strong winds, flash flooding, and lighting. Thunderstorms can cause a wide variety of damage to the safety and well-being of the public. These storm events are a common hazard for Baltimore City. There have been previous records of property damage, injury, and in some cases death, caused by thunderstorms and lightning in Baltimore City.

Figure 7-1 illustrates the formation of a thunderstorm system. Thunderstorms form when warm, moist surface air rises causing the water vapor to cool and condense into clouds. These clouds eventually grow upward into areas below freezing, building up enough to fall as rain. When two water/ice particles collide, they bounce off each other. Many collisions by these particles build up regions of electric charges causing bolts of lightning and sound waves commonly referred to as thunder (NOAA-NSSL 2023).

Thunderstorms can lead to flooding, landslides, strong winds, and lightning. Roads could become impassable from flooding, downed trees and power lines, or a landslide. Downed utility poles can lead to utility losses, such as electricity, phone, and water (from loss of pumping and filtering capabilities). Lightning can damage homes and injure people. In the United States, an average of 182 people are injured and 33 people are killed by lightning each year (FEMA n.d.). An estimated 100,000 thunderstorms occur each year in the United States, with approximately 2,000 occurring at any moment. Approximately, 10 percent of thunderstorms are classified as severe meaning it has hail one inch or greater, wind gusts greater than 57.5 mph., or a tornado (NOAA n.d.). During the warm season, thunderstorms are responsible for most of the rainfall.

Figure 7-1. Formation of Thunderstorms and Tornadoes



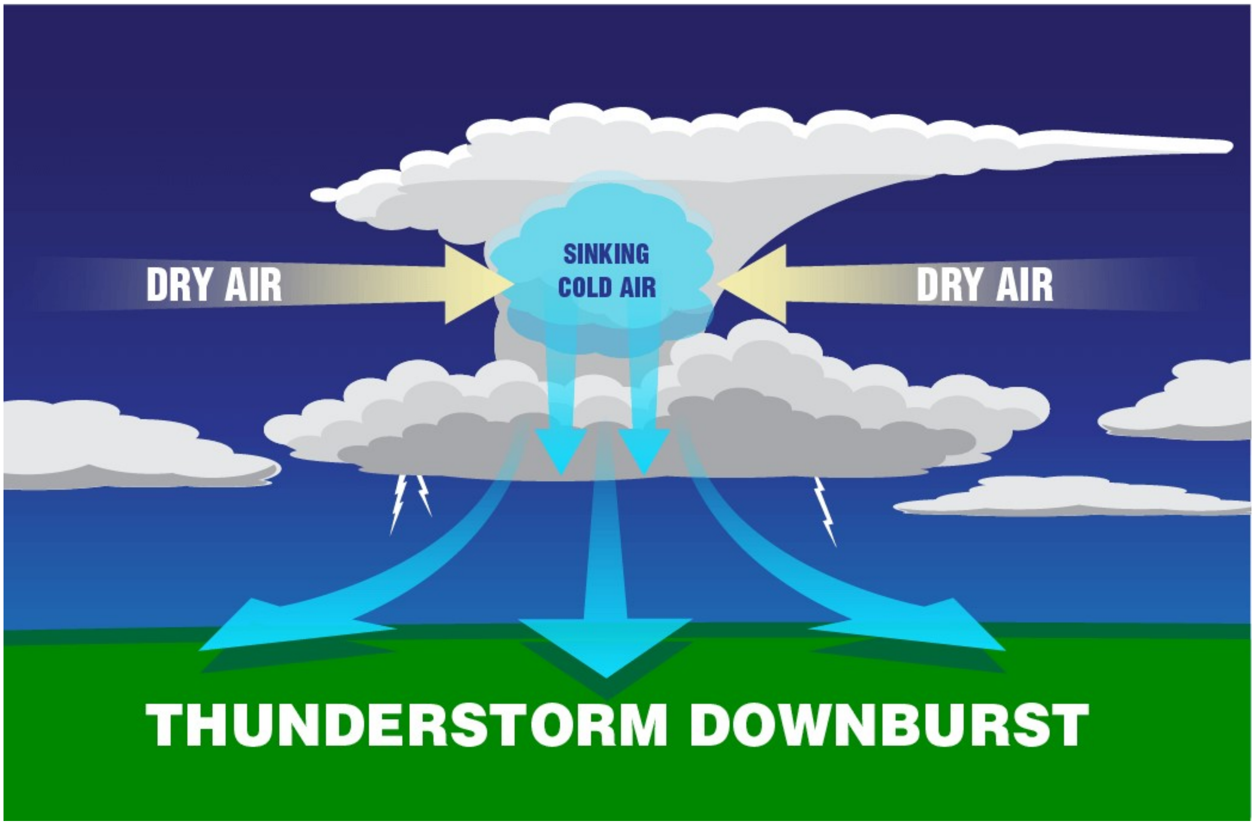
Source: Pearson Prentice Hall, Inc., 2010

7.1.3 Derecho

A derecho is a widespread, fast-moving windstorm. It can be as destructive as a tornado or hurricane. Derechos typically consist of high-speed straight-line winds. High wind events are categorized as derechos if the wind damage swath is greater than 240 miles and includes wind gusts of at least 58 mph (NWS n.d.). Derechos are often accompanied by rapidly moving thunderstorms. They generally occur between the months of May and August when temperatures are warmer.

Derechos are formed during thunderstorm downbursts; wet air in the thunderstorm comes into contact with the drier air surrounding the thunderstorm and the water in the air evaporates. The evaporation cools the surrounding air making the air dense and causing it to rapidly sink to the ground creating strong winds called downbursts. Derechos happen when downbursts occur over a large area (NOAA/SciJinks 2023). Figure 7-2 shows the formation of a derecho.

Figure 7-2. Formation of a Derecho



Source: NOAA 2023

In June of 2012, Maryland, Virginia, and Washington D.C. experienced one of the most severe derecho events recorded. The derecho traveled more than 750 miles and produced winds over 75 mph. The severe storm event resulted in major power outages, damaged communication systems, and seven direct fatalities, three of these being in the State of Maryland (NWS 2012). The major metropolitan area of Baltimore City is most vulnerable to derecho events and impacts on critical infrastructure and communication lines can adversely affect the community's safety.

7.1.4 Tornado

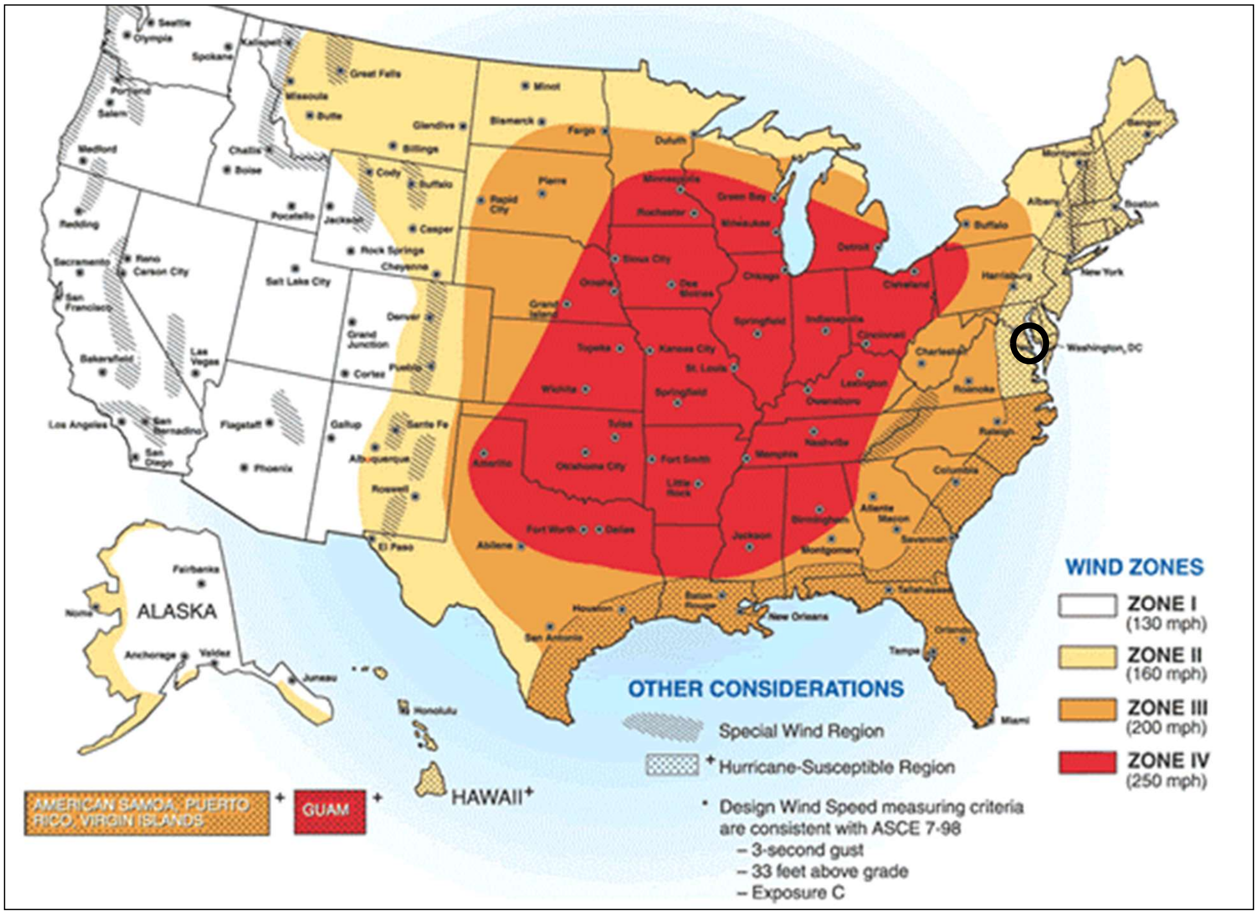
Tornadoes develop from severe thunderstorms or hurricanes and are generally produced when warm, moist winds combine with cool, dry winds causing the air to separate and rise rapidly. Damage paths can be greater than 1-mile wind and 50 miles long. Tornadoes typically move at speeds between 30 and 125 mph and can generate combined wind speeds (forward motion and speed of the whirling winds) exceeding 300 mph. A weak tornado may last a few minutes while strong tornadoes can last 20 minutes to an hour (NWS n.d.). Tornadoes are most likely to occur in Maryland from April to November in the late afternoon through the evening (MDEM n.d.). Figure 7-1 shows the formation of tornadoes.

Most of the damage caused by this hazard to Baltimore City is from wind-blown debris from a tornado's high wind velocity. This hazard impacts Baltimore City by disrupting the daily activities of both the public and service industries, causing injury through damage, destroying critical infrastructure and homes, and more.

7.2 Location

Severe storms impact the entire City and include many hazardous conditions such as windstorms, high wind, thunderstorms, tornadoes, and winter storms. Wind threats are one of the main conditions caused by severe storm events. According to the FEMA Wind Zones of the United States map, Baltimore City is located in wind zone II and is in a hurricane susceptible region, where wind speeds can reach up to 160 mph. Figure 7-3 illustrates wind zones across the United States, which indicate the impacts of the strength of wind activity by region.

Figure 7-3. FEMA Wind Zones of the United States



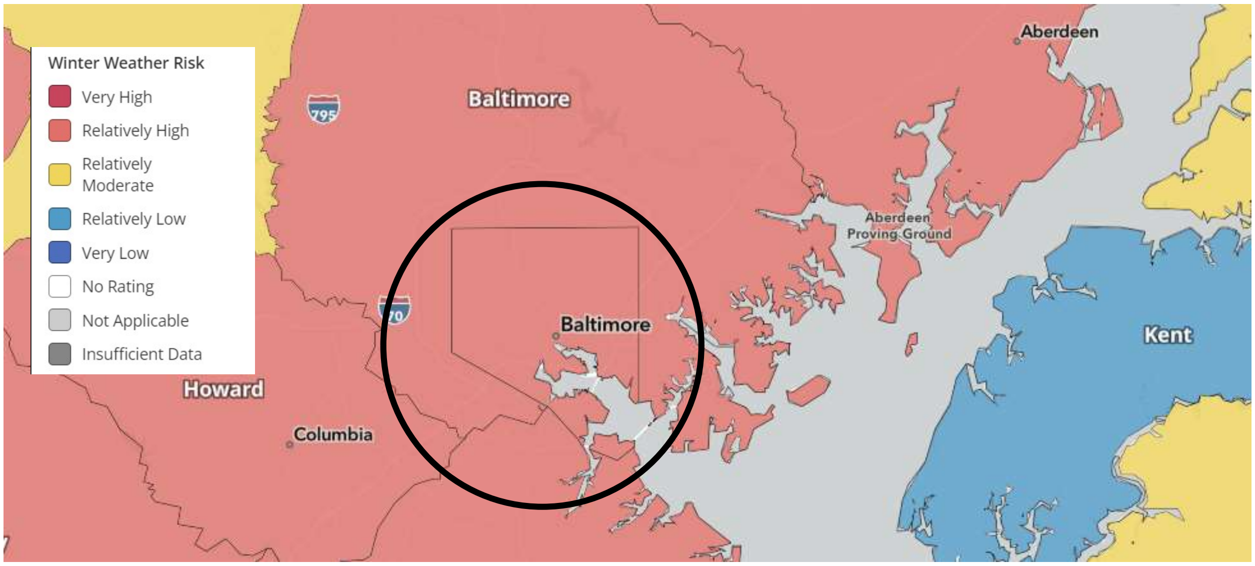
Source: FEMA n.d.
Note: The black circle indicates the approximate location of Baltimore City.

7.2.1 Winter Storm

Winter storms affect the entire City. On average Baltimore City receives 19.3 inches of snow annually (NCEI n.d.). The severity of damage normally depends upon how dense the population is and the stability of the infrastructure. Baltimore City's metropolitan area, consisting of dense populations and numerous tall structures, is the most at risk of winter storm impacts. Some of these impacts may include traffic jams, accidents, and the inaccessibility of medical or shelter facilities.

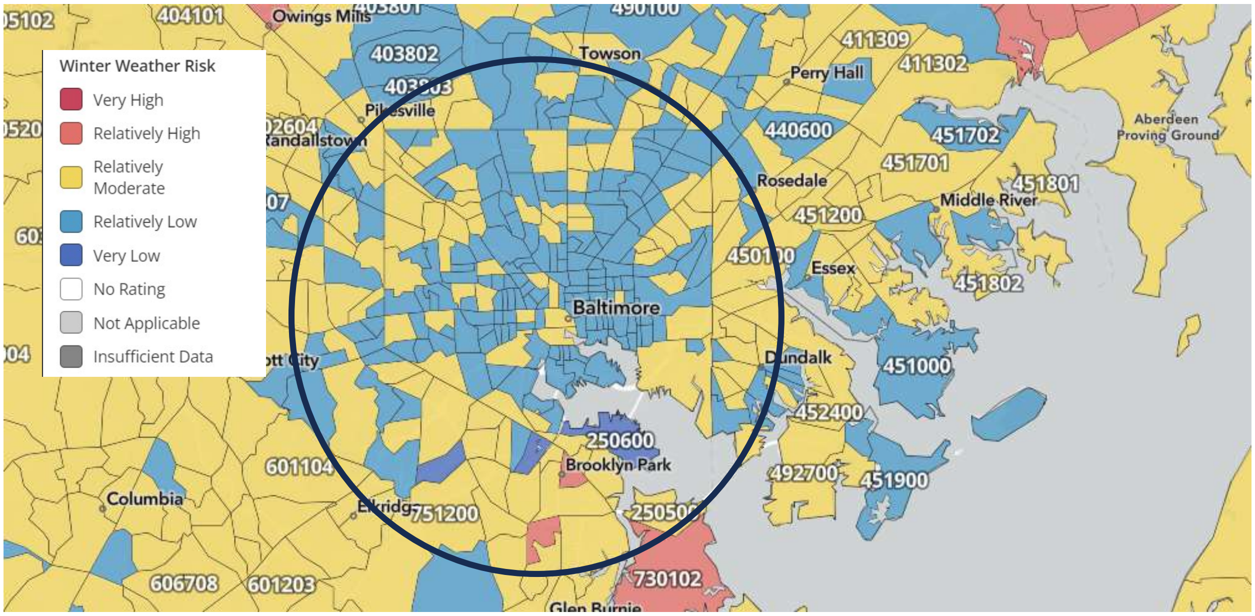
Figure 7-4 displays the Winter Weather Risk Index for the United States (the black circle is representative of Baltimore City vicinity). According to the National Risk Index, on the county scale, Baltimore City has a relatively high risk for winter weather; on the census tract scale (Figure 7-5), Baltimore City ranges from relatively moderate to relatively low risk for winter weather (FEMA 2023)

Figure 7-4. National Risk Index, Winter Weather Risk Index Score Using the County Scale



Source: FEMA 2023
Note: The black circle indicates the approximate location of Baltimore City.

Figure 7-5. National Risk Index, Winter Weather Risk Index Score Using the Census Tract Scale



Source: FEMA 2023
Note: The black circle indicates the approximate location of Baltimore City.

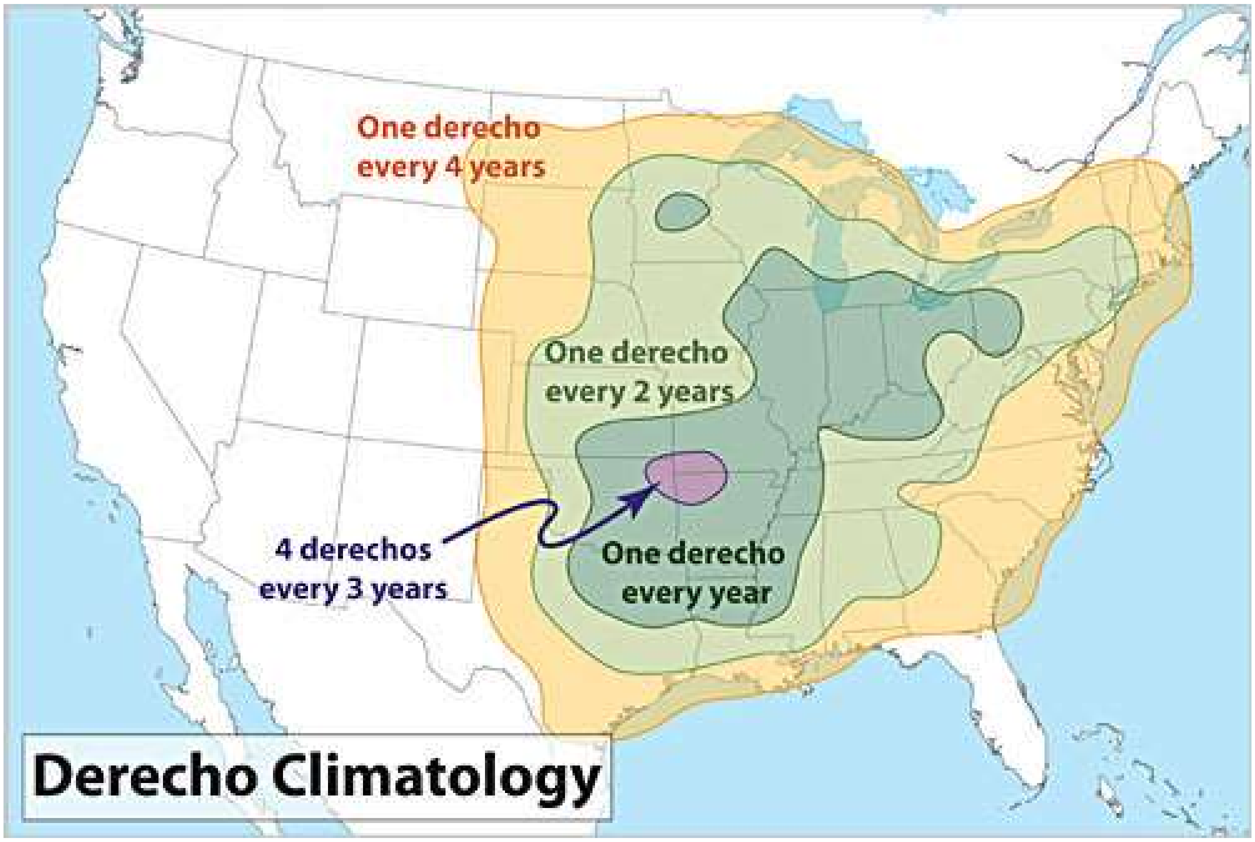
7.2.2 Thunderstorm

Thunderstorms can occur anywhere in Baltimore City. Often they affect small areas at a time, compared to winter storms or heavier flood events. Injuries and fatalities due to thunderstorms are relatively low for the state. According to NCEI, only 15 injuries and 4 fatalities were recorded in Maryland since 1996. Several thunderstorm events occur each year within Baltimore City. However, recorded damage from these events has not had a significant detrimental impact on Baltimore City's infrastructure and community as a whole.

7.2.3 Derecho

Derechos are a unique warm-weather phenomenon that occurs ahead of a squall line and generally occurs east of Texas. Although occurrences are rare than other storm events such as tornadoes, derechos still have the potential to occur anywhere within Baltimore City's jurisdictional boundaries. These severe storm events normally take place in the summer months and downdraft winds can increase the chances of occurrence. Figure 7-6 shows the approximate location and frequency of derechos across the United States. Baltimore is likely to experience one derecho every four years (NWS n.d.).

Figure 7-6. Location and Frequency of Derechos



Source: NWS 2023

7.2.4 Tornado

A tornado may occur anywhere within Baltimore City if conditions are suitable. These suitable conditions are seen by the rising of warm humid air inside a large thunderstorm. Tornadoes can cause extensive damage as they move through a city and neighboring communities. The risk depends upon the population density and stability of infrastructure in the area. Baltimore City's metropolitan areas are most vulnerable to tornado impacts due to a dense population and built infrastructure. Several tornadoes occur each year in the state of Maryland. However, many of these tornadoes touch down in rural areas causing limited damage to the community and critical infrastructure.

Tornadoes are most likely to occur in the southeast of the U.S. in cooler months, in the southern and central Plains in May and June, and the northern Plains and Midwest during early summer (NOAA n.d.).

7.3 Extent

Severe storms have the power to cause drastic impacts on the community and are a common natural hazard for those who work, play, and reside in Baltimore City. One of the main conditions involved in any severe storm event is high winds. Whether during cold dry winters or hot rainy summers, high winds can cause damage as a result of severe storm-related events that occur in Baltimore City. The NWS categorizes and displays wind threats for the U.S. with the High Wind Hazard Map (NOAA-NWS 2023). Table 7-1 shows defined threat levels.

Table 7-1. High Wind Hazards Threat Level

High Wind Threat Level	Threat Level Description
Extreme	An Extreme Threat to Life and Property from High Wind: "Damaging high wind" with sustained speeds greater than 58 mph, or frequent wind gusts greater than 58 mph. Damaging wind conditions are consistent with a high wind warning.
High	**A High Threat to Life and Property from High Wind:** "High wind" with sustained speeds of 40 to 57 mph. Wind conditions are consistent with a high wind warning.
Moderate	**A Moderate Threat to Life and Property from High Wind:** "Very windy" with sustained speeds of 26 to 39 mph or frequent wind gusts of 35 to 57 mph. Wind conditions are consistent with a wind advisory.
Low	**Low Threat to Life and Property from High Wind:** "Windy" conditions. Sustained wind speeds of 21 to 25 mph, or frequent wind gusts of 30 to 35 mph.
Very Low	A Very Low Threat to Life and Property from High Wind: "Breezy" to "Windy" conditions. Sustained wind speeds around 20 mph, or frequent gusts of 25 to 30 mph.
Non-Threatening	**No Discernable Threat to Life and Property from High Wind:** The sustained wind speeds are non-threatening; "breezy" conditions may still be present.

Source: National Weather Service, n.d.

Baltimore City on average experiences non-threatening wind hazard levels. These daily winds have no discernable threat to life or property, as defined by Table 7-1. However, during the event of a severe storm (i.e., thunderstorm) when the wind threat is high, the National Weather Service may issue a High Wind Warning for Baltimore City. Normally High Wind Warnings are issued for Baltimore City when they reach Extreme threat levels. These winds can reach up to 60 mph in most cases and be life-threatening and cause property damage.

7.3.1 Winter Storm

Dump trucks disposing of snow during 2010 "Snowmageddon" snowstorms

Source: The Baltimore Sun 2020

Winter Storms can result in extremely dangerous situations and may actively occur for several days. This hazard event is categorized by OEM as Winter Storm Warnings, Winter Storm Watches, and Winter Weather Advisories. A warning is issued by Baltimore City when hazardous winter weather is imminent or occurs in the form of heavy snow, freezing rain, and/or heavy sleet. Warnings are usually issued up to 24 hours in advance of the expected event. A watch is when Baltimore City sends out an alert to the public warning of a possible blizzard, heavy snow, freezing rain, and/or heavy sleet. Watches are normally issued up to 48 hours in advance of the beginning of a winter storm. An advisory is issued by Baltimore City when there is a large accumulation of snow, freezing rain, drizzle, and/or sleet. This alert is to allow the community to take the necessary precautions to prepare for the winter storm impacts. If precautions are not taken, life-threatening situations are possible (USDOHS 2022).

Winter storms can also be categorized by the Winter Storm Severity Index (WSSI), a national rating system by the National Weather Service. The WSSI helps to inform the community on potential winter storm impacts, such as property and transportation damage, and disruption to daily activities. The impact scale is shown below:

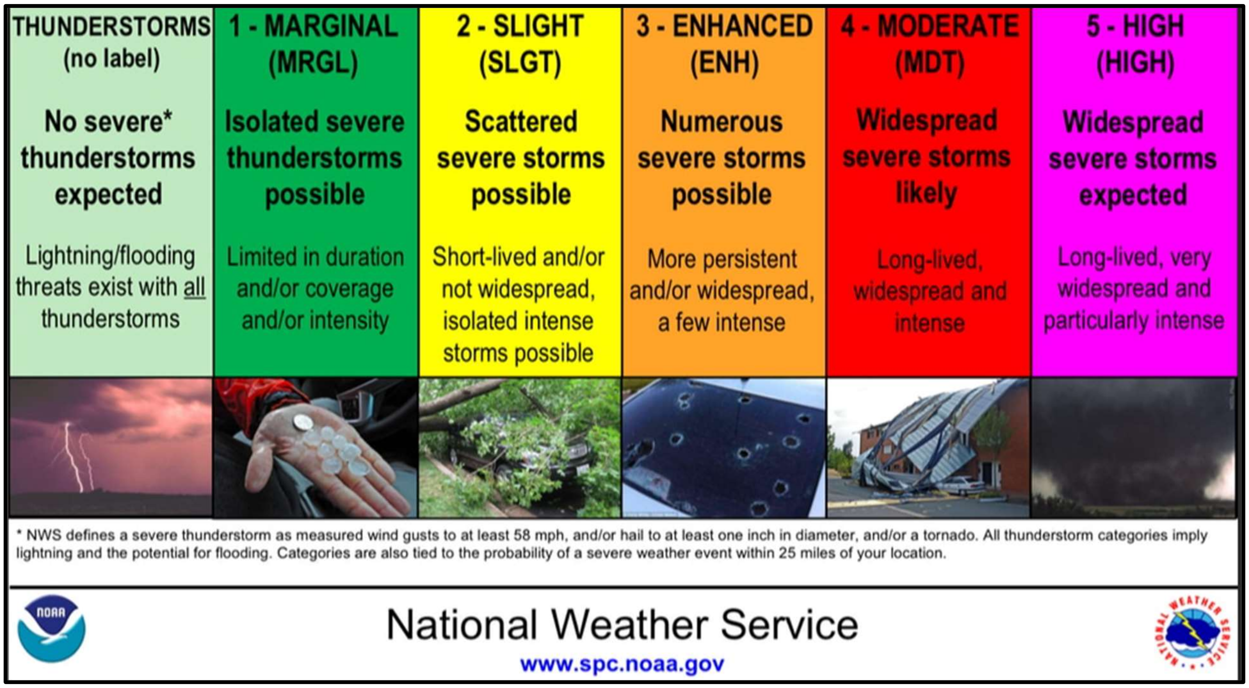
- No impact
- Limited Impacts: little to no impacts expected.
- Minor Impacts: expected inconvenience to daily activities and use caution when driving.
- Moderate Impacts: expected disruptions to daily activities and hazardous travel conditions. Schools/businesses may close.
- Major Impacts: expected considerable disruptions to daily activities and dangerous travel conditions. Schools/businesses will close.
- Extreme Impacts: expected substantial and long-lasting disruption and damage to daily activities. Impossible, life-threatening travel conditions. Schools/businesses will be closed for several days.

The WSSI scale is shown on a map with colors indicating the severity. It is measured by analyzing the potential impacts of snow amount, snow load, ice accumulation, flash freezes, blowing snow, and ground blizzards. This scale system allows the community to make informed decisions before a winter storm event (NWS, Winter Storm Severity Index n.d.).

7.3.2 Thunderstorm

Thunderstorms are measured by wind speed, hail size, and lightning severity. Winds resulting from thunderstorms are less than what is seen during a tropical cyclone. However, speeds of up to 168 mph have occurred. Figure 7-7 gives the risk categories for thunderstorm events as defined by the National Weather Service (NOAA, n.d.)

Figure 7-7. Severe Thunderstorm Risk Categories



Source: NOAA, n.d.

7.3.3 Derecho

Derechos are measured by wind speeds and size. High wind events are categorized as derechos if the wind damage swath is greater than 240 miles and includes wind gusts of at least 58 mph (NWS n.d.).

7.3.4 Tornado

Tornadoes are measured using the Fujita scale. Table 7-2 gives the Fujita scale from F0 to F5, the wind speed for each category, and examples of potential damage. According to NOAA, most of the tornadoes that have a touchdown in Baltimore City have been on the F0 to F1 range. There was a record of an F3 tornado near the Brooklyn Park area in 1961 with resulting property damage of $250,000 (Delmarva 2023). F3 tornadoes have the potential to cause severe damage by tearing off roofs on stable structures and have even been seen to overturn trains.

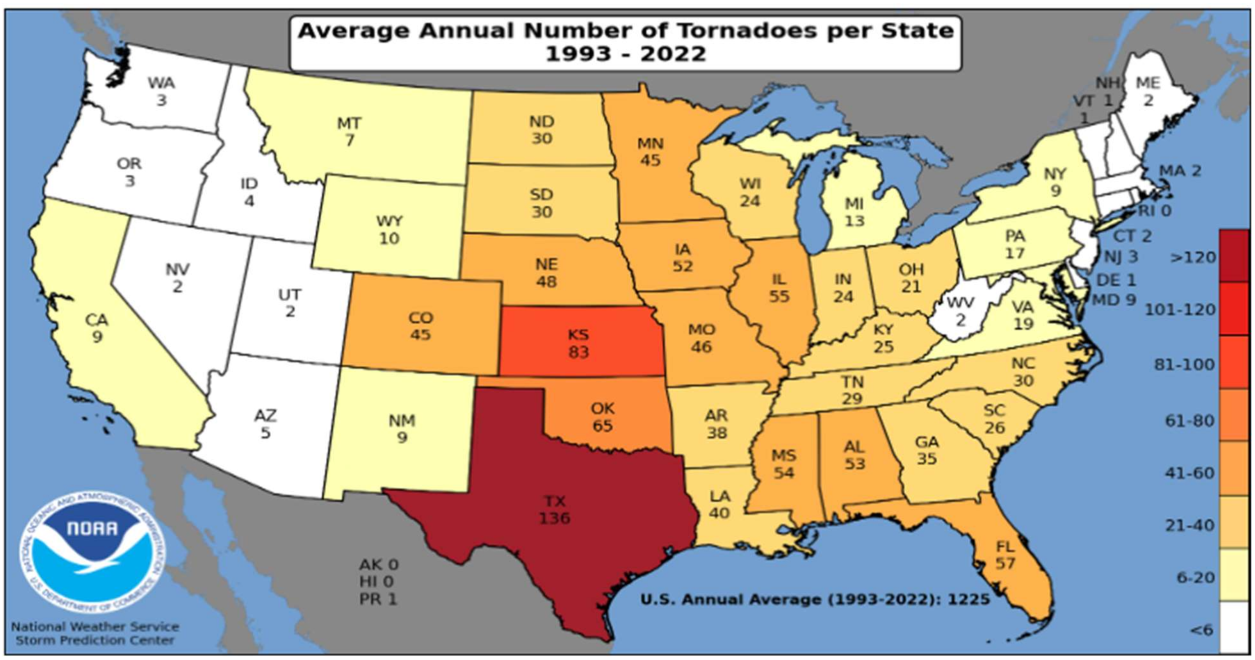
Table 7-2. Fujita Tornado Intensity Scale

Category	Wind Speed	Damage Potential
F0	Gale Tornado 40-72 mph	Light damage: some damage to structures and signs; uprooted small trees.
F1	Moderate Tornado 73-112 mph	Moderate damage: Lower limit is the beginning of a hurricane's wind speed; damage to roofs, mobile homes, and automobiles.
F2	Significant Tornado 113-157 mph	Considerable damage: Roofs torn off houses; demolished mobile homes; large trees uprooted or snapped in half.
F3	Severe Tornado 158-206 mph	Severe damage: Roofs and walls torn off well-constructed houses; overturned trains; trees uprooted; cars lifted off the ground and thrown.
F4	Devastating Tornado 207-260 mph	Devastating damage: Well-constructed houses leveled; weak foundational structures thrown; cars thrown, and large missiles generated.
F5	Incredible Tornado 261-318 mph	Incredible damage: Houses with strong frames and foundations lifted off the ground and carried; auto-sized missiles flying through air more than 100 yards; trees debarked.

Source: FEMA, Understanding Your Risks: Identifying Hazards and Estimating Losses, 2-21.

According to NOAA, the State of Maryland experiences an average of 9 tornado events each year. Figure 7-8 shows the average annual number of tornadoes per state, between 1993 to 2022. Maryland has one of the highest yearly tornado averages in the northeast U.S. Only second to Pennsylvania, which has the highest yearly average of 17 occurrences, and tied with New York state.

Figure 7-8. Average Annual Number of Tornadoes per State



Source: NOAA Weather Service Storm Prediction Center, 2023.

7.4 Previous Occurrences and Losses

Many sources provide historical information regarding previous occurrences and losses associated with severe storm events throughout Baltimore City. Regarding the 2023 DP3 update, the accuracy of the monetary figures discussed is based only on the available information in cited sources.

7.4.1 FEMA Major Disaster and Emergency Declarations

Baltimore City experienced nine FEMA disaster (DR) or emergency (EM) declarations since 1950 for severe storm-related events. Table 7-3 lists the major FEMA declarations related to severe storm events from 1950 to 2022.

Table 7-3. FEMA Flood Disaster and Emergency Declarations in Baltimore City (1950 to 2022)

Date(s) of Event	Date of Declaration	Event Type	FEMA Declaration Number	Description
September 14, 1979	September 14, 1979	Severe Storms, Tornadoes, and Flooding	DR-601-MD	Maryland Severe Storms, Tornadoes, and Flooding
March 13 – 17, 1993	March 16, 1993	Snowfall and Winter Storm	EM-3100-MD	Maryland Severe Snowfall and Winter Storm
January 6 – 12, 1996	January 11, 1996	Blizzard	DR-1081-MD	Maryland Blizzard
January 25 – 30, 2000	April 10, 2000	Winter Storm	DR-1324-MD	Maryland Winter Storm
February 14 – 23, 2003	March 14, 2003	Snowstorm	EM-3179-MD	Maryland Snowstorm
December 18 – 20, 2009	February 19, 2010	Winter Storm and Snowstorms	DR-1875-MD	Maryland Severe Winter Storm and Snowstorm
February 5 – 11, 2010	May 6, 2010	Winter Storms and Snowstorms	DR-1910-MD	Maryland Severe Winter Storms and Snowstorms
June 29 – July 8, 2012	August 2, 2012	Severe Storms and Straight-line Wind	DR-4075-MD	Maryland Severe Storms and Straight-line Winds
January 22 – 23, 2016	March 4, 2016	Winter Storm and Snowstorms	DR-4261-MD	Maryland Severe Storm and Snowstorm

7.4.2 Previous Events

Table 7-4 identifies the known severe storm events that impacted Baltimore City between January 1950 and June 2023. According to NOAA-NCEI, there have been 100 thunderstorm wind events; 3 tornado events; 4 lightning hazard events; 23 strong wind events; and 44 winter storm events. Descriptions for some of these events are not included in this profile, due to unavailable information on the NOAA NCEI Storm Events Database.

Table 7-4. Severe Storm Events That Impacted Baltimore City Between January 1950 and June 2023

Hazard Type	Number of Occurrences Between 1950 and 2023	Total Fatalities	Total Injuries	Total Property Damage	Total Crop Damage
Strong and High Wind	44	1	8	$7.868 million	$2,000
Thunderstorm (hail, lighting, thunderstorm wind)	119	2	22	$1.110 million	$500
Tornado	3	2	3	$200,000	$0
Winter Storm	169	4	19	$1.605 million	$0
TOTAL	**335**	**9**	**52**	**$10.783 million**	**$2,500**

Source: NECI, FEMA, 2023
Note: With so many sources reviewed for this plan update, loss and impact information for many events could vary. Therefore, the accuracy of the monetary figures discussed is based only on the available information in cited sources about Baltimore City specifically.

7.5 Probability of Future Hazard Events

Based on historic and recent events, it is highly likely that severe storm events will continue to occur in Baltimore City. In addition, as the climate continues to change, the probability for future events such as winter storms, tornadoes, thunderstorms, etc. may likely increase in quantity and severity. Events such as these will likely occur in varied severity for both the State and City. It is anticipated that the communities within Baltimore City will continue to experience direct and indirect impacts from severe storm events into the future. Table 7-5 lists the probability of future occurrences of severe storm events in Baltimore City. The probability of these hazards to occur in Baltimore City within any given year is 100% chance for thunderstorm winds; 4.2% for tornado events; 5.6% chance for lightning hazard strikes; 31.9% chance for other strong wind events; and 61.1% chance for severe winter storm events.

Table 7-5. Occurrence of Severe Storm Events

Hazard Type	Number of Occurrences (1950-2022)	% Chance of Occurrence in Any Given Year
Thunderstorm Wind	100	100%
Tornado	3	4.2%
Lightning	4	5.6%
Strong Wind	23	31.9%
Winter Storm	44	61.1%
Total	**174**	**100%**

Source: NCEI, 2023
Note: With so many sources reviewed for this plan update, loss and impact information for many events could vary. Therefore, the accuracy of the monetary figures discussed is based only on the available information in cited sources about Baltimore City specifically.

7.6 Potential Impacts of Climate Change

Climate temperatures are rising due to high amounts of greenhouse gases in the atmosphere absorbing the sun's energy and warming the environment. The Intergovernmental Panel on Climate Change (IPCC) provides evidence for this phenomenon in the latest IPCC report on global warming (IPCC I. P., Climate Change 2021: Physical Science Basis, 2021). Global temperatures are expected to rise by 2.7 degrees Celsius by the end of the century. The seven warmest years on record have all occurred in the last decade. The year 2020 is the second warmest year, with 2016 being the warmest.

Although the climate is always changing, the rate at which global warming is taking place is unprecedented. As temperatures are rising so are sea levels. Sea Level rise is a result of two phenomena, glacial ice melts and thermal expansion. Large land-based ice sheets and mountain glaciers are melting at alarming rates due to rising global temperatures. These permafrost areas store much of the Earth's water and carbon through carbon sequestration. As these ice sheets melt, they add to the ocean's volume by about 2 mm per year on average (NASA, 2023). Glacial ice sheets are a natural form of carbon sequestration, and as a result, release greenhouse gases into the atmosphere when they melt (Wadham, 2019). Another phenomenon contributing to sea level rise is thermal expansion. Thermal expansion is when water molecules expand due to a temperature rise. Higher temperatures result in a greater distance between water molecules as the cohesive forces holding them together expand. This thermal expansion contributes to an overall increase in global sea levels. Approximately 1/3 of the global sea level rise recorded since 2004 has been caused by thermal expansion (NASA, Understanding Sea Level - Thermal Expansion, 2023).

The rapid rise in global temperatures on such a large scale has resulted in a higher frequency and intensity of extreme weather events to occur. Severe storms such as thunderstorms, tornadoes, lightning strikes, and strong winds will all be exacerbated by climate change (UMCES 2021). This could result in increased risk and vulnerability to severe storm hazards for Baltimore City if mitigation actions and plans are not implemented. Incorporating climate change projections into Baltimore City's hazard planning process is critical to prepare and mitigate all future severe storm events.

7.7 Vulnerability Assessment

7.7.1 Impacts on Population

The entire population of Baltimore City is vulnerable to severe storm events. Risk and vulnerability are dependent upon the population density, critical infrastructure, and mitigation actions or plans already implemented within the community. The metropolitan areas of Baltimore are most vulnerable to severe storm events. Severe inundation, lightning strikes, strong winds, and more can severely impact the daily lives and overall safety of the people in the Baltimore metropolitan area.

Table 7-6 shows the total population of Baltimore City and each City Council District. There are 591,489 people who are exposed to severe storm hazards in Baltimore City. District 11 has the highest population with over 48 thousand vulnerable to severe storm hazards. Table 7-6 also breaks down the population into groups that may have a higher vulnerability due to economic and social factors, such as: Persons over the age of 65; those under the age of 5;

non-English speaking; and those with disabilities. These populations may have a higher overall vulnerability to severe storm events than the general population, refer to subsection 9.15.1.1 Impacts on Socially Vulnerable Populations and Underserved Communities for more information.

Table 7-6. Total Population for Baltimore City

City Council District	Total Population	Over 65 Years	Under 5 Years	Non-English Speaking	Disability
1	43,739	4,481	3,344	1,141	4,200
2	45,252	5,528	3,009	1,376	5,394
3	42,257	5,988	1,669	470	5,485
4	45,027	6,401	3,113	371	5,601
5	43,601	8,122	3,762	1,176	6,613
6	41,604	8,355	2,356	546	7,741
7	39,638	6,177	1,895	349	7,764
8	46,396	7,799	2,947	392	8,376
9	35,869	4,927	2,024	641	8,523
10	41,521	4,755	3,468	1,054	7,685
11	48,022	5,774	2,182	907	6,231
12	37,130	4,203	1,690	575	6,388
13	38,768	4,701	2,684	582	6,814
14	42,664	6,316	2,324	702	5,891
Baltimore City (Total)	**591,489**	**83,527**	**36,468**	**10,283**	**92,707**

Source: U.S. Census Bureau 2021, ACS
Note: Persons per household = 2.32. The number used to calculate the Non-English-Speaking population.

Impacts on Socially Vulnerable Populations and Underserved Communities

Socially vulnerable populations within Baltimore City have a higher vulnerability to severe storm events. Table 7-6 lists the total population for Baltimore City and highlights vulnerable groups such as those 65 and older, under the age of 5, non-English speaking, or those with disabilities. Safe evacuation, access to shelter, or necessary medical supplies are all factors that can be severely impacted by severe storms. In 2022, over 14% of Baltimore's population are persons 65 years or over (USCB 2022). This percentage of the population is highly vulnerable to severe storm impacts, which can be life-threatening. In addition to this, approximately 12% of Baltimore's population has medical conditions (USCB 2022). This population is highly vulnerable to severe storms as medical supplies and assistance can be limited or inaccessible during these hazard events.

Homelessness in Baltimore City is also a great concern, as these populations are significantly at risk of hazards due to their exposure and general lack of a structurally sound structure. The Point-in-Time (PIT) Count is a federally mandated survey conducted annually that seeks to determine how many people are experiencing homelessness on any given night in Baltimore City. In 2022, the PIT Count revealed a total of 1,597 people were counted in emergency shelters, transitional housing, and unsheltered spaces such as encampments. This is down from 2,193 people in 2020 and follows a four-year downward trend (Baltimore City 2022). The 2023 PIT occurred in January of 2023; however, the results have not yet been made public.

It is important for Baltimore City to incorporate socially vulnerable populations into their mitigation efforts, to lessen the overall risk to present and future severe storm hazards.

7.7.2 Impacts on Structures

General Building Stock

Severe storms, such as thunderstorms, derechos, and tornadoes, generally cause damage or even destruction to buildings throughout Baltimore City. For the purpose of this DP3 update, the general building stock was categorized into four major occupancy classes: residential (single and multi-family dwellings); commercial buildings; industrial buildings; government, religion, agricultural, and education buildings. There are a total of 211,044 residential dwellings located in Baltimore City, with a total replacement cost value of over $100 billion. For commercial buildings there are a total of 13,970 located in Baltimore City, with a total replacement cost value of over $209 billion; and for industrial buildings, there are a total of 746, with a total replacement cost value of over $7 billion. Severe storms have the potential to impact all building classes. With high replacement costs, Baltimore City can experience not only impacts on safety and well-being but also impacts on the overall economy after a severe storm event.

Critical Facilities

Critical facilities are those which have high significance to the daily lives, health, and well-being of those located within Baltimore City. These facilities are critical for maintaining a safe environment. The lack of access to or function of these critical facilities can have the potential to result in loss of life during and after hazard events. Examples of critical facilities can include medical facilities; police stations; fire stations; schools; and emergency operation centers. Severe storm impacts from thunderstorms, derechos, tornadoes, and more can result in damage to these facilities resulting in the inability to perform and provide help to people during and after a hazard event.

According to Hazus data, there are 2,598 critical facilities within Baltimore City. District 11 has the most critical facilities, at a total of 353; while district 8 has the least number of critical facilities, at 114. These critical facilities for Baltimore City are vital to the response and recovery after a severe storm hazard event. Damage and destruction can impede their ability to provide support and increase the overall risk the community faces to severe storm events.

Critical Infrastructure

Damage to critical infrastructure is both dangerous and costly. Severe storms have the potential to damage or even cause total destruction to many of Baltimore City's critical infrastructure. Some critical infrastructure could include residential structures, commercial structures, stormwater systems, and other structures that are vital to the health of the community.

Community Lifelines

Community lifelines can be identified as any structure which is critical to the safety of the people within Baltimore City during and after a hazard event. This could include transportation measures such as major highways, ports, and railways; it could also include communication systems such as phone towers, satellites, radios, and mass notification systems. When a community lifeline is down, the risk of a hazard event is increased. Severe storm impacts have the potential to damage or interrupt a community lifeline from functioning properly and increase Baltimore City's overall risk of the hazard during and after an event. According to Hazus data, there were 2,042 identified FEMA-designated lifelines within Baltimore City. These included mostly highway bridges and light rail stations, which provide critical transportation and evacuation during and after a severe storm event. These 99 lifelines are vulnerable to severe storm impacts, and if damaged can impede evacuation or supplies to affected areas, further delaying response and recovery activities after the hazard event.

7.7.3 Impacts on the Economy

Severe storm events have significant economic impacts by resulting in substantial damage costs to buildings and structures, and interruption to daily business activity. According to Hazus data, there are 227,856 buildings total located in Baltimore City, with a total replacement cost value of over $193 billion. Severe storm events which can cause mass destruction in a short period, such as tornadoes or flash flooding, perhaps have the highest risk to the economy. More buildings and structures which are damaged or destroyed result in more total replacement costs for the community and City. As well, these impacts lower economic activity causing less available funds for restoration and replacement in the aftermath of severe storm events.

7.7.4 Impacts on Natural, Historic, and Cultural Resources

Severe storms can impact the environment because they can cause flash flooding, damaging winds, and destructive hailstorms. Flash flooding negatively impacts the environment as it can cause pollutants to enter the nearby waterbodies and damage critical habitats. Severe storms which result in tornadoes can cause mass destruction of Baltimore City's historical infrastructure. Many of the historical buildings and homes are not built to withstand such high winds, and are more vulnerable than other infrastructure, to severe storm hazards. Additionally, lighting strikes, which result from severe storm hazards can cause fires that damage habitat and natural resources. Baltimore City is susceptible to lightning strikes and hailstorms which can cause further physical damage to already vulnerable infrastructure.

Tree canopy is also affected by severe storm events through high winds during events such as thunderstorms, tornadoes, and derechos. The downing of trees due to high winds may limit the shaded area available in Baltimore City, further exacerbating other hazards such as extreme temperature (refer to section 9).

Due to the developed nature of Baltimore City, all historic and cultural resources are susceptible to impacts from severe storms. These resources may be impacted in the same manner as the general building stock and critical facilities.

7.7.5 Cascading and Compounding Impacts

Severe storm events have the potential to occur simultaneously and/or cause the occurrence of each other. For example, a thunderstorm event can cause tornado hazards to occur within the impact area. Flooding can also be seen due to the severity of precipitation. Refer to Section 3 (Flooding), for more information on flood hazards within Baltimore City.

Since severe storm events do not stay within jurisdictional boundaries, and often evolve into other systems, hazards in other states have the potential to impact the state of Maryland as well. Many winter storm events are large in scale and can affect an entire region, causing other impacts such as extreme temperatures and precipitation. Refer to Section 9 (Extreme Temperature), for more temperature-related hazard events.

7.7.6 Future Changes that May Impact Vulnerability

It is important to understand future projections that may impact Baltimore City's overall vulnerability to severe storms. This understanding could benefit the future development planning efforts within Baltimore City and ensure that sound mitigation and preparedness measures are in place.

Changes in Land Use and Development

All land use and development areas within Baltimore City are at risk of severe storm events. Updates to building codes and regulations may help to lessen the risk to development. As well, new development and land use practices should consider incorporating response action plans or integrative technology into their plans to lessen impacts from extreme severe storm events like tornadoes.

The continuation of high-rise building development in urban areas may increase the vulnerability to such hazards. Potential new development and subsequent increases in impervious surfaces may exacerbate flooding and ponding from severe storms.

Changes in Population

Baltimore has experienced a decrease in its population since 2010. According to the U.S. Census Bureau, Baltimore City's population decreased by approximately 4.75 percent between 2010 and 2021 (U.S. Census 2021). Estimated population projections provided by the Maryland Department of Planning indicate that Baltimore City's population will begin to increase going into 2030, reaching a total population of approximately 596,390 persons, and continue to increase into 2040 to a population of 599,220 (Maryland Department of Planning 2020).

Any increase in population increases Baltimore City's overall risk of severe storm events. Careful planning and mitigation actions, such as warning systems and safety shelters, can benefit the growing population and lower the overall vulnerability Baltimore City has to severe storms.

7.7.7 Change in Vulnerability Since 2018 DP3

Baltimore City continues to be vulnerable to severe storm hazards. Updated population and building stock statistics were used in the current risk assessment. Further, exposure for both the population and critical facilities was analyzed. These updated datasets provide a more accurate exposure analysis for the hazard.

Section 8. Drought

Key changes reflected in the 2023 DP3 update:

- The hazard description, including location, extent, previous occurrences and losses, and future probability, has been updated.
- Information has been added about the potential impacts of climate change on the drought hazard.
- The 2018 DP3 did not include a vulnerability assessment for the drought hazard; the 2023 DP3 update includes a vulnerability assessment combined with the hazard description. The vulnerability assessment addresses the impacts to population, structures, and natural/historic/cultural resources.
- Information has been added about integration of cascading and compounding impacts.
- Information has been added about future changes that may impact vulnerability.

8.1 Description

Droughts affect Baltimore City's industries and make day-to-day tasks more difficult to complete because water usage has to be monitored.

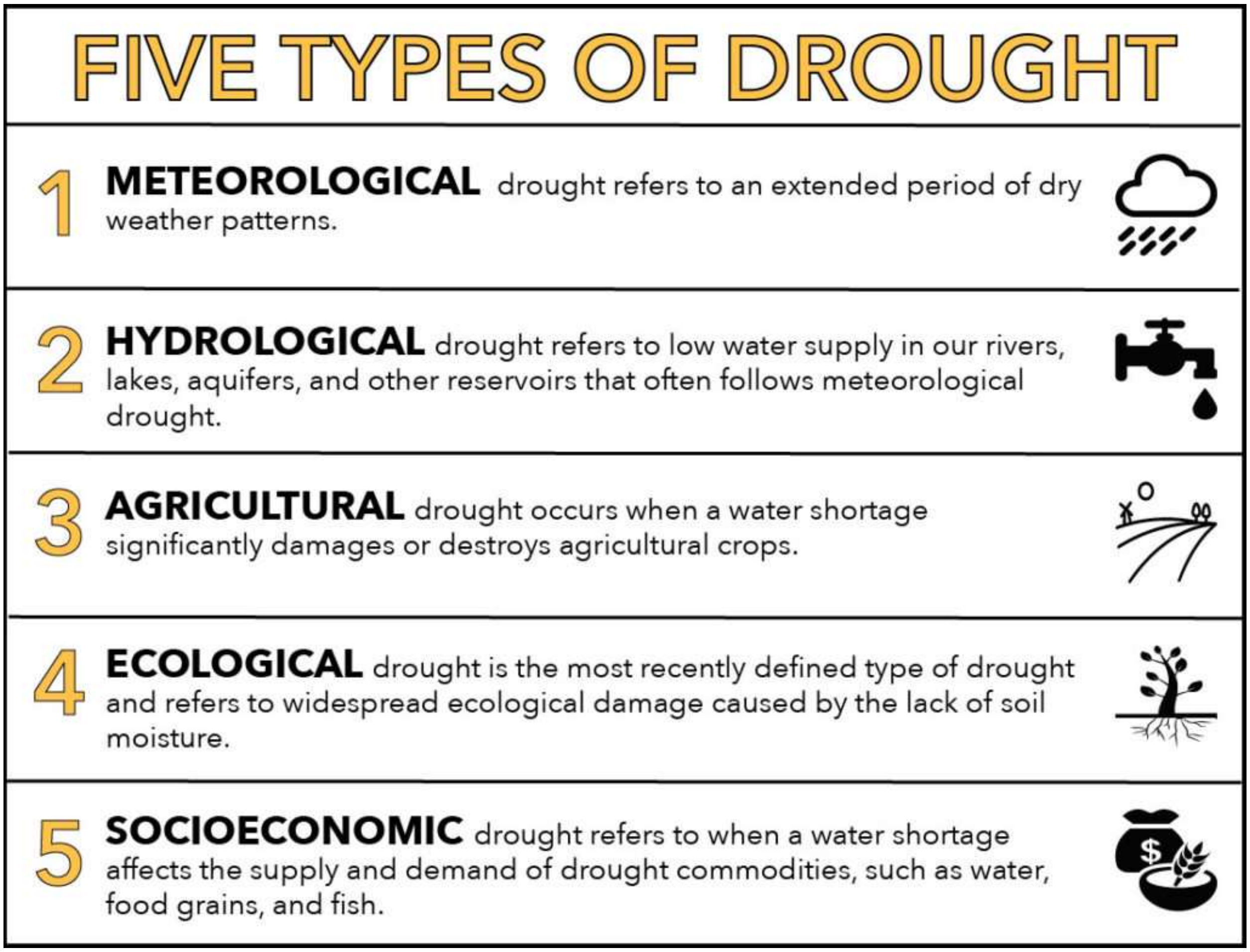
Key Terms

- Drought—A deficiency of precipitation over an extended period of time resulting in a water shortage (U.S. Drought Monitor 2023).

Drought is defined as a period of prolonged dryness. It is normal for Baltimore City to experience wet winter and spring seasons and drier summers. This fluctuation allows for reservoirs to fill and act as natural resources for water during the drier periods. When experiencing drought, Baltimore City's reservoirs may not retain enough water, causing a depletion in the total water supply available and limiting the public water supply for human consumption. The *Baltimore City Climate Action Plan* states that Baltimore City experienced the lowest levels in groundwater and stream flows during the year 2002 to 2003. Subsequently, water use restrictions were put in place to help restore the water supply back to normal (City of Baltimore Office of Sustainability 2012).

The National Weather Service (NWS) has defined four types of droughts: meteorological drought, hydrological drought, agricultural drought, and socioeconomic drought. These types of droughts are further discussed in Figure 8-1.

Figure 8-1. Five Types of Drought



Source: Living with Drought 2023

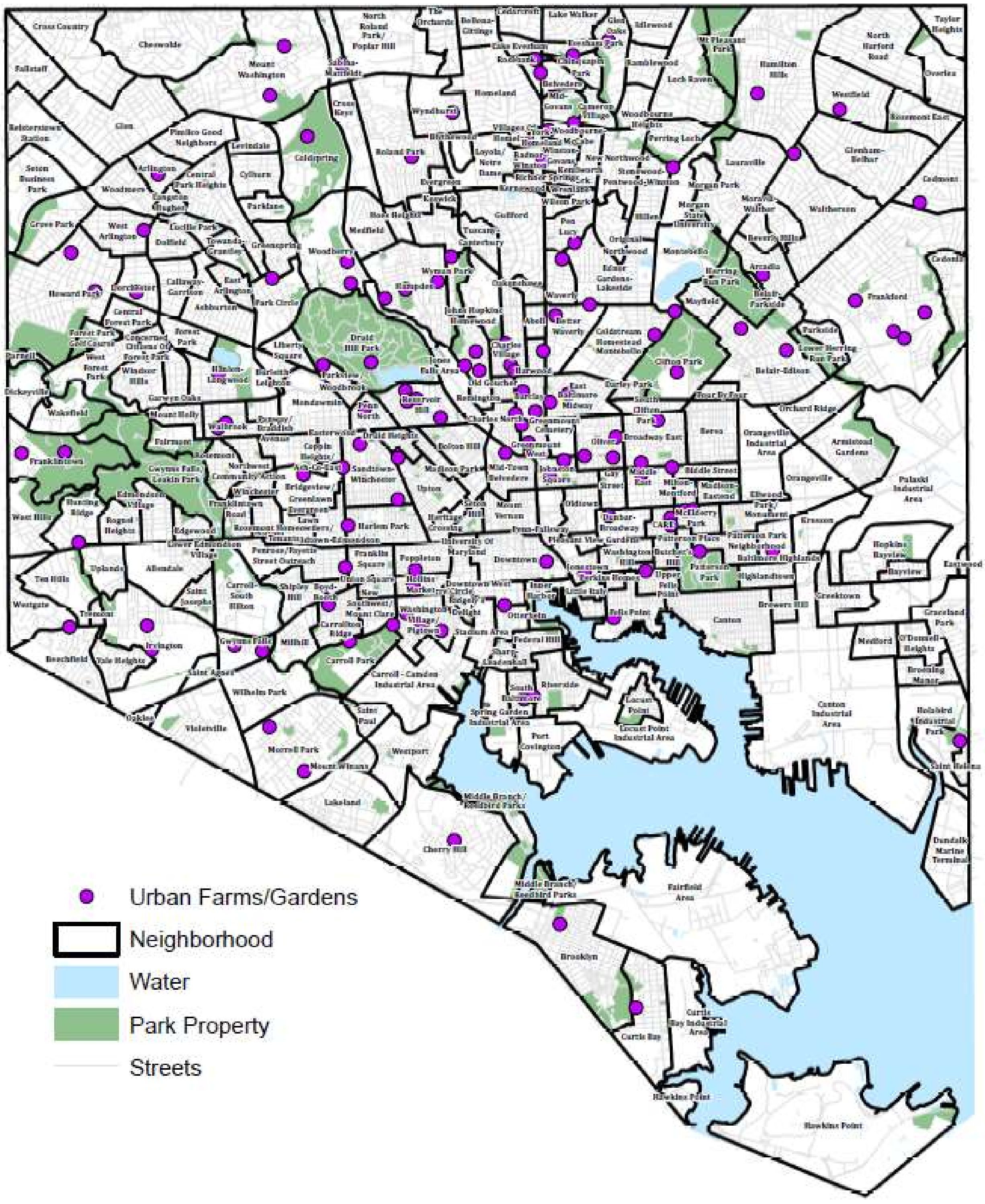
8.2 Location

Droughts occur on a regional scale; therefore, all areas within Baltimore City have equal risk of exposure to this hazard. The likelihood of drought occurring in Baltimore City is dependent upon the climatic and atmospheric conditions of the region.

8.2.1 Agriculture

When a drought occurs, the agricultural industry is most at risk in terms of economic impact and damage. For Baltimore City, this means urban agriculture operations could be severely impacted. According to the Baltimore City Department of Planning, there are approximately 120 food-producing community gardens and urban farms in Baltimore City, totaling approximately 32 acres (Baltimore Office of Sustainability 2019). Baltimore City was able to serve more than 5 million breakfasts and more than 10.5 million lunches to kids attending public school with the help from these community and urban gardens and farms (Baltimore Office of Sustainability 2019). Figure 8-2 depicts the location of urban farms and gardens across Baltimore City.

Figure 8-2. Urban Farms and Gardens in Baltimore City



Source: Baltimore Office of Sustainability 2019

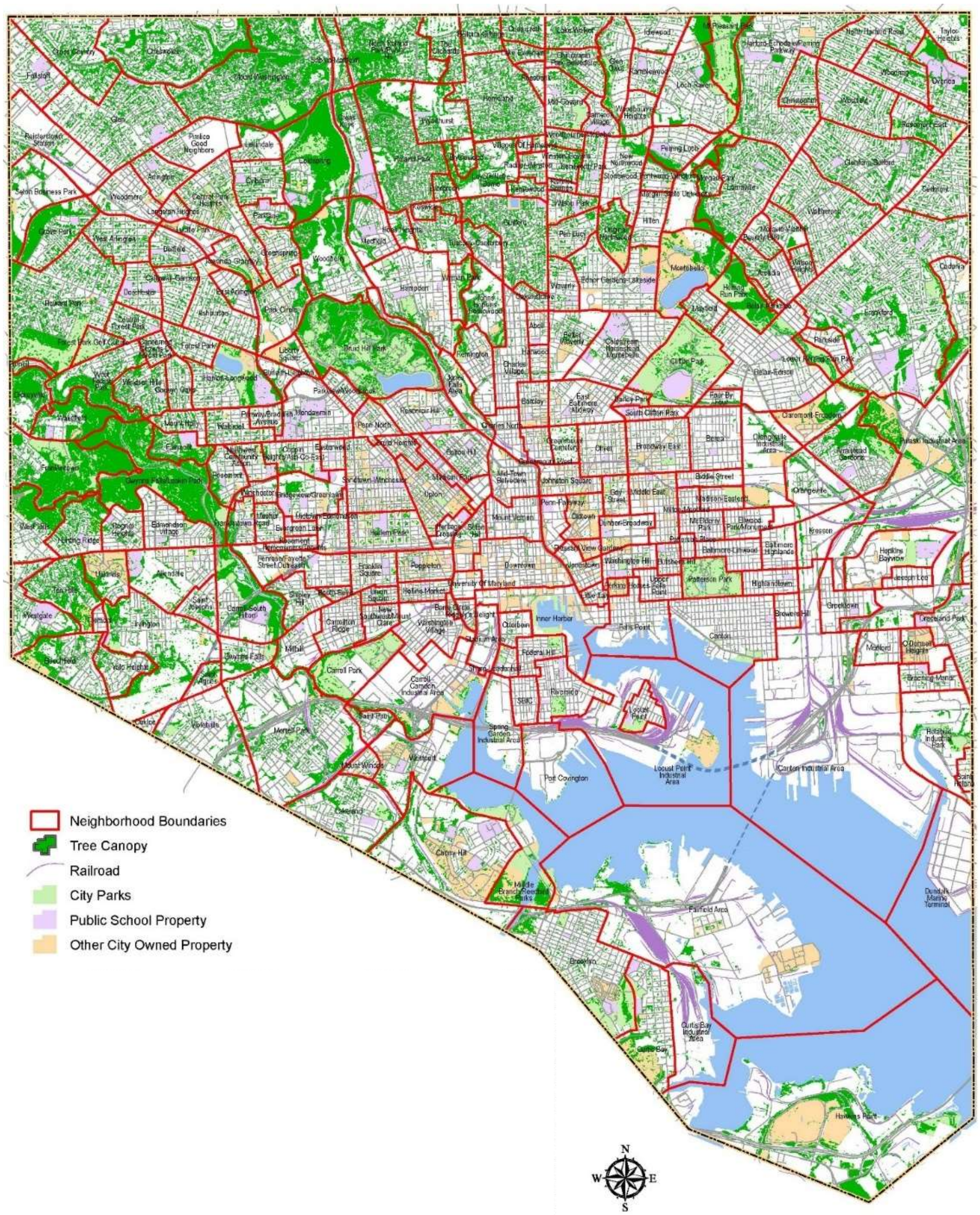
8.2.2 Tree Canopy

Tree canopy refers to the part of Baltimore City that is shaded by trees. In 2017, the Maryland Department of Natural Resources and the U.S. Forest Service measured Baltimore City's existing tree canopy at 27.4 percent. Trees provide clean air, reduce rainwater runoff and erosion, temper climate, and reduce air temperatures (Baltimore City Department of Recreation & Parks 2023). Tree canopy in Baltimore City can be affected by drought in varying degrees depending on the severity of the event. The most obvious issue is the fast dieback and degradation of the crowns of the trees, which can lead to scattered dead foliage along City sidewalks and pathways. Longer droughts can stunt the growth of plants and trees, which may inhibit them from growing tall enough to provide shaded areas within Baltimore City. Degrading tree canopy also impacts species that rely on these trees for shade and shelter, which affects the overall biodiversity of parks located in Baltimore City (Salle, et al. 2021). Figure 8-3 illustrates the tree canopy in Baltimore City.

Grow Center tree giveaway

Image provided by BoS

Figure 8-3. Baltimore Neighborhood Tree Canopy



Source: Baltimore City Department of Recreation & Parks 2023

8.2.3 Urban Heat Island

Heat islands are urbanized areas that experience higher temperatures than outlying areas. Structures such as buildings, roads, and other infrastructure absorb and re-emit the sun's heat more than natural landscapes (i.e., forests and waterbodies). Urban areas, where these structures are highly concentrated and greenery is limited, become "islands" of higher temperatures relative to outlying areas. Daytime temperatures in urban areas are about 1–7°F higher than temperatures in outlying areas, and nighttime temperatures are about 2-5°F higher (U.S. EPA 2023). Trees and vegetation help reduce temperatures in urbanized areas. Drought conditions increase tree mortality, leading to more heat islands in Baltimore City.

8.2.4 Surface Water

In addition to urban agriculture and tree canopy, surface water supplies are susceptible to severe impacts from drought. Baltimore City DPW stores potable water in three surface reservoirs: Prettyboy, Lock Raven, and Liberty. These reservoirs house 86 billion gallons of potable water to supply 1.8 million people living in Baltimore City and Anne Arundel, Baltimore, Carroll, and Howard Counties (Baltimore City Department of Public Works n.d.). Reservoirs are continuously monitored, and the Maryland Department of the Environment (MDE) performs monthly monitoring of precipitation, stream flow, groundwater levels, and reservoir storage. At full capacity, the three City reservoirs can provide potable water for approximately 350 days (Maryland Department of the Environment 2021). Drought can result in a loss of water supply as demand increases but precipitation to fill the reservoirs decreases. Figure 8-4 depicts the three reservoirs along with watersheds located in Baltimore City.

8.3 Extent

The State of Maryland has an average rainfall of 43.6 inches. Droughts vary in degrees of severity; however, there are indicators to look for when monitoring a potential drought. During the Drought of 2002, smaller streams dried up, which dried out both aquatic and terrestrial flora and fauna and increased levels of salinity in the Chesapeake Bay. This led to increased invasive species interference, and some native species died out.

The severity of a drought depends on the degree of moisture deficiency, the duration, and the size and location of the affected area. The longer the drought and the larger the area impacted, the more severe the potential impacts (NOAA 2022). The U.S. Drought Monitor and the Palmer Drought Severity Index are used to determine areas of drought and the potential impacts. Additionally, the Maryland Department of the Environment performs monthly evaluations of hydrologic indicators to determine drought conditions.

8.3.1 U.S. Drought Monitor

The U.S. Drought Monitor (USDM) within the National Drought Mitigation Center uses six classifications for drought: normal conditions, abnormally dry (D0), moderate drought (D1), severe drought (D2), extreme drought (D3), and exceptional drought (D4) (USDM 2023). Moderate and severe droughts have short-term impacts, typically last less than six months, and primarily affect agriculture and grasslands. Extreme and exceptional droughts have longer-term impacts, typically last longer than six months, and start to affect hydrology and ecology.

Figure 8-4. Baltimore Region Reservoirs

Source: Baltimore County Government 2023

During a Drought Watch, the State of Maryland notifies municipal and county governments of the Drought Watch status, continues to evaluate the drought biweekly, and activates the Water Conservation Plan. The Drought Watch aims for a 5–10 percent water reduction goal.

During a Drought Warning, the State of Maryland notifies municipal and county governments of the Drought Warning status and activates conservation measures. The Drought Warning aims for a 10–15 percent water reduction goal.

Table 8-1 provides examples of observed drought impacts and how they relate to the USDM.

Table 8-1. Examples of Observed Drought Impacts for Maryland

Drought Impacts	
Abnormally Dry: D0	Crop growth is stunted; planting is delayed
	Fire danger is elevated; spring fire season starts early
	Lawns brown early; gardens begin to wilt
	Surface water levels decline
Moderate: D1	Honey production declines
	Irrigation use increases; hay and grain yields are lower than normal
	Trees and landscaping are stressed; fish are stressed
	Voluntary water conservation is requested; reservoir and lake levels are below normal capacity
	Wildfires and ground fires increase
Severe: D2	Fish kills occur; wildlife move to farms for food
	Golf courses conserve water
	Producers begin feeding cattle; hay prices are high
	Specialty crops are impacted in both yield and fruit size
	Trees are brittle and susceptible to insects
	Warnings are issued on outdoor burns; air quality is poor
	Water quality is poor; groundwater is declining; irrigation ponds are dry; outdoor water restrictions are implemented
Extreme: D3	Crop loss is widespread; Christmas tree farms are stressed; dairy farmers are struggling financially
	Extremely reduced flow to ceased flow of water is observed; river temperatures are warm; wells are running dry; people are digging more and deeper wells
	Water recreation and hunting are modified; wildlife disease outbreak is observed
	Well drillers and bulk water haulers see increased business
Exceptional: D4	Maryland has experienced little exceptional (D4) drought since the inception of the U.S. Drought Monitor, so no D4-level drought impacts are recorded in the Drought Impact Reporter

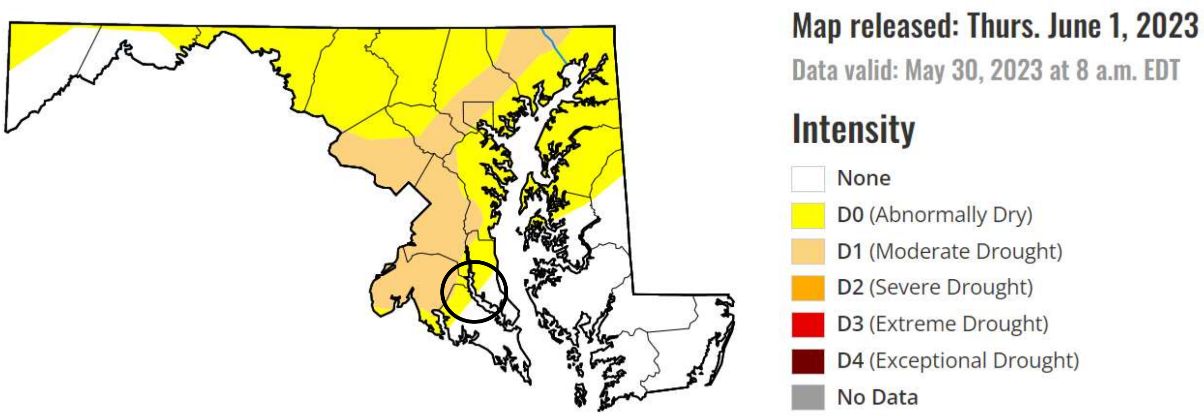
Source: USDM 2023

Figure 8-5 illustrates the levels of drought within the State of Maryland on May 30, 2023. Baltimore City is highlighted light orange, indicating that as of May 30, 2023, Baltimore City was classified to be in a moderate drought.

8.3.2 Palmer Drought Severity Index

Drought is also monitored through the Palmer Drought Severity Index (PDSI). According to the National Integrated Drought Information System (NIDIS), the PDSI was developed in 1965 and indicates prolonged and abnormal moisture deficiency or excess. It uses temperature and precipitation data to calculate water supply and demand, incorporates soil moisture, and is considered most effective for assessing moisture conditions in unirrigated cropland. The PDSI primarily indicates long-term drought and has been used extensively as a signal to initiate drought relief (NIDIS 2015). Refer to Table 8-2 for the PDSI classifications.

Figure 8-5. Maryland Drought Monitor



Source: US Drought Monitor 2023
Note: The black circle indicates the rough location of Baltimore City.

Table 8-2. PDSI Classifications

Palmer Classifications	
4.0 or more	Extremely wet
3.0 to 3.99	Very wet
2.0 to 2.99	Moderately wet
1.0 to 1.99	Slightly wet
0.5 to 0.99	Incipient wet spell
0.49 to -0.49	Near normal
-0.5 to -0.99	Incipient dry spell
-1.0 to -1.99	Mild drought
-2.0 to -2.99	Moderate drought
-3.0 to -3.99	Severe drought
-4.0 or less	Extreme drought

Source: NDMC 2023

8.3.3 State of Maryland Drought Evaluations

In Maryland, drought conditions are evaluated on a regional basis using hydrologic indicators, including precipitation, stream flow, groundwater levels, and reservoir storage. The State also looks at the condition of water supplies, status of utilities, temperature, season of year, and other relevant factors. Conditions of each are rated as Normal, Watch, Warning, or Emergency. Maryland determines a drought condition by notifying municipal and county governments and continuing to evaluate drought status on a biweekly basis. A drought watch aims to reduce water usage by 5–10 percent, and a drought warning aims to reduce water usage by 10–15 percent (Maryland Department of the Environment 2023).

8.4 Previous Occurrences and Losses

Many sources provided historical information regarding previous occurrences and losses associated with drought throughout Baltimore City.

8.4.1 FEMA Major Disaster and Emergency Declarations

Between 1953 and 2023, Baltimore City was not included in any drought-related major disaster declaration (DR) or emergency declaration (EM) (FEMA 2023).

8.4.2 Previous Events

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 (City of Baltimore 2018). Table 8-3 lists drought events that impacted Baltimore City between 1950 and 2023. Figure 8-6 shows the news article documenting the first statewide emergency declaration for drought.

Figure 8-6. Statewide Drought Emergency Announcement

Drought is emergency; conserve, governor says

7-30-99

DOUG KAPUSTIN : SUN STAFF

Waterline recedes: *A man fishes in Liberty Reservoir, where lack of rain has lowered the water level 24 feet. Gov. Parris N. Glendening said a statewide response is needed.*

Rain shortfall among worst in state history; restrictions imminent

By GREG GARLAND
SUN STAFF

Gov. Parris N. Glendening declared a statewide drought emergency yesterday — the first in Maryland history — and said mandatory water conservation measures "almost certainly" will be imposed as early as next week.

In the meantime, he called on Marylanders to voluntarily conserve water and said the state will provide $3 million to help farmers while also seeking federal aid.

Glendening made the announcements while standing on the banks of Liberty Reservoir, which is down 24 feet and now holds less than half its capacity of 43 billion gallons of water.

The reservoir along the Carroll-Baltimore County line is one of three that supply water to 1.8 million people in the Baltimore area.

"We are in one of the worst droughts Maryland has ever experienced," Glendening said, adding that the problem demanded a statewide response.

"In the past, we have left this up to individual communities," he said. "But with water supplies very seriously stressed across the state, and with forecasters predicting only minimal relief, it is vital that we take a coordinated,

[*See Drought, 4A*]

Source: Baltimore Sun 1999

Table 8-3. Drought Events in Baltimore City, 1950–2023

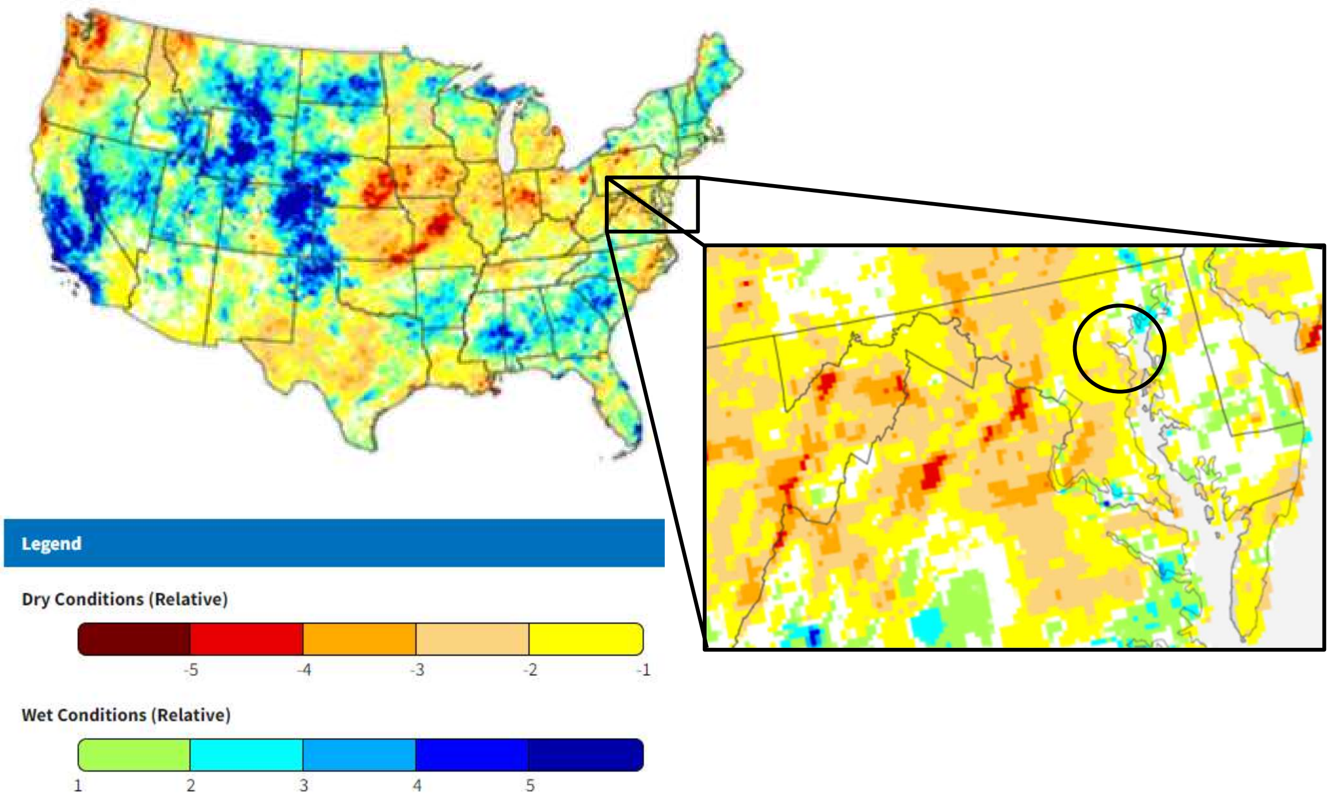
Date(s) of Event	Event Type	FEMA Declaration Number (if applicable)	Baltimore City included in declaration?	Location Impacted	Description
July 1-December 31, 1998	Drought	N/A	N/A	Citywide	The 6-month precipitation total at BWI Airport was only 7.06 inches, 13.66 inches below normal. Water reserves were greatly affected by the persistent drought. The Liberty Reservoir that serves Baltimore City was down 24 feet and only at half of its capacity. Stream flows on rivers within the Potomac and Shenandoah River basins were 85 percent below normal. More than 2,000 households and businesses were forced to receive water from a temporary pipeline linked to the Frostburg flow. Crop damage was reported and totaled around $1.67 million.
September 1998-August 1999	Drought	N/A	N/A	Citywide	From September 1998 through August 1999, precipitation was a staggering 12–16 inches below average. During the first week of August, the USGS reported ground water levels in Central Maryland were 16 feet below the surface, just under the minimum level. The drought cost Maryland farmers over $75 million. Baltimore City reported losing over 300 street trees due to the drought.
April 5-May 5, 2002	Drought	N/A	N/A	Citywide	Maryland Governor issues an executive order declaring a drought emergency and imposing Level 1 mandatory restrictions for all areas except for Baltimore City service area. All state residents were asked to reduce water use by 10 percent.
October 1-31, 2007	Drought	N/A	N/A	Citywide	Rainfall deficits totaled nearly 10 inches making water restrictions become mandated throughout the month.
September 23-October 23, 2010	Drought	N/A	N/A	Citywide	Jellyfish were documented moving into the Inner Harbor due to drought raising the salinity of the water because there was less water flowing in from freshwater rivers.
August 13-September 12, 2012	Drought	N/A	N/A	Citywide	The size of the dead zone in the Chesapeake Bay decreased from 30 percent to 12 percent in August because there was less runoff from precipitation to encourage the growth of algal blooms.

Source: FEMA 2023; NCEI 2023; National Drought Mitigation Center 2023
Note: With so many sources reviewed for this plan update, loss and impact information for many events could vary. Therefore, the accuracy of monetary figures discussed is based only on the available information in cited sources in relation to Baltimore City specifically.

8.5 Probability of Future Hazard Events

The frequency of droughts is difficult to forecast as drought occurrences are cyclical in nature and will occur in the future. Based on national annual data from 1980 to present, Baltimore City has minor dry soil conditions (illustrated in Figure 8-7).

Figure 8-7. U.S. Gridded Palmer Drought Severity Index (PDSI) (1980–2023)



Source: NIDIS 2023

Based on historic and more recent events, it is likely that drought events will occur in Baltimore City in the future. Climate projections indicate air temperature will continue to rise. As temperatures increase in the future, the probability of future droughts will most likely increase as well (see Section 8.6). Therefore, it is likely that droughts of varied severity will occur in the State and Baltimore City in the future. It is estimated that Baltimore City will continue to experience direct and indirect impacts of drought and its impacts on occasion, with the secondary effects causing potential disruption or damage to agricultural activities and creating shortages in water supply within communities. Table 8-4 shows the probability of future occurrences in Baltimore City.

Table 8-4. Future Occurrence of Drought Events in Baltimore City

Hazard Type	Number of Occurrences Between 1950 and 2022	% Chance of Occurrence in Any Given Year
Drought	6	12.17

Source: NCEI 2023
Note: Disaster occurrences include federally declared disasters since the 1950 Federal Disaster Relief Act, and selected events since 1968. Due to limitations in data, not all drought events occurring between 1953 and 1996 are accounted for in the tally of occurrences. As a result, the number of hazard occurrences is underestimated.

In Section 3.0, the identified hazards of concern for Baltimore City are ranked (Table 3-5). The probability of occurrence, or likelihood of the event, is one parameter used for hazard rankings. Based on historical records and input from the CPT, HMAC, and community members, the probability of drought occurring in Baltimore City is considered “occasional.”

8.6 Potential Impacts of Climate Change

Climate is determined not only by average temperature and precipitation but also by the type, frequency, and intensity of weather events. Temperatures in the northeast rose by nearly 2°F between 1895 and 2011, and some models show the region experiencing a warming of 4.5–10°F by the 2080s, assuming conditions stay as trending. Both globally and at the local scale, climate change has the potential to alter the prevalence and severity of extremes such as droughts. While predicting changes of drought events under a changing climate is difficult, understanding vulnerabilities to potential changes is a critical part of estimating future climate change impacts on human health, society, and the environment (EPA 2016). Longer warm seasons also affect plant health and productivity, which will greatly impact Baltimore City’s urban farming initiatives. With warmer overall weather, risks of pests such as ticks, deer, and mice increase due to a longer reproduction season, which leads to an increased risk of Lyme disease (University of Maryland 2023).

With a warmer climate, droughts can become more frequent, more severe, and longer lasting. According to the National Climate Assessment, variable precipitation and rising temperatures are intensifying droughts, increasing heavy downpours, reducing snowpack, and causing declines in surface water quality. Future warming will add to the stress on water supplies and impact the availability of water supply (USGCRP 2018). Additionally, Maryland experiences increased downpours and intense rainfall spurts, which causes tremendous soil erosion and flooding. Due to the speed and rate at which the precipitation falls, the soil is unable to absorb as much water as it would with a gradual precipitation event, making droughts able to happen at a faster rate (University of Maryland 2023).

Average precipitation is likely to increase during the winter and spring months but not change significantly during the summer and fall months. Rising temperatures will melt snow earlier in spring and increase evaporation, and thereby dry the soil during the summer and fall. In July 2008, the University of Maryland’s Center for Environmental Science projected an additional 2° F of warming by 2025 for the entire State. If emissions are reduced by 2050, there is the possibility of a 4.8° F increase in the summer. If emissions are not reduced, the State of Maryland could see a temperature increase of nearly 9° F by the year 2100 (University of Maryland Center for Environmental Science 2008). Currently, projections are following the high emission scenario. As a result, the changing climate is likely to intensify flooding during the winter and spring and drought during the summer and fall.

Saltwater intrusion is another concern farther inland or upstream in bays, rivers, and wetlands due to lack of freshwater runoff. Saltwater can further intrude into aquifers near the coast, which may impact soils and growing areas and infiltrate personal human-used freshwater sources, intensifying droughts' effects (EPA 2017).

In general, the tourism industry of Baltimore City is threatened due to the economy being partially based around the Inner Harbor. Sea level rise and degradation of water and air quality will impact tourism that is focused on water-based activities that the harbor currently offers (U.S. Climate Resilience Toolkit 2022).

8.7 Vulnerability Assessment

To understand risk, a community must evaluate what assets are exposed or vulnerable in the hazard area identified. The entire City has been identified as exposed to the drought hazard. Therefore, all assets in Baltimore City (population, structures, critical facilities, and lifelines), as described in Section 3 (Risk Assessment), are exposed and potentially vulnerable.

8.7.1 Impacts on Population

The entire population of Baltimore City (591,489 people) is vulnerable to drought events. Drought conditions can affect people's health and safety, including health problems related to low water flows and poor water quality and health problems related to dust. Droughts also can lead to loss of human life (NDMC 2013). Other possible impacts on health from drought include effects on air quality; diminished living conditions related to energy, air quality, and sanitation and hygiene; compromised food and nutrition; and increased incidence of illness and disease. Health implications of drought are numerous and can include readily available access to drinking water (CDC 2012).

Impacts on Socially Vulnerable Populations and Underserved Communities

Social vulnerability is defined as the susceptibility of social groups to the adverse impacts of natural hazards, including disproportionate death, injury, loss, or disruption of livelihood. Social vulnerability considers the social, economic, demographic, and housing characteristics of a community that influence its ability to prepare for, respond to, cope with, recover from, and adapt to environmental hazards. According to FEMA's National Risk Index, socially vulnerable populations in Baltimore City have a very high susceptibility to the adverse impacts of natural hazards when compared to the rest of the United States (FEMA n.d.).

Socially vulnerable populations are most susceptible to drought events based on several factors, including their physical and financial ability to react or respond during a drought. Vulnerable populations include:

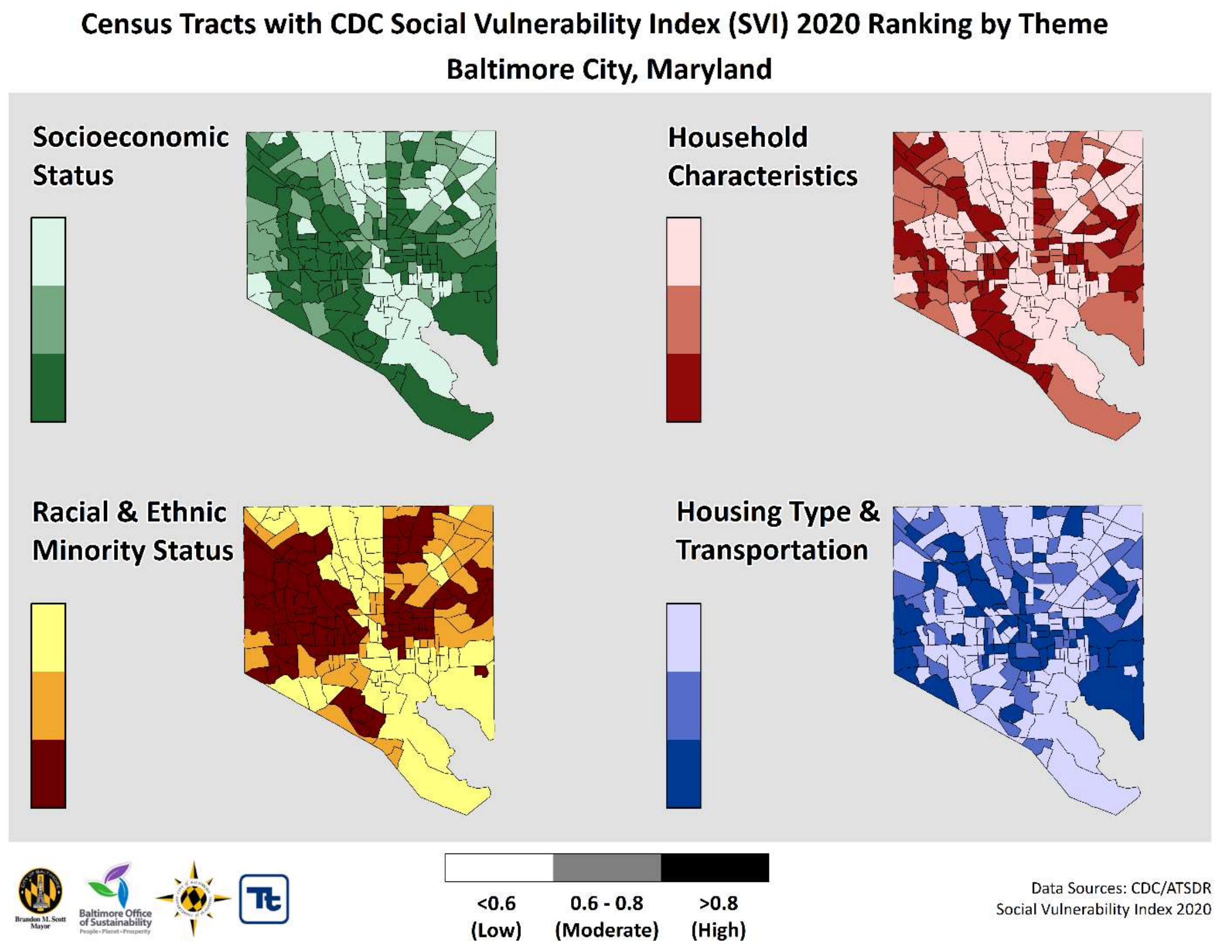
- Individuals experiencing homelessness,
- Older adults (over 65 years old),
- Economically disadvantaged,
- People who are linguistically isolated or have limited English proficiency,
- People with life-threatening illnesses, and

- People who have limited access to water in non-drought conditions.

According to the 2021 American Community Survey, there are roughly 84,000 persons over age 65 (14.1 percent of the total population); approximately 36,000 persons (6.2-percent of the total population) under the age of 5; just over 10,000 persons (1.7-percent of the total population) which do not speak English; an estimated 93,000 persons (15.7-percent of the total population) who have a disability; and about 116,000 persons (19.5-percent of the total population) living at or below the poverty level. Socially vulnerable populations may require extra water supplies or need assistance to obtain water and are more likely to seek or need medical attention. Additionally, economically disadvantaged individuals and individuals experiencing homelessness may not have access to a safe water source.

Figure 8-8 shows the CDC SVI for census tracts in Baltimore City. The figure shows the four themes of the CDC's SVI, with darked census tracts representing geographic areas of higher social vulnerability where individuals may face increased vulnerabilities from droughts.

Figure 8-8. CDC Social Vulnerability Index by Census Tract



Source: CDC/ATSDR 2020

8.7.2 Impacts on Structures

General Building Stock

A drought event is not expected to directly affect any structures. However, risk to structures may increase during droughts as fire-fighting capabilities may be diminished due to limited water supply for fire suppression.

Critical Facilities, Infrastructure, and Community Lifelines

All critical facilities and infrastructure and community lifelines in Baltimore City are exposed to the drought hazard. Critical facilities will experience similar issues as described above for general building stock. Water supply facilities may be affected by short supplies of water. It is essential that community lifelines remain operational during extreme temperature events so that the lifelines may address any issues affecting health, safety, and economic security. As mentioned, drought events generally do not impact buildings; however, droughts can impact critical facilities associated with potable water supplies.

8.7.3 Impacts on the Economy

Droughts impact the economy of an area in many ways. Baltimore City's urban agriculture program may experience decreased crop yield, thereby impacting the earnings of the farmers and driving up the cost of produce for consumers. Low water levels will affect any industry powered by hydroelectric power due to decreased production. The Inner Harbor is a lynchpin of the tourism industry in Baltimore City; the area would experience significant challenges due to a reduced number of tourists.

Droughts also can spur additional brushfires due to the dry environmental conditions, which can devastate large areas depending on how large the fire becomes (NOAA 2016). An increase in brushfires, and fires in general, in Baltimore City may cause a strain on Baltimore City's Fire Department. An increased number of responses would also impact the health and integrity of the Fire Department's staff and equipment, potentially costing Baltimore City and its taxpayers extra money.

8.7.4 Impacts on Natural, Historic, and Cultural Resources

Droughts can impact the environment because they can trigger wildfires, increase insect infestations, and exacerbate the spread of disease in animals and humans (NOAA 2000). Droughts will also impact water resources that are relied upon by aquatic and terrestrial species. Ecologically sensitive areas, such as wetlands, can be particularly vulnerable to drought periods because they are dependent on a relatively consistent water level and soil moisture availability to sustain growth. As a result, these types of habitats can be negatively impacted after long periods of drought. Additionally, tree canopy is affected by drought conditions because it leads to tree branch and foliage death that limits shade area available to City residents.

Droughts also have the potential to lead to water pollution. Rainwater typically dilutes pollutants in water sources, but in a drought, those pollutants become concentrated due to the lack of rainwater to dilute any pollutants in water sources. Contaminated water supplies may be harmful to plants and animals. If water is not getting into the soil, the ground may become unstable (CDC 2022).

Although droughts do not pose significant threats to historic buildings, this hazard may pose a threat to historic and cultural landscapes as described above.

Due to the developed nature of Baltimore City, all historic and cultural resources are susceptible to impacts from drought. These resources may be impacted in the same manner as the general building stock and critical facilities.

8.7.5 Cascading and Compounding Impacts

Drought increases conditions that may trigger fires in Baltimore City, such as dead and dying trees, and grasses. Drought can lead to increasing temperatures and evaporation of moisture, which are ideal dry conditions for wildfire events to occur. Dry, hot, and windy weather combined with dry vegetation makes some areas more susceptible to sparking wildfires when met with a spark created by humans or natural events, including lightning (National Integrated Drought Information System 2020). Additionally, droughts can lead to the following:

- Long-term damage to crop quality and crop losses,
- Insect infestation leading to crop losses and reduced tree canopy, and
- Reduction in the ability to perform outdoor activities, which could result in loss of tourism and recreation opportunities.

8.7.6 Future Changes that May Impact Vulnerability

Understanding future changes that impact vulnerability in Baltimore City can assist in planning for future development and ensuring that appropriate mitigation, planning, and preparedness measures are in place. Baltimore City considered the following factors to examine potential conditions that may affect hazard vulnerability:

- Potential or projected development,
- Projected changes in the population, and
- Other identified conditions as relevant and appropriate, including the impacts of climate change.

Changes in Land Use and Development

All projected land use and development are at risk of being impacted by drought events. The ability of new land use to withstand drought impacts can be enhanced through updated land use practices and consistent enforcement of codes and regulations. New development will change the landscape where buildings, roads, and other infrastructure potentially replace open land and vegetation. Growing urbanization will contribute to an increase in the urban island heat effect, which exacerbates high temperatures and can enhance the effects of droughts.

Changes in Population

Baltimore has experienced a decrease in its population since 2010. According to the U.S. Census Bureau, Baltimore City's population decreased by approximately 4.75 percent between 2010 and 2021 (U.S. Census 2021). Estimated population projections provided by the Maryland Department of Planning indicate that Baltimore City's population will begin to increase going into 2030, reaching a total population of approximately 596,390 persons and continue to increase into 2040 to a population of 599,220 (Maryland Department of Planning 2020).

Climate Change

Climate temperatures are rising due to high levels of greenhouse gases in the atmosphere absorbing the sun's energy and warming the environment. The Intergovernmental Panel on Climate Change (IPCC) provides evidence for this phenomenon in the latest IPCC report on global warming (IPCC I. P., Climate Change 2021: Physical Science Basis, 2021). Global temperatures are expected to rise by 2.7° Celsius by the end of the century. The seven warmest years on record have all occurred in the last decade: 2020 was the second warmest year on record; 2016 was the warmest year on record.

Although the climate is always changing, the rate of global warming is unprecedented. Climate change is affecting both people and resources in Baltimore City, and these impacts are projected to continue growing. Other impacts from climate change include an unequal distribution of precipitation, which can lead to an increase in drought events. The 2018 National Climate Assessment noted that the number of hot days are increasing, and the frequency of heatwaves in the United States jumped from an average of two per year in the 1960s to six per year by the 2010s (Maryland Commission on Climate Change 2021).

8.7.7 Change in Vulnerability Since 2018 DP3

Baltimore City continues to be vulnerable to the drought hazard. Updated population and building stock statistics were used in the current risk assessment. Further, exposure for both the population and critical facilities was analyzed. These updated datasets provide a more accurate exposure analysis to the drought hazard. Due to hazard events and rising temperatures since the previous plan, Baltimore City's vulnerability has increased since 2018.

Section 9. Extreme Temperatures

Key changes reflected in the 2023 DP3 update:

- The 2018 DP3 only addressed extreme heat; the 2023 DP3 update addresses both extreme heat and extreme cold.
- The hazard description, including location, extent, previous occurrences and losses, and future probability, has been updated and includes both extreme heat and extreme cold.
- Information has been added about how climate change will impact the extreme temperature hazard.
- The 2023 DP3 update includes a vulnerability assessment combined with the hazard description. The vulnerability assessment addresses the impacts to population, structures, and natural/historic/cultural resources.
- Information has been added about integration of cascading and compounding impacts.
- Information has been added about future changes that may impact vulnerability.

9.1 Description

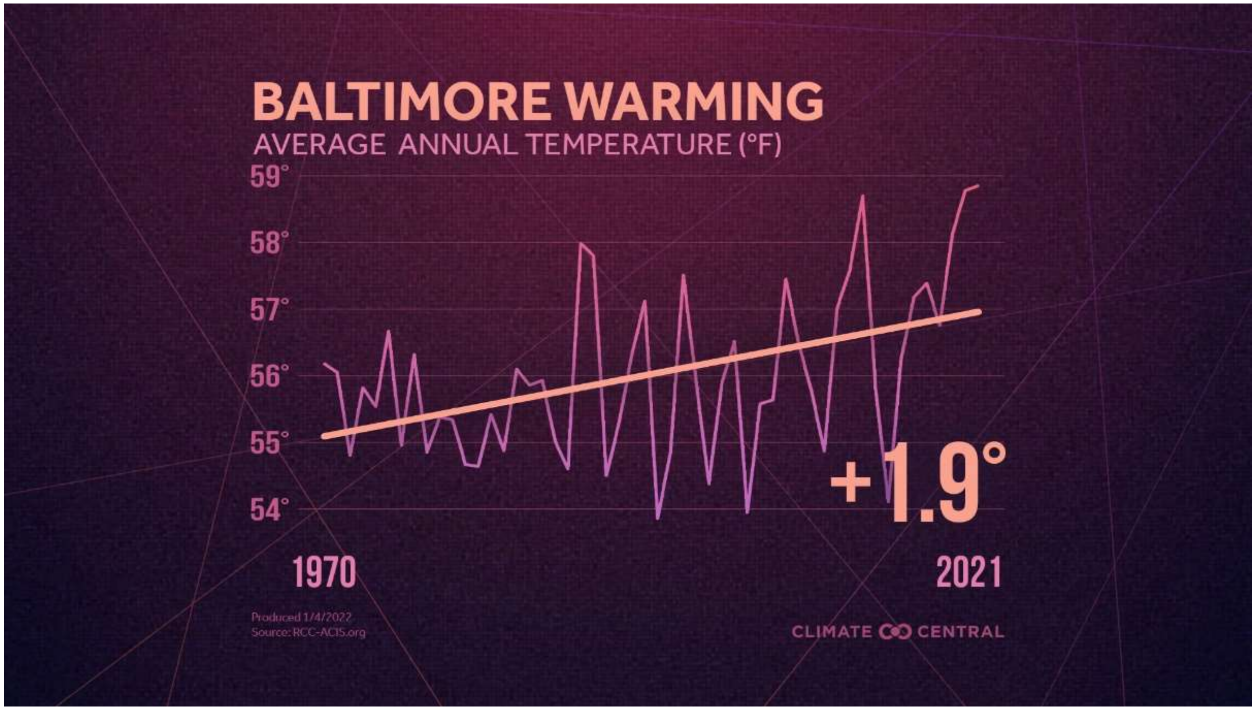
Extreme temperature includes both heat and cold events, which can have a significant impact on human health, commercial/agricultural businesses, and primary and secondary effects on infrastructure (such as burst pipes and power failure). Extreme temperature events can also lead to severe health impacts such as frostbite or heat exhaustion, which can be detrimental to some socially vulnerable populations. What constitutes “extreme cold” or “extreme heat” can vary across different areas of the country based on the population’s experience. The annual average temperature of Baltimore City is shown in Figure 9-1 The potential impacts of extreme temperatures include:

- Drought and limited drinking water supply for residents
- Increased energy demand and subsequent power failures due to increased demand
- Adverse health impacts in vulnerable populations, such as older adults and persons experiencing homelessness
- Damage to aging infrastructure and buildings such as highways and roads being damaged by excessive heat as the asphalt softens, and damage from extreme cold temperatures during the freeze and thaw cycles.

Key Terms

- Extreme Heat—A period of excessively hot weather, with temperatures averaging 10 degrees or more above the average temperature for the specific region (CDC 2012).
- Extreme Cold—A period of excessively cold weather, with temperatures below the average low (CDC 2012).
- Code Blue Extreme Cold Alert— An emergency declaration where temperatures are expected to be 13°F or below. (Baltimore City Health Department 2022)
- Code Red Extreme Heat Alert— An emergency declaration during periods of extreme heat events. (Baltimore City Health Department 2022).

Figure 9-1. Annual Average Temperature in Baltimore City



Source: Climate Central 2022

9.1.1 Extreme Heat

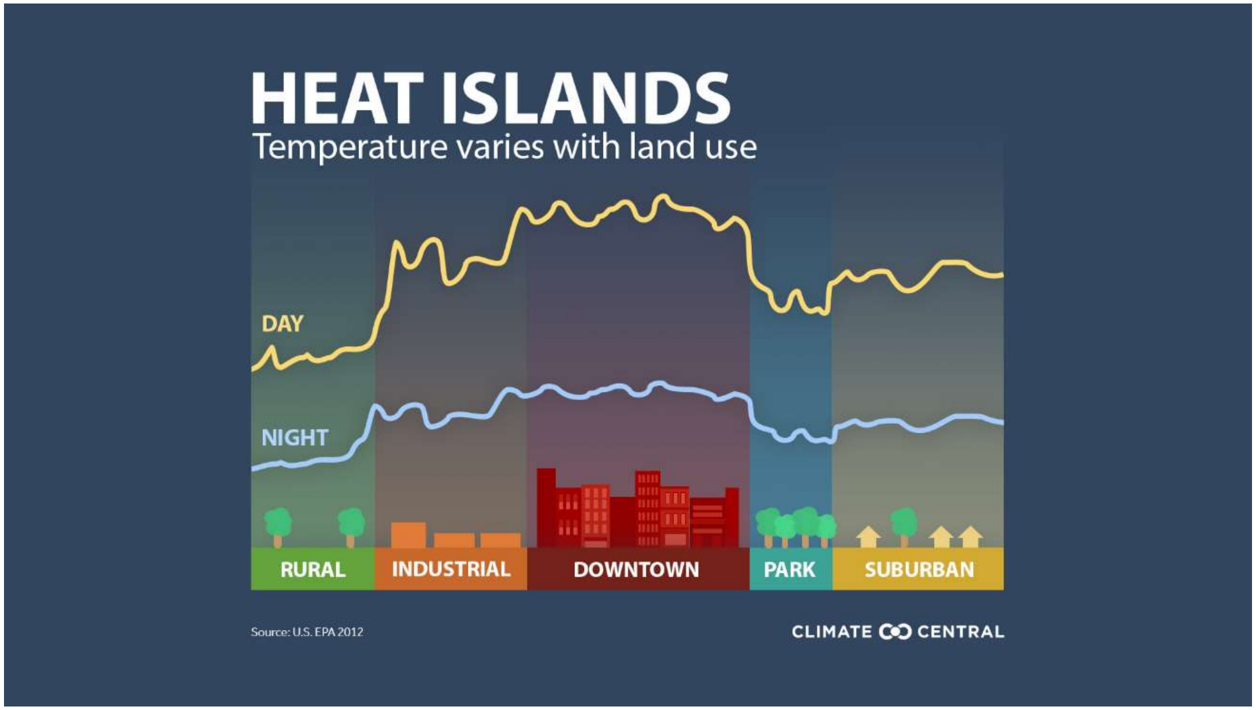
Extreme heat is defined as temperatures that hover 10 degrees or more above the average high temperature for a region and that last for several weeks (CDC 2012). Humid or muggy conditions occur when a “dome” of high atmospheric pressure traps hazy, damp air near the ground. A heat wave is a period of abnormally and uncomfortably hot and unusually humid weather that lasts two or more days (NOAA 2009).

Depending on the severity, duration, and location, extreme heat events can create secondary hazards, including dust storms, droughts, wildfires, water shortages, and power outages. These secondary hazards could result in a broad and far-reaching set of impacts throughout a local area or an entire region.

Extreme heat is the number one weather-related cause of death in the United States. During 1999–2020, the annual number of deaths from excessive heat ranged from a low of 297 in 2004 to a high of 1,153 in 2020 (CDC 2022).

The average temperature for Baltimore City in the middle of summer is 89°F, which can be exacerbated in areas with low foliage or tree cover (US Climate Data 2023). Neighborhoods that are closer to urban areas are more exposed to high heat conditions due to the Urban Heat Island (UHI) effect. Figure 9-2 depicts how heat impacts land uses differently.

Figure 9-2. Urban Heat Island



Source: Climate Central 2023

Baltimore City issues Code Red Extreme Heat Alerts to give residents time to react and prepare for extreme heat events. To learn more about Code Red Extreme Heat Alerts, visit the [Baltimore City Health Department's Code Red] website.

Code Red Extreme Heat Alerts

- Alerts are issued before 6 a.m., if possible.
- Cooling centers are opened throughout the City.
- Additional heat-related messaging and outreach occurs (Baltimore City Health Department 2022).

It is important to note that extreme heat can contribute to poor air quality and cascade into larger concerns. Extreme heat can increase the concentration of ground-level ozone in the air, leading to poor air quality. Additionally, air is often stagnant during high heat days and pollutants become concentrated in the air worsening air quality. Air pollution has the potential over time to be highly hazardous to the health of people. Temporarily hazardous air conditions can occur as a result of natural and human-caused hazards, including wildfires, high winds and dust, stratospheric ozone intrusion, hazardous material accidents, structural fires, and fireworks (National Park Service 2018).

9.1.2 Extreme Cold

Extreme cold events occur when temperatures drop well below normal temperatures expected for an area. For example, near-freezing temperatures are considered “extreme cold” in regions relatively unaccustomed to winter weather. Conversely, “extreme cold” might be used to describe temperatures below 0°F in regions that are subjected to temperatures below freezing on more of a regular basis. For the purposes of this plan, extreme cold temperatures are characterized when the expected temperature or wind chill drops to approximately 13°F or below (Baltimore City Health Department 2022).

Extensive exposure to extreme cold temperatures can cause frostbite or hypothermia and become life-threatening. Extreme cold also can cause emergencies in susceptible populations, such as those without shelter, those who are stranded, or those who live in a home that is poorly insulated or without heat (such as mobile homes). Infants and older adults are most susceptible to the effects of extreme changes in temperatures and are particularly at risk, but anyone can be affected (CDC 2012).

Several health hazards are related to extreme cold temperatures and include wind chill, frostbite, and hypothermia.

- Wind chill is not the actual temperature but rather how wind and cold feel on exposed skin. As the wind increases, heat is carried away from the body at an accelerated rate, driving down the body temperature.
- Frostbite is damage to body tissue caused by extreme cold. A wind chill of -20°F will cause frostbite in just 30 minutes. Frostbite can cause a loss of feeling and a white or pale appearance in extremities.
- Hypothermia is a condition brought on when the body temperature drops to less than 95°F, and it can be deadly. Warning signs of hypothermia include uncontrollable shivering, memory loss, disorientation, incoherence, slurred speech, drowsiness, and apparent exhaustion (Mayo Clinic 2022).

Baltimore City issues Code Blue Extreme Cold Alerts to give residents time to react and prepare for extreme cold events. To learn more about Code Blue Extreme Cold Alerts, visit the Baltimore City Health Department's Code Blue website.

Code Blue Extreme Cold Alerts

- Alerts are issued by 5 p.m. on the preceding day.
- City-funded shelters will shelter-in-place to ensure any individual experiencing homelessness and wanting shelter will be accommodated. Private homeless shelters will be encouraged to extend their hours and keep individuals indoors.
- On nights when Code Blue Extreme Cold has been declared, the Salvation Army FEEDMORE canteen provides hot drinks and other items to individuals experiencing homelessness (Baltimore City Health Department 2022).

9.2 Location

Extreme temperatures can occur anywhere throughout the State of Maryland and Baltimore City. Depending on the season, Baltimore City is susceptible to extreme cold and extreme heat events. Extreme temperatures can affect the entirety of Baltimore City.

9.2.1 Agriculture

When extreme heat or cold events occur, the agricultural industry is most at risk in terms of economic impact and damage. City urban agriculture operations may be severely impacted due to freezes or heat events that may kill off crops or affect their productivity. According to the Baltimore City Department of Planning, there are approximately 119 food-producing community gardens and urban farms in Baltimore, totaling approximately 32 acres of area that may be impacted by extreme heat and cold events.

9.2.2 Urban Heat Island

Larger urbanized areas can magnify the impacts of the extreme heat hazard due to the UHI effect. According to the U.S. Environmental Protection Agency (EPA), a review of research and data found that in the United States, the UHI effect results in urban daytime temperatures of 1–7°F higher than temperatures in outlying areas and nighttime temperatures about 2–5°F higher (EPA 2022).

Error! Reference source not found. depicts the average daily minimum (nighttime) air temperature. Heavily urbanized arears surrounding major transportation routes and those areas radiating from the City's downtown area tend to have higher nighttime temperatures. The maps in **Error! Reference source not found.** represent 2016 (map a), 2017 (map b), 2018 (map c), 2019 (map d), 2020 (map e), 2021 (map f), and 2022 (map g). Nighttime temperatures have increased during the period of 2016 – 2022.

Maximum (daytime) temperatures are depicted in Figure 9-3. In contract to nighttime temperatures, higher daytime temperatures are experienced also most entirely across the City. Areas with lower daytime temperatures are largely centered around large greenspaces such as Leakin Park to the west, Druid Hill Park in the central part of the City, and Herring Run Park in the northeast. The maps in Figure 9-3 represent 2016 (map a), 2017 (map b), 2018 (map c), 2019 (map d), 2020 (map e), 2021 (map f), and 2022 (map g). Daytime temperatures have increased during the period of 2016 – 2022.

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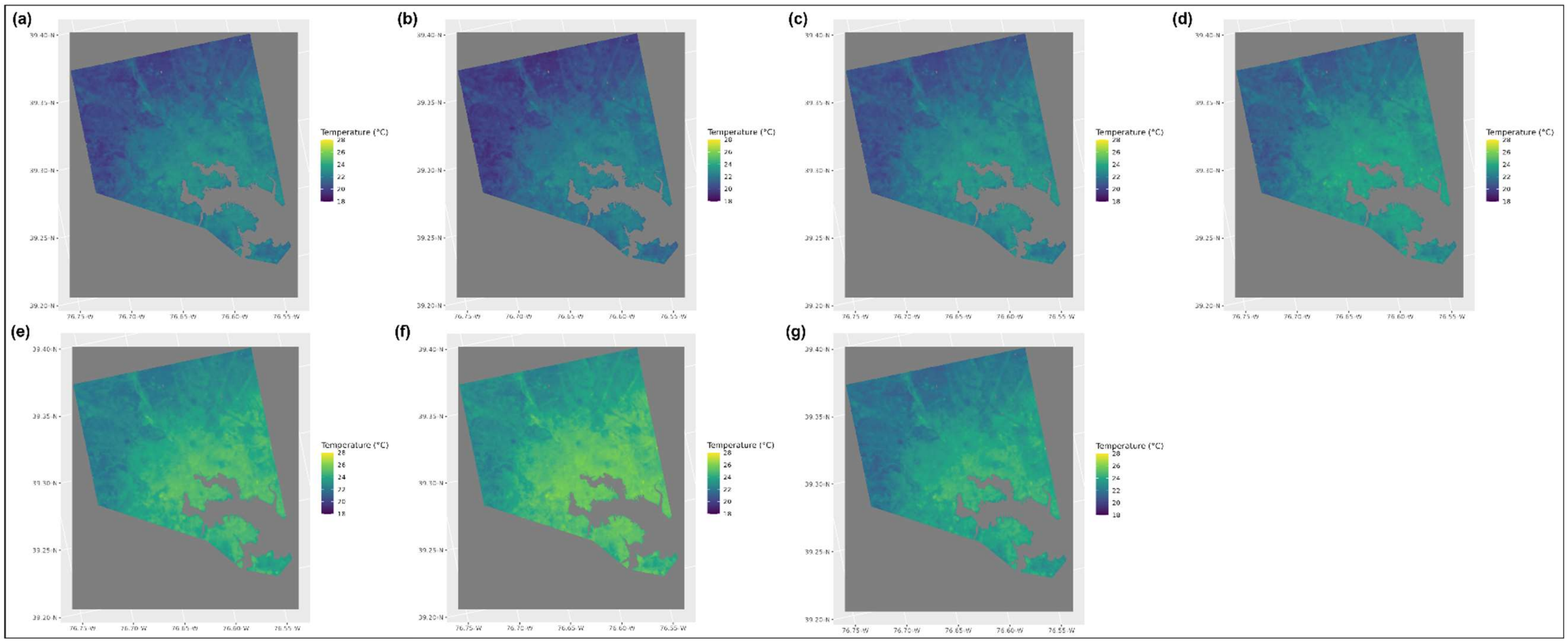
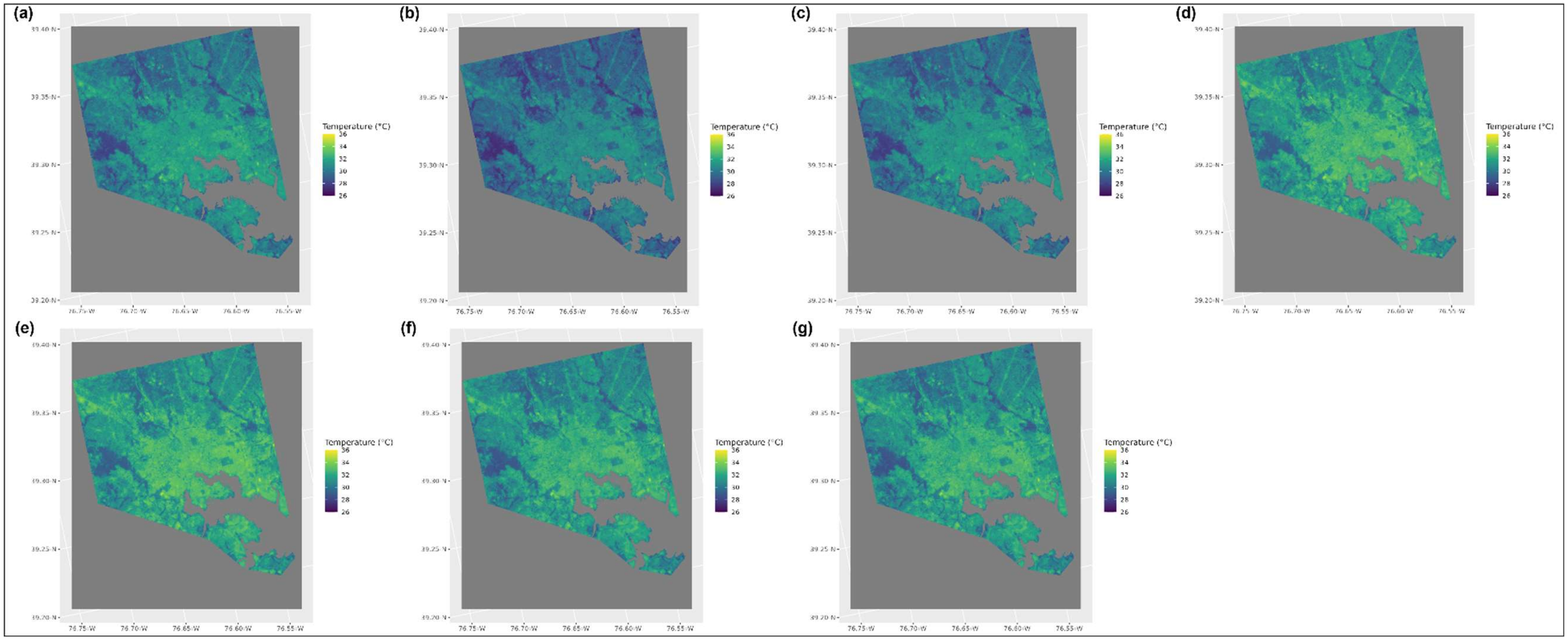


Source: Corpuz, et al. 2023

Figure 9-3. Average Daily Maximum (Daytime) Air Temperature for Summer (June – August)



Source: Corpuz, et al. 2023

Extreme cold temperatures occur throughout the winter season and accompany some winter storm events throughout Baltimore City. The extreme cold hazard can exacerbate winter weather by freezing or refreezing precipitation, making extreme cold a dangerous secondary hazard.

9.2.3 Tree Canopy

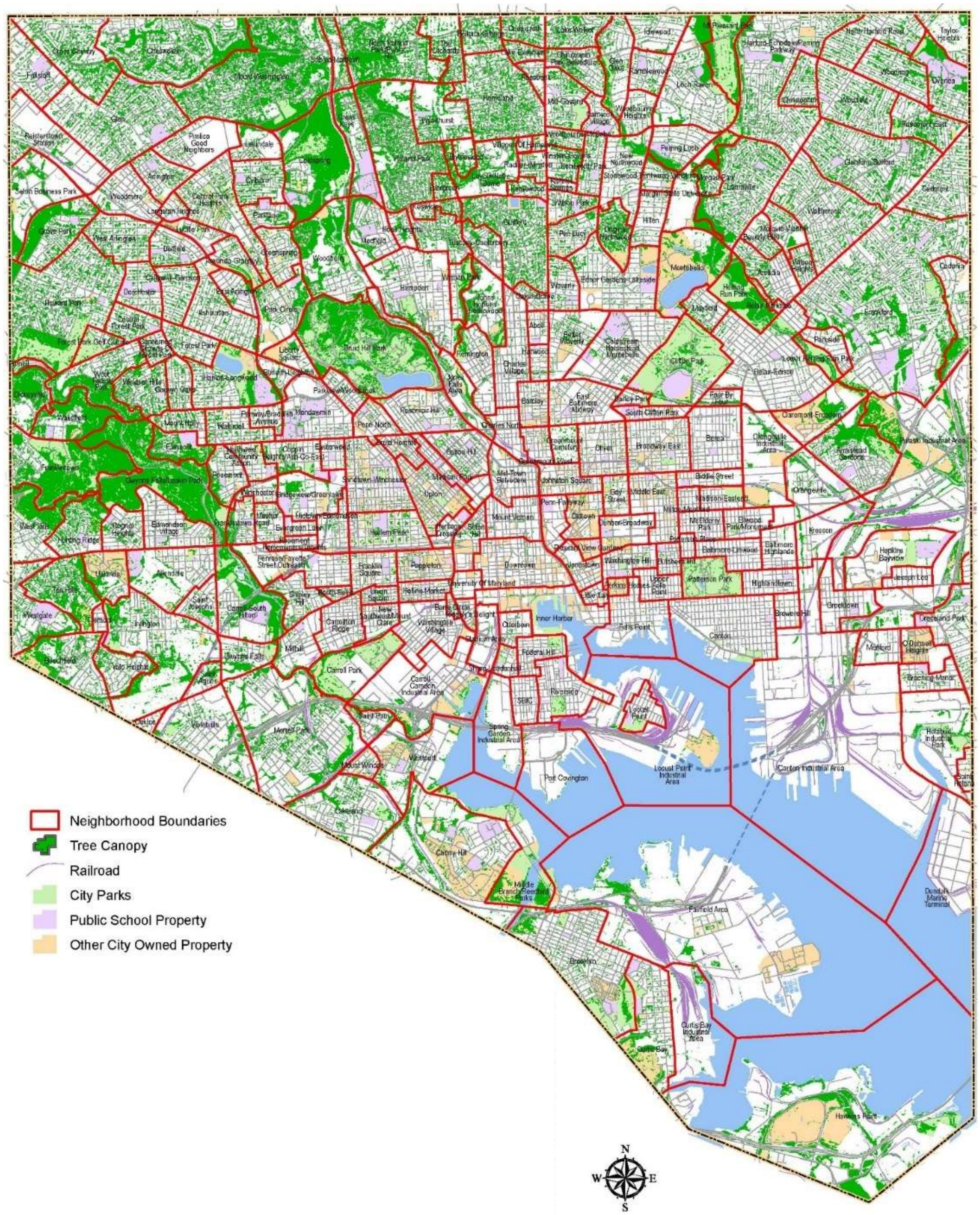
Baltimore City also has a lower percentage of tree canopy cover toward the center of Baltimore City, making this area particularly vulnerable to extreme heat events (see Figure 9-4). Additionally, droughts can be associated with extreme heat events and could negatively affect the size of tree canopies, making areas that are well-covered vulnerable. Maryland's climate is trending toward warmer and wetter conditions with more extreme temperature events. Temperatures have risen approximately 2.5°F since the beginning of the 20th century, and the number of very hot days (maximum temperature over 95°F) has increased since 1900 (University of Maryland Extension n.d.).

9.2.4 Surface Water

In addition to urban agriculture and tree canopy, surface water supplies are susceptible to severe impacts from drought. Extreme heat events can result in droughts that could result in a loss of water supply as demand increases but precipitation to fill the reservoirs decreases.

Baltimore City DPW stores potable water in three surface reservoirs: Prettyboy, Lock Raven, and Liberty. These reservoirs house 86 billion gallons of potable water to supply 1.8 million people living in Baltimore City and Anne Arundel, Baltimore, Carroll, and Howard Counties (Baltimore City Department of Public Works n.d.). The location of the reservoirs is shown in Figure 9-5. Reservoirs are continuously monitored, and the Maryland Department of the Environment (MDE) monitors precipitation, stream flow, groundwater levels, and reservoir storage monthly. At full capacity, the three City reservoirs can provide potable water for approximately 350 days (Maryland Department of the Environment 2021).

Figure 9-4. Baltimore Neighborhood Tree Canopy



Source: Baltimore City Department of Recreation & Parks 2023

Figure 9-5. Baltimore Region Reservoirs

Source: Baltimore County Government 2023

9.3 Extent

9.3.1 Extreme Heat

The National Weather Service (NWS) has created a heat index chart that takes into account the temperature and relative humidity to estimate the likelihood of heat disorders with prolonged exposure. The heat index is given in °F and corresponds with the temperature that the body feels (NWS 2023). Figure 9-6. shows the heat index value for shaded areas; full sun exposure can increase the index by up to 15°F. Table 9-1. describes the adverse effects of prolonged exposure to direct sunlight on an individual.

Figure 9-6. NWS Heat Index Chart

Temperature (°F)

Relative Humidity (%)	80	82	84	86	88	90	92	94	96	98	100	102	104	106	108	110
40	80	81	83	85	88	91	94	97	101	105	109	114	119	124	130	136
45	80	82	84	87	89	93	96	100	104	109	114	119	124	130	137	
50	81	83	85	88	91	95	99	103	108	113	118	124	131	137		
55	81	84	86	89	93	97	101	106	112	117	124	130	137			
60	82	84	88	91	95	100	105	110	116	123	129	137				
65	82	85	89	93	98	103	108	114	121	128	136					
70	83	86	90	95	100	105	112	119	126	134						
75	84	88	92	97	103	109	116	124	132							
80	84	89	94	100	106	113	121	129								
85	85	90	96	102	110	117	126	135								
90	86	91	98	105	113	122	131									
95	86	93	100	108	117	127										
100	87	95	103	112	121	132										

Likelihood of Heat Disorders with Prolonged Exposure or Strenuous Activity

Caution · Extreme Caution · Danger · Extreme Danger

Source: NWS 2015

Table 9-1. Adverse Effects of Prolonged Exposure to Direct Sunlight

Category	Heat Index	Effects on the Body
Caution	80°F–90°F	Fatigue possible with prolonged exposure and/or physical activity
Extreme Caution	90°F–103°F	Heat stroke, heat cramps, or heat exhaustion possible with prolonged exposure and/or physical activity
Danger	103°F–124°F	Heat cramps or heat exhaustion likely, and heat stroke possible with prolonged exposure and/or physical activity
Extreme Danger	125°F or higher	Heat stroke highly likely

Source: NWS

The Maryland Department of Health monitors extreme heat conditions from May through September each year. In the event of extreme heat conditions, the NWS will issue advisories, warnings, and watches:

- **Excessive Heat Watch** – An Excessive Heat Watch is issued when conditions are favorable for an excessive heat event in the next 12–48 hours. An Excessive Heat Watch is used when the risk of a heat wave has increased, but its occurrence and timing are still uncertain. An Excessive Heat Watch provides enough lead time so those who need to prepare can do so, such as cities that have excessive heat event mitigation plans (Maryland Department of Health 2023).
- **Excessive Heat Warning** – An Excessive Heat Warning is issued within 12 hours of the onset of extremely dangerous heat conditions. An Excessive Heat Warning is used

when the maximum heat index is expected to be 105°F or higher for at least two days and nighttime air temperatures will not drop below 75°F; regionally, the NWS issues an Excessive Heat Warning when the heat index is expected to exceed 110°F or conditions are such to pose a risk to life and property (Maryland Department of Health 2023).

- **Heat Advisory** – A Heat Advisory is issued within 12 hours of the onset of extremely dangerous heat conditions. A Heat Advisory is used when the maximum heat index is expected to be 100°F or higher for at least two days, and nighttime air temperatures will not drop below 75°F; regionally, NWS issues a Heat Advisory when the ambient temperature is expected to rise above 100°F, or the heat index is expected to reach 105 to 110°F. When determining the first Heat Advisory for the summer, these thresholds may be lower (Maryland Department of Health 2023).
- **Excessive Heat Outlook** – An Excessive Heat Outlook is typically issued when the potential exists for an excessive heat event within three to seven days. The Excessive Heat Outlook is designed to provide information to people who may need time to prepare for the event (NWS n.d.).

As noted previously, extreme heat can be magnified by poor air quality. The U.S. Environmental Protection Agency set National Ambient Air Quality Standards for six common air pollutants: ozone, particulate matter, carbon monoxide, lead, sulfur dioxide, and nitrogen dioxide (EPA 2022a). These "criteria air pollutants" cause human and environmental health issues.

9.3.2 Extreme Cold

The magnitude of extreme cold temperatures is measured through the Wind Chill Temperature (WCT) index, which calculates the dangers from winter winds and freezing temperatures through advanced science, technology, and computer modeling (NWS n.d.). Extreme cold and wind chill can also lead to winter weather and icy road conditions, which contribute to thousands of traffic-related deaths. Figure 9-7. presents the WCT.

The NWS issues a variety of freeze/cold watches, warnings, and advisories depending on the severity of the wind chill (NWS n.d.):

- **Wind Chill Warning** – Issued when dangerously cold wind chill values are expected or occurring.
- **Wind Chill Watch** – Issued when dangerously cold wind chill values are possible.
- **Wind Chill Advisory** – Issued when seasonably cold wind chill values but not extremely cold values are expected or occurring.
- **Hard Freeze Warning** – Typically issued when temperatures are expected to drop below 28°F and typically kills most commercial crops and residential plants. This warning is designed to inform people who may need time to prepare for the event.
- **Freeze Warning** – Typically issued when temperatures are forecasted to go below 32°F for a long period of time.
- **Freeze Watch** – Issued when there is potential for significant, widespread freezing temperatures within the following 24–36 hours.
- **Frost Advisory** – Indicates that areas of frost are expected or occurring and threaten sensitive vegetation.

Figure 9-7. Wind Chill Index

Wind (mph)	Temperature (°F)																	
Calm	40	35	30	25	20	15	10	5	0	-5	-10	-15	-20	-25	-30	-35	-40	-45
5	36	31	25	19	13	7	1	-5	-11	-16	-22	-28	-34	-40	-46	-52	-57	-63
10	34	27	21	15	9	3	-4	-10	-16	-22	-28	-35	-41	-47	-53	-59	-66	-72
15	32	25	19	13	6	0	-7	-13	-19	-26	-32	-39	-45	-51	-58	-64	-71	-77
20	30	24	17	11	4	-2	-9	-15	-22	-29	-35	-42	-48	-55	-61	-68	-74	-81
25	29	23	16	9	3	-4	-11	-17	-24	-31	-37	-44	-51	-58	-64	-71	-78	-84
30	28	22	15	8	1	-5	-12	-19	-26	-33	-39	-46	-53	-60	-67	-73	-80	-87
35	28	21	14	7	0	-7	-14	-21	-27	-34	-41	-48	-55	-62	-69	-76	-82	-89
40	27	20	13	6	-1	-8	-15	-22	-29	-36	-43	-50	-57	-64	-71	-78	-84	-91
45	26	19	12	5	-2	-9	-16	-23	-30	-37	-44	-51	-58	-65	-72	-79	-86	-93
50	26	19	12	4	-3	-10	-17	-24	-31	-38	-45	-52	-60	-67	-74	-81	-88	-95
55	25	18	11	4	-3	-11	-18	-25	-32	-39	-46	-54	-61	-68	-75	-82	-89	-97
60	25	17	10	3	-4	-11	-19	-26	-33	-40	-48	-55	-62	-69	-76	-84	-91	-98

Frostbite Times: 30 minutes; 10 minutes; 5 minutes

$$\text{Wind Chill (°F)} = 35.74 + 0.6215T - 35.75(V^{0.16}) + 0.4275T(V^{0.16})$$

Where, T= Air Temperature (°F) V= Wind Speed (mph)

Effective 11/01/01

Source: NWS 2001

9.4 Previous Occurrences and Losses

Many sources provided historical information regarding previous occurrences and losses associated with extreme temperatures throughout Baltimore City. With so many sources reviewed for the DP3, loss and impact information for many events could vary. Therefore, the accuracy of the monetary figures discussed is based only on the available information in cited sources.

9.4.1 FEMA Major Disaster and Emergency Declarations

Between 1953 and 2023, Baltimore City was not included in any FEMA disaster declarations (DR) or emergency declarations (EM) for extreme temperature-related events. Baltimore City has experienced multiple declarations relating to severe winter weather where extreme cold temperatures were a factor; however, the declarations were made due to snowstorms.

9.4.2 Previous Events

Table 9-2 identifies the known extreme temperature events that impacted Baltimore City between 1953 and June 2023.

Table 9-2. Extreme Temperature Events in Baltimore City, 2000-2023

Date(s) of Event	Event Type	FEMA Declaration Number	City included in Declaration?	Location Impacted	Description
March 3, 1998	Cold/Wind Chill	N/A	N/A	Citywide	A series of cold fronts ushered in only the second arctic air mass of the winter of 1997/98.
January 2, 2000	Excessive Heat	N/A	N/A	Citywide	Unseasonably warm temperatures of up to 68°F hit Baltimore City. Normal temperatures for this time of year are typically in the lower 40s.
January 21-22, 2000	Extreme Cold/Wind Chill	N/A	N/A	Citywide	Winds blew across Baltimore City at 15–30 MPH, making wind chill temperatures from 10–25°F below zero. The wind also blew snow back onto the roads making for difficult driving conditions.
January 27-29, 2000	Extreme Cold/Wind Chill	N/A	N/A	Citywide	Low temperatures on the 28th included 9°F at Baltimore/Washington International Airport.
December 22-23, 2000	Extreme Cold/Wind Chill	N/A	N/A	Citywide	Temperatures dropped into the teens, which created wind chills between 10–20°F below zero. As the winds subsided on the 23rd, temperatures ranged from the single digits above zero to the lower teens.
December 7, 2002	Cold/Wind Chill	N/A	N/A	Citywide	Long standing low temperature records were set on the morning of the 7th as a fresh snowpack, calm winds, and clear skies allowed temperatures to plummet around 20 to 30 degrees below normal overnight. At Baltimore/Washington International Airport, a 117-year-old record low temperature was broken. At 5:04 AM the temperature fell to 6 degrees. This exceeded the previous record of 15 degrees set in 1885.
January 10, 2004	Cold/Wind Chill	N/A	N/A	Citywide	Very cold Arctic air settled over Western Maryland, North Central Maryland, and the Baltimore Metropolitan area. The minimum temperatures ranged from the single digits to the lower teens, and north winds measured 10 to 15 mph. This produced wind chills on the average of 10 degrees below zero. Baltimore City issued a Code Blue and opened the Federal Street shelter because of the bitter cold air. There were dozens of cases of broken water mains and pipes.

Date(s) of Event	Event Type	FEMA Declaration Number	City included in Declaration?	Location Impacted	Description
January 15, 2004	Cold/Wind Chill	N/A	N/A	Citywide	Minimum temperatures across the region were in the single digits and teens. Strong northwest and west winds (20 to 25 mph with gusts to 35 mph) produced wind chills of 5 to 10 below zero on the night of the 15th and the early morning of the 16th.
July 21-23, 2011	Excessive Heat	N/A	N/A	Citywide	Heat indices were measured up to 123°F with a combination of high heat and high humidity, and one fatality was documented due to high heat.
June 29, 2012	Excessive Heat	N/A	N/A	Citywide	Excessive moisture in the air contributed to high humidity, and heat indices were documented at over 105°F.
July 5, 2012	Excessive Heat	N/A	N/A	Citywide	Hot and humid conditions were reported, with heat indices measured up to 112°F. Three fatalities were reported in Baltimore City due to heat.
July 18, 2012	Excessive Heat	N/A	N/A	Citywide	Heat indices were reported up to 113°F. Thunderstorms and showers developed and produced damaging wind gusts and hail.
July 26, 2012	Excessive Heat	N/A	N/A	Citywide	Heat indices were reported to be up to 112°F.
July 19, 2013	Excessive Heat	N/A	N/A	Citywide	Heat indices were around 110°F, and dew points were recorded in the mid-70s.
August 13, 2016	Excessive Heat	N/A	N/A	Citywide	Heat indices around 110°F were reported due to unseasonably hot and humid conditions.
January 5, 2018	Cold/Wind Chill	N/A	N/A	Citywide	Arctic air and gusty winds caused low wind chills to develop; wind chill was reported between -5°F to -15°F.
July 3, 2018	Excessive Heat	N/A	N/A	Citywide	Heat indices around 110°F were reported. The Maryland Department of Health reported 8 fatalities due to the excessive heat in Baltimore City. The fatalities occurred during the week of July 3–July 9.
January 21, 2019	Cold/Wind Chill	N/A	N/A	Citywide	A low pressure system moved up the eastern seaboard of the United States on January 20th, with cold temperatures and strong northwest winds funneling behind the system; the combination of cold temperatures and strong winds produced wind chills as low as -5°F.
January 30, 2019	Cold/Wind Chill	N/A	N/A	Citywide	A combination of cold temperatures and strong winds produced wind chills as low as -10°F.

Date(s) of Event	Event Type	FEMA Declaration Number	City included in Declaration?	Location Impacted	Description
July 19-21, 2019	Excessive Heat	N/A	N/A	Citywide	Temperatures from the mid-90s to 100°F combined with dew points of nearly 70°F created dangerously high heat index values of over 110°F.

Source: FEMA 2023; NCEI 2023

9.5 Probability of Future Hazard Events

It is anticipated that Baltimore will continue to experience direct and indirect impacts of extreme temperature events annually that may induce secondary hazards, such as infrastructure deterioration or failure, utility failures, power outages, etc. Additionally, climate change is expected to increase the severity and frequency of extreme heat events in Baltimore City.

For the 2023 DP3 update, the most up-to-date data was collected to calculate the probability of future occurrence of extreme temperature events for Baltimore City. Information from NOAA-NCEI storm events database and the 2018 Baltimore DP3 were used to identify the number of extreme temperature events that occurred between 1872 and 2022. Table 9-3 presents the probability of future events for extreme temperatures in Baltimore City.

Table 9-3. Future Occurrence of Extreme Temperature Events in Baltimore City

Hazard Type	Number of Occurrences Between 1872 and 2022	% Chance of Occurrence in Any Given Year
# days ≤ 13°F (minimum temperature)	110	73%
# days ≥ 99°F (maximum temperature)	80	53%
Total	190	100%

Source: NOAA 2023

In Section 3, the identified hazards of concern for Baltimore City are ranked (Table 3-5). The probability of occurrence, or likelihood of the event, is one parameter used for hazard rankings. Based on historical records and input from the CPT, HMAC, and community members, the probability of occurrence for extreme temperature in Baltimore City is considered 'frequent'.

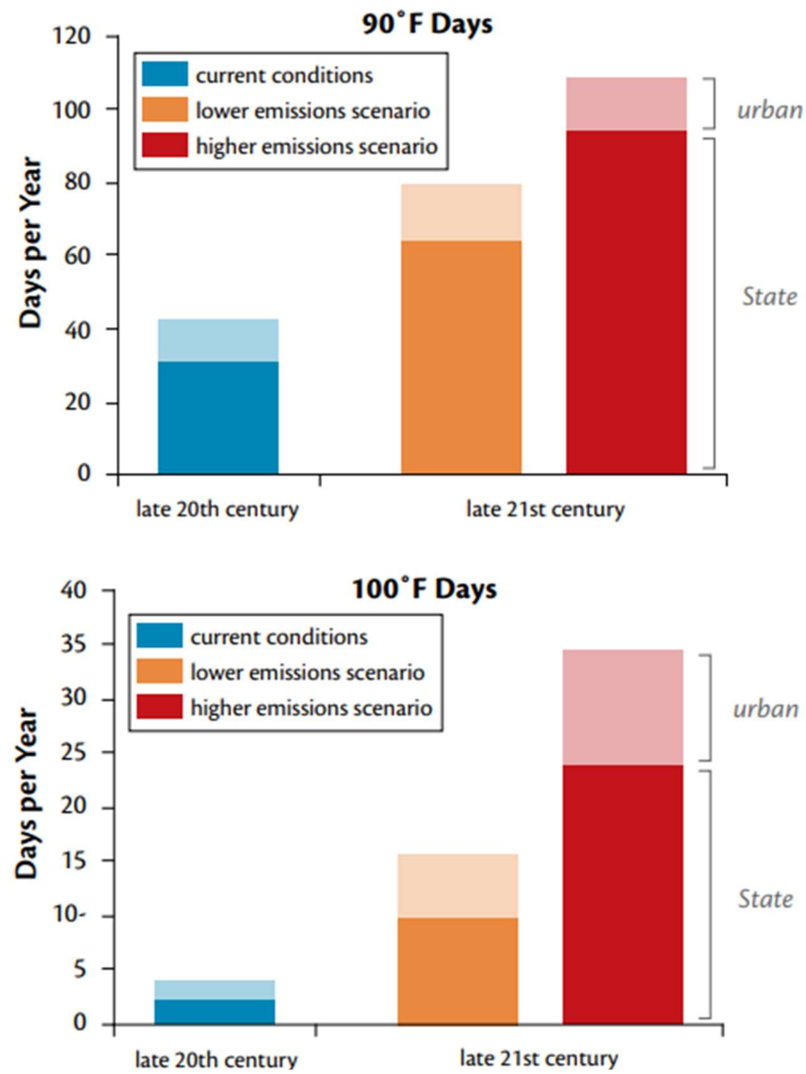
9.6 Potential Impacts of Climate Change

Climate temperatures are rising due to high amounts of greenhouse gases in the atmosphere absorbing the sun's energy and warming the environment. The Intergovernmental Panel on Climate Change (IPCC) provides evidence for this phenomenon in the latest IPCC report on global warming (IPCC 2022). Global temperatures have risen by 2.5°F since the beginning of the 20th century. The seven warmest years on record have all occurred in the last decade: 2020 was the second warmest year on record; 2016 was the warmest year on record. (NOAA 2022).

Although the climate is always changing, the rate at which global warming is taking place is unprecedented. The 2018 National Climate Assessment noted that the number of hot days is increasing, and the frequency of heatwaves in the United States jumped from an average of two per year in the 1960s to six per year by the 2010s (Maryland Commission on Climate Change 2021). This is affecting the seasonality of the northeast, which is experiencing mild winters and earlier springs, altering the ecosystems and environments that encompass the northeast. These less distinct seasons are leading to further changes within the forests, wildlife, snowpack, and streamflow. From a commerce perspective, extremely hot and cold events also impact crop production, which influences the price of crops. Changing climate also leads to more intense storms due to extreme temperature fluctuations and also leads to degradation of air and water quality (U.S. Climate Resilience Toolkit 2022).

In July 2008, the University of Maryland's Center for Environmental Science projected an additional 2°F of warming by 2025. If emissions are lowered by 2050, there is the possibility for a 4.8°F increase in the summer. If emissions are not reduced, the State of Maryland could see a temperature increase of nearly 9°F by the year 2100 (University of Maryland Center for Environmental Science 2008). Currently, projections are following the high emission scenario. Figure 9-8. shows the number of days with high temperatures reaching or exceeding 90° and 100°F in the late 20th century and illustrates the projected increase for the late 21st century under low and high emission scenarios.

Figure 9-8. Number of Days in Maryland with High Temperatures



Source: University of Maryland Center for Environmental Science (UMCES) 2008

While extremely cold days are projected to decrease, climate change impacts are contributing to an increased probability of weather abnormalities, including severe winters.

Within the mid-Atlantic region, more than half of the largest snowstorms on record have occurred since 2003, with record cold temperatures being records in 2014 and 2015 (University of Maryland Extension 2023).

Climate change is affecting both people and resources in Baltimore City, and these impacts are projected to grow. Impacts specifically relating to fluctuations in extreme temperatures are being felt at the state and city levels. For the State of Maryland, extreme temperatures impact human well-being and safety, the economy, and the natural systems of the region. In Baltimore City, many of these impacts are the same. Heat exhaustion and hypothermia are just some direct impacts to human health due to extreme temperatures. Others include disruption to daily activities and businesses, decrease in tourism, altering of the natural built environment, and more. As climate change continues to influence extreme temperature fluctuations in both duration and intensity, Baltimore City will experience more direct and indirect impacts in the future.

Baltimore City's focus on Food Policy and Planning makes the extreme temperature hazard a concern to Baltimore City. Climate change has started to impact extreme cold temperatures by leading to more mild winters yet more intense storm events. This is detrimental to Maryland's climate because decreased cold temperatures affect plant health and productivity through increased warming and refreezing periods. Detrimental effects on crop production and yield impact the prices of vegetables and fruits and the products made from crops grown. Furthermore, this impacts vulnerable populations that may not afford to feed themselves or their families as prices rise (University of Maryland Extension 2023).

9.7 Vulnerability Assessment

To understand risk, a community must evaluate what assets are exposed or vulnerable in the hazard area identified. The entire City has been identified as exposed to the extreme temperature hazard. Therefore, all assets in Baltimore City (population, structures, critical facilities, and lifelines), as described in Section 3 (Risk Assessment), are exposed and potentially vulnerable.

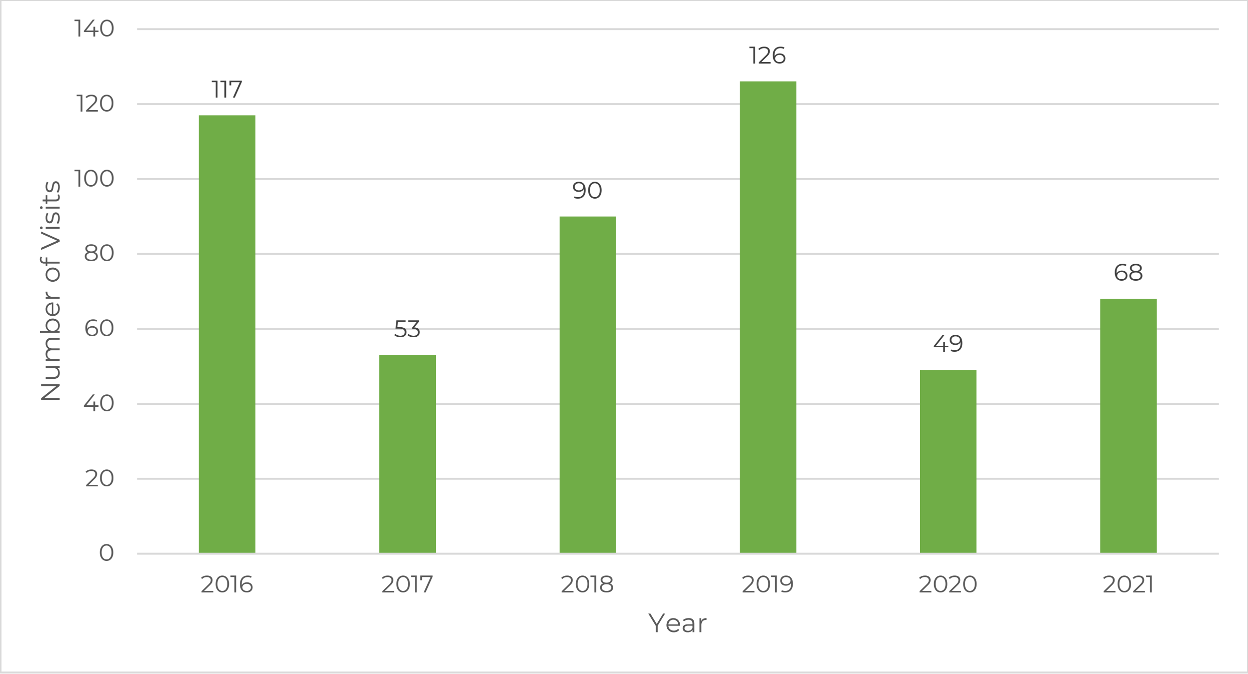
9.7.1 Impacts on Population

According to the Centers for Disease Control and Prevention (CDC), populations most at risk from extreme cold and heat events include the following: (1) older adults, who are less able to withstand temperatures extremes due to their age, health conditions, and limited mobility to access shelters; (2) infants and children up to age 4; (3) individuals with chronic medical conditions (e.g., heart disease, high blood pressure); (4) individuals experiencing economic hardships that cannot afford proper heating and cooling; and (5) the general public who may overexert themselves during work or exercise during extreme heat events or experience hypothermia during extreme cold events (CDC 2022).

Meteorologists are able to accurately forecast extreme heat and cold event development and the severity of the associated conditions with several days of lead time. These forecasts provide an opportunity for public health and other officials to notify vulnerable populations, implement short-term emergency response actions, and focus surveillance and relief efforts on those at greatest risk. Adhering to extreme temperature warnings can significantly reduce the risk of temperature-related deaths. Baltimore City issues a Code Blue Extreme Cold Alert, which is a multi-agency effort to reduce the number of deaths associated with extreme cold events by offering temporary sheltering options and enhanced outreach and messaging during period of extreme cold. Similarly, Baltimore City issues a Code Red Extreme Heat Alert, which is designed to reduce exposure to extreme heat events, minimize heat-related illness, and inform the public of nearby cooling centers that are open for the residents.

To assess extreme heat impacts in Baltimore City, BCHD conducted an analysis of heat-related emergency department visits utilizing data provided by the Maryland Health Services Cost Review Commission (HSCRC) for Baltimore City residents for 2016 – 2021. Heat-related emergency department visits were defined by a principal diagnosis of excessive natural heat or effects of heat and light. Figure 9-9 depicts the number of heat-related emergency department visits; it is important to note that the 2020 – 2021 estimates were impacted by the COVID-19 pandemic and likely do not reflect the actual heat-related illness experienced by City residents during that time.

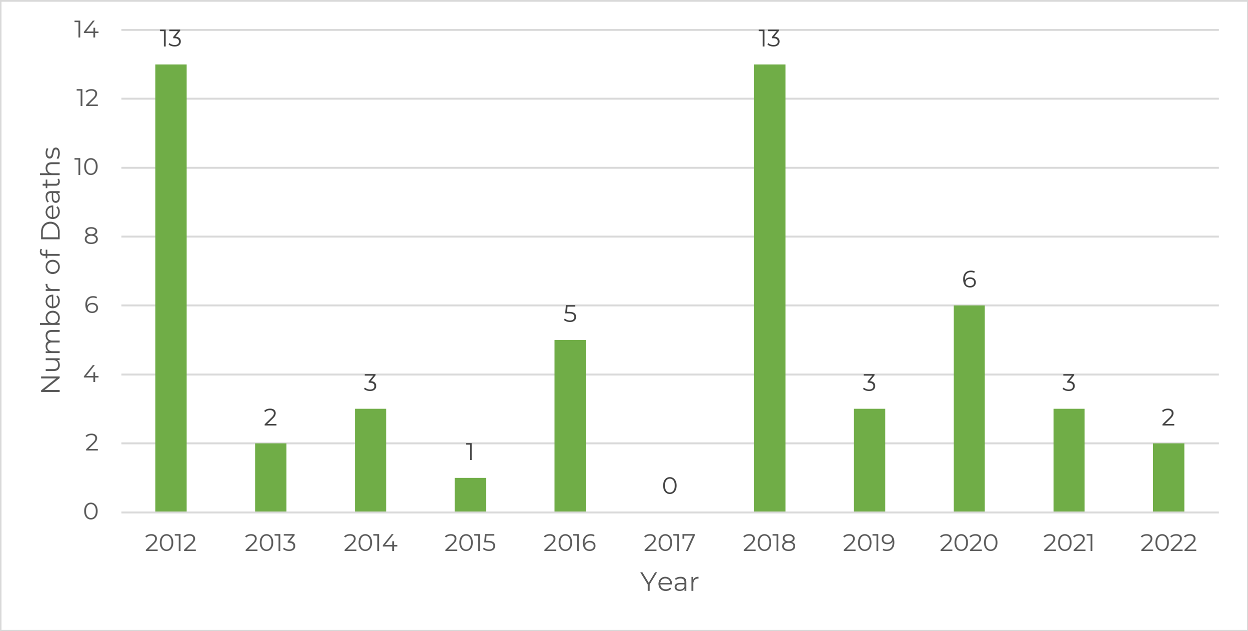
Figure 9-9 Heat-related Emergency Department Visits 2016 - 2021



Source: HSCRC 2021
Note: The 2020 – 2021 estimates were impacted by the COVID-19 pandemic and likely do not reflect the actual heat-related illness experienced by City residents during that time.

The Maryland Department of Health's Heat-related Illness Surveillance period tracks heat-related deaths for Baltimore City. The highest number of deaths reported between 2012 – 2022 was 13 for both 2012 and 2018 (see Figure 9-10). A breakdown of deaths per year is provided in. Three heat advisories were declared in 2022, with two heat-related deaths occurred in Baltimore City (Maryland Department of Health 2022).

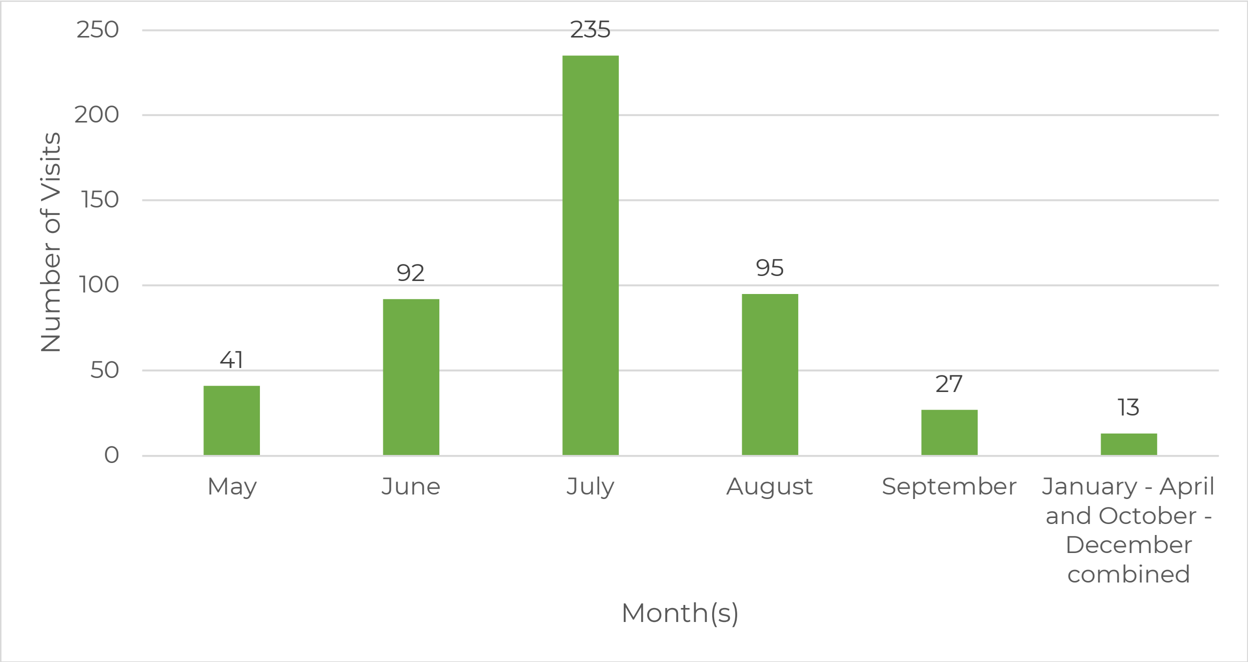
Figure 9-10 Heath-related Deaths from May 15 to September 15 (Extreme Heat Season) (2012 - 2022)



Source: Maryland Department of Health 2023

During 2016 – 2021, more emergency department visits were recorded in July, as depicted in Figure 9-11. The average temperature in July in Baltimore City is 78.3° and is the hottest month in Baltimore City on average (NOAA 2023).

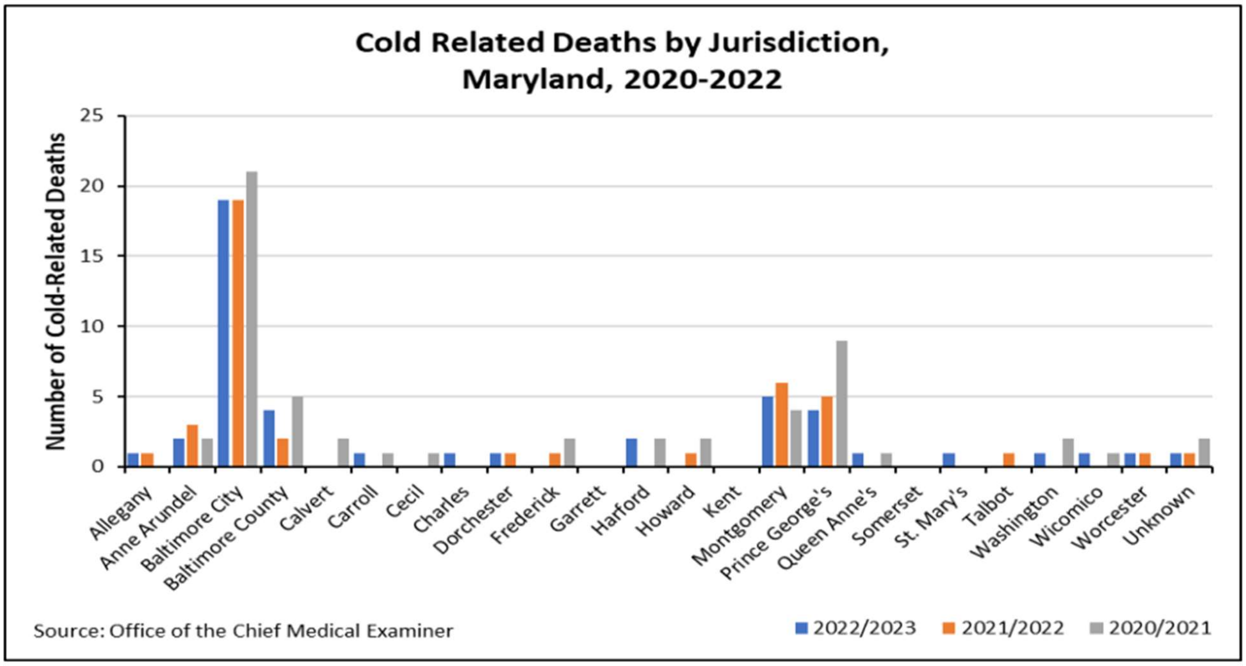
Figure 9-11 Heat-related Emergency Department Visits by Month (2016 - 2021)



Source: HSCRC 2021
Note: The 2020 – 2021 estimates were impacted by the COVID-19 pandemic and likely do not reflect the actual heat-related illness experienced by City residents during that time.

During the 2022 - 2023 cold season monitoring period, the State of Maryland recorded 46 cold-related deaths, 21 of which were among the unhoused population. Nearly half of these cold-related deaths occurred in Baltimore City, followed by Baltimore County, Anne Arundel County, Montgomery County, and Prince George's County (see Figure 9-12). The largest number of fatalities occurred in December (Maryland Department of Health 2023). On average temperatures average 38.6°F in January for Baltimore City (NOAA 2023). The highest number of emergency department chief complaint visits were also highest in Baltimore City during this time period.

Figure 9-12. Maryland Cold-Related Deaths from November 8 – March 27 (Extreme Cold Season) by Jurisdiction (2020 – 2023)



Source: Maryland Department of Health 2023

9.7.2 Impacts on Socially Vulnerable Populations and Underserved Communities

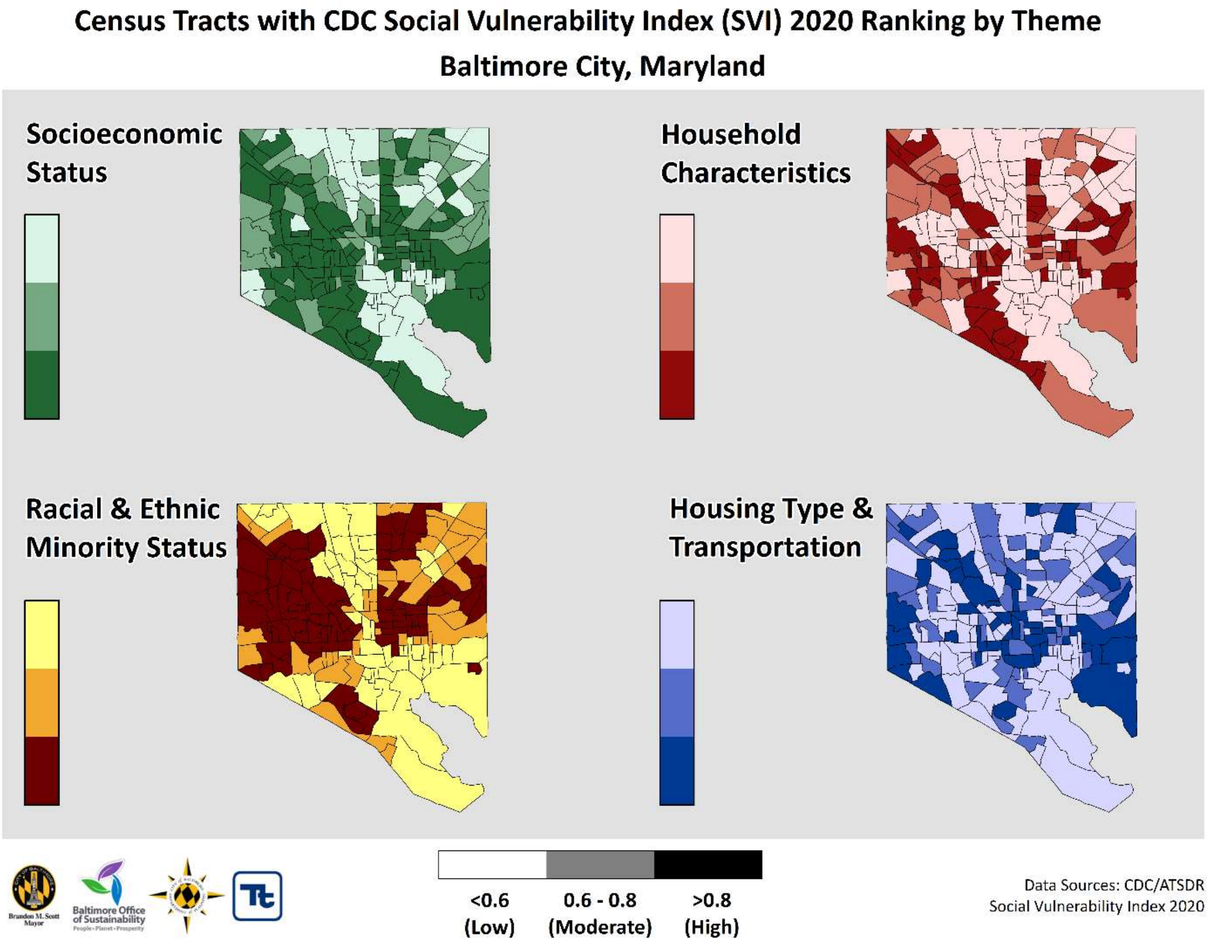
Social vulnerability is defined as the susceptibility of social groups to the adverse impacts of natural hazards, including disproportionate death, injury, loss, or disruption of livelihood. Social vulnerability considers the social, economic, demographic, and housing characteristics of a community that influence its ability to prepare for, respond to, cope with, recover from, and adapt to environmental hazards.

According to FEMA's National Risk Index, socially vulnerable populations in the City have a very high susceptibility to the adverse impacts of natural hazards, when compared to the rest of the United States (FEMA n.d.).

According to the 2021 American Community Survey, there are roughly 84,000 persons over age 65 (14.1 percent of the total population); approximately 36,000 persons (6.2-percent of the total population) under the age of 5; just over 10,000 persons (1.7-percent of the total population) which do not speak English; an estimated 93,000 persons (15.7-percent of the total population) who have a disability; and about 116,000 persons (19.5-percent of the total population) living at or below the poverty level.

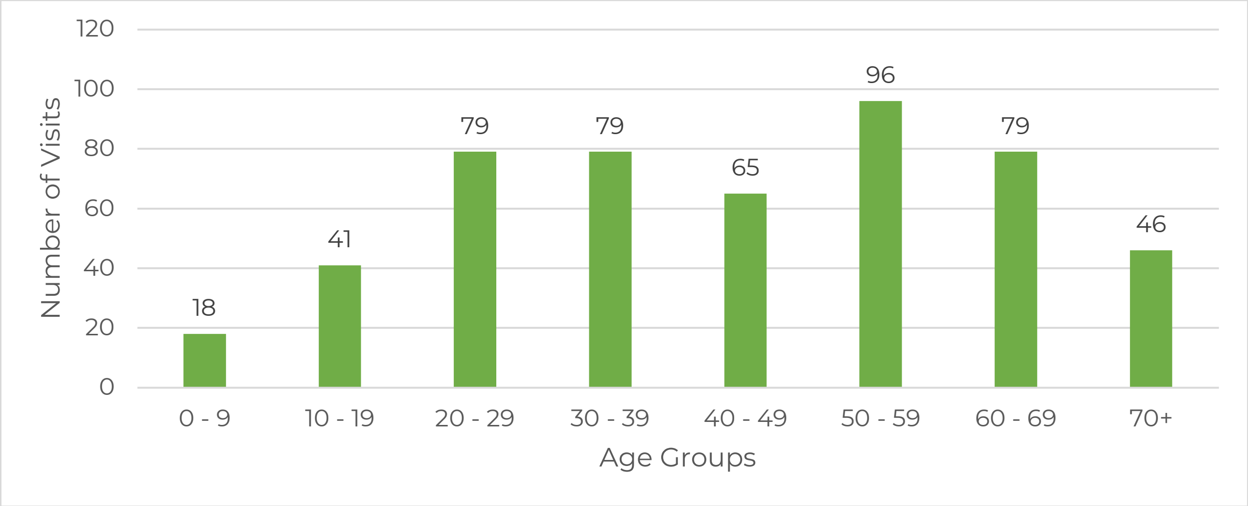
Figure 9-13 shows the census tracts with CDC Social Vulnerability Index for the themes in Baltimore City.

Figure 9-13. CDC Social Vulnerability Index by Census Tract



Between 2016 – 2021 the majority of heat-related emergency department visits were by individuals aged 50 and older, which accounted for 43.9% of the visits during this time period. However, individuals aged A breakdown of heat-related emergency department visits by age is provided in Figure 9-14. The age groups between 20 – 39 accounted for 31.4% of visits during this time period, which can be an indicator that heat has the potential to impact individuals in age ranges that are not generally considered to have a higher vulnerability.

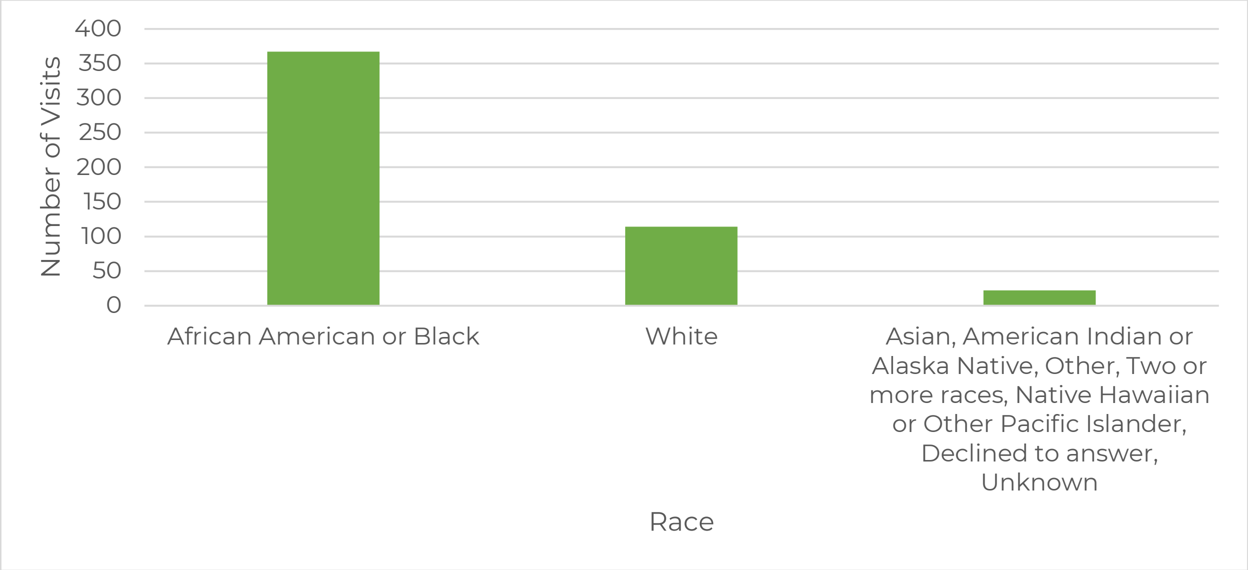
Figure 9-14 Heat-related Emergency Department Visits by Age (2016 - 2021)



Source: HSCRC 2021
Note: The 2020 – 2021 estimates were impacted by the COVID-19 pandemic and likely do not reflect the actual heat-related illness experienced by City residents during that time.

Data for heat-related emergency department visits also indicated differences related to sex and race. Within Baltimore City a majority of males visited the emergency department, accounting for 329 visits (65.4%), while females accounted for 174 (34.6%). No data was reported on those who identify as non-gender conforming or non-binary. Approximately three quarters (73%) of all heat-related emergency department visits were among African Americans, 22.6% among Whites, and 4.4% among those who identified as Asian, American Indian, Alaska Native, Other, two more races, Native Hawaiian, declined to answer, or unknown (see Figure 9-15).

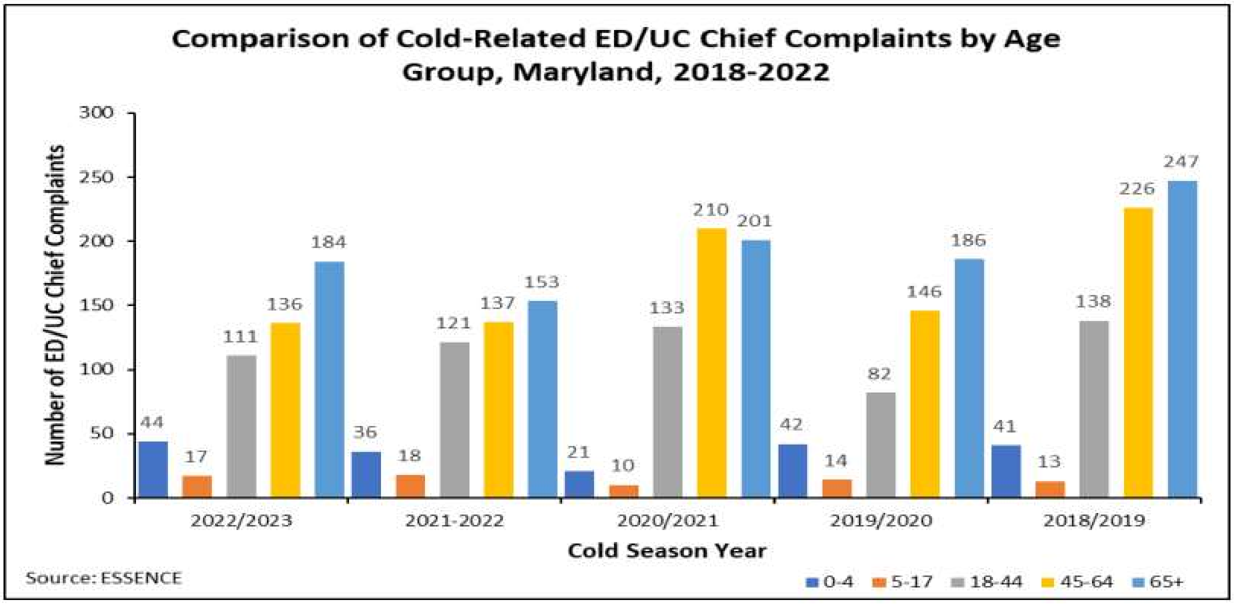
Figure 9-15 Heat-related Emergency Department Visits by Race (2016 - 2021)



Source: HSCRC 2021
Note: The 2020 – 2021 estimates were impacted by the COVID-19 pandemic and likely do not reflect the actual heat-related illness experienced by City residents during that time.

For extreme cold, the distribution of cold-related emergency department visits was highest in the 65 year and older age group, followed by the 45 – 64 year age group; this is consistent with previous years (2018/2019 – 2021/2022) where the 45 – 64 year and 65 year and older age groups had the largest number of emergency department and urgent care chief complaints. Figure 9-16 provides a breakdown of cold-related emergency department visits by age from 2018 – 2022.

Figure 9-16. Cold-Related Emergency Department Visits by Age (2018 – 2022)



Source: Maryland Department of Health 2023

9.7.3 Impacts on Structures

General Building Stock

All buildings are exposed to the extreme temperature hazard. Refer to Section 3 (Risk Assessment), which summarizes the building inventory in Baltimore City. Extreme heat generally does not impact buildings; however, elevated summer temperatures increase the energy demand for cooling. Losses can be associated with the overheating of heating, ventilation, and air conditioning (HVAC) systems. Extreme cold temperature events can damage buildings through freezing/bursting pipes and freeze/thaw cycles as well as increasing vulnerability to home fires due to people spending more time indoors and using more appliances and equipment that has the potential to cause more fires.

Critical Facilities, Infrastructure, and Community Lifelines

All critical facilities, infrastructure, and community lifelines in Baltimore City are exposed to the extreme temperature hazard. Critical facilities, infrastructure, and lifelines will experience similar issues as described above for general building stock. Additionally, it is essential that critical facilities remain operational during natural hazard events. Extreme heat events can sometimes cause short periods of utility failures, commonly referred to as brownouts, due to increased usage from air conditioners and other energy-intensive appliances, which can prevent facilities from performing their essential operations. Similarly, heavy snowfall and ice storms associated with extreme cold temperature events can cause power interruption. Backup power is recommended for critical facilities and infrastructure so that continuity of operations can occur during hazard events.

9.7.4 Impacts on the Economy

Baltimore City is ambitiously striving to address urban food system resilience, food insecurity and health inequities, through research, education and program activities that range from mapping the food environment to strengthening city policy, ensuring soil safety for urban farmers, and paving the way for food systems resilience planning (City of Baltimore 2016). Extreme temperatures impact crop growth and development through intense freezing and warming periods which affects the overall price of goods that are produced using those crops. Additionally, urban farmers who rely on these crops as a primary source of income are also greatly affected due to reduced or unsellable crops.

Extreme temperatures also can foster conditions for strong storms that may lead to expensive cleanup efforts and affect Baltimore City's ability to receive and ship goods, which can affect the economy (Wilson 2021).

9.7.5 Impacts on Natural, Historic, and Cultural Resources

Extreme temperature events can have a major impact on the environment. For example, freezing and warming weather patterns create changes in natural processes. Intense cooling and warming periods can affect crop and tree growth and can contribute to tree canopy degradation, which can limit shade and negatively affect biodiversity. An excess amount of snowfall and earlier warming periods may affect natural processes such as flow within water resources (USGS n.d.). Likewise, when heavy rains fall on snow-covered ground, runoff rates may be exacerbated with warming winter weather. Extreme heat events can have particularly negative impacts on aquatic systems, contributing to fish kills, aquatic plant die-offs, and increased likelihood of harmful algal blooms.

Historic sites and buildings are at risk from the extreme temperature hazard. Historic buildings are susceptible to damage from extreme temperature events. Proper strategies help safeguard the building and its collections, saving money, and potentially avoiding disasters. Whether an institution or building owner chooses to seasonally lower or maintain a constant year-round temperature, sudden and dramatic fluctuations should be minimized. This slow heating or cooling will give collection materials time to acclimate to the new temperature and the corresponding new humidity levels within the building (CCAHA 2019).

Cultural heritage sites, particularly those impacted by the elements, are subject to weathering processes. Climate change is a potential threat to these sites as it exacerbates the expected rates of decay and contributes to the appearance of new decay. This is because climatic changes may aggravate the physical, chemical, and biological mechanisms causing degradation by affecting the structure and/or composition of the affected materials. Changes in temperature, precipitation, and atmospheric moisture, and wind intensity, in addition to sea-level rise, desertification, and the interaction between climatic changes and air pollution have been identified by the United Nations Educational, Scientific and Cultural Organization (Sesana, et al. 2021).

Due to the developed nature of Baltimore City, all historic and cultural resources are susceptible to impacts from extreme temperature. These resources may be impacted in the same manner as the general building stock and critical facilities.

9.7.6 Cascading and Compounding Impacts

Extreme temperature events can exacerbate the drought hazard, increase the potential risk of wildfires, and escalate severe storm and severe winter weather events for Baltimore City. For example, extreme heat events may accelerate evaporation rates, which may dry out the air and soils making some terrestrial plants and soil more susceptible to catching fire. Extreme variation in temperatures could also create ideal atmospheric conditions for severe storms or worsen the outcome of severe winter weather during freezing and thawing periods.

Additionally, extreme heat can trigger and increase health challenges; these challenges can be further exacerbated by poor air quality. Trees and other vegetation can serve to reduce the impacts associated with extreme heat and also provide benefits for improving air quality.

9.7.7 Future Changes that May Impact Vulnerability

Understanding future changes that impact vulnerability in Baltimore City can assist in planning for future development and ensuring that appropriate mitigation, planning, and preparedness measures are in place. Baltimore City considered the following factors to examine potential conditions that may affect hazard vulnerability:

- Potential or projected development
- Projected changes in the population
- Other identified conditions as relevant and appropriate, including the impacts of climate change.

Changes in Land Use and Development

All projected land use and development are at risk of being impacted by extreme temperature events. The ability of new development to withstand extreme temperature impacts can be enhanced through land use practices and consistent enforcement of codes and regulations for new construction. New development will change the landscape where buildings, roads, and other infrastructure potentially replace open land and vegetation. Extreme cold temperatures can impact pipe and utility development and may discourage development due to high cost of repairs. Growing urbanization will contribute to an increase in the urban island heat effect, which exacerbates high temperatures. Additionally, transformation of pervious surfaces (including vegetation) to impervious surfaces causes an island of higher temperatures and can lead to an increased area that can freeze and cause traffic accidents.

Changes in Population

Baltimore has experienced a decrease in its population since 2010. According to the U.S. Census Bureau, Baltimore City's population decreased by approximately 4.75 percent between 2010 and 2021 (U.S. Census 2021). Estimated population projections provided by the Maryland Department of Planning indicate that Baltimore City's population will begin to increase going into 2030, reaching a total population of approximately 596,390 persons and continue to increase into 2040 to a population of 599,220 (Maryland Department of Planning 2020). An increase in the population will increase Baltimore City's risk from extreme temperature events.

Climate Change

Climate change is affecting both people and resources in Baltimore City, and these impacts are projected to grow. Impacts specifically relating to fluctuations in extreme temperatures are being felt at the state and city levels. For the State of Maryland, extreme temperatures impact human well-being and safety, the economy, and the natural systems of the region. In Baltimore City, many of these impacts are the same. Heat exhaustion and hypothermia are just some direct impacts to human health due to extreme temperatures. Others include disruption to daily activities and businesses, decrease in tourism, altering of the natural built environment, and more. As climate change continues to have an influence on extreme temperature fluctuations in both duration and intensity, Baltimore City will experience more direct and indirect impacts in the future.

9.7.8 Change in Vulnerability Since 2018 DP3

Baltimore City continues to be vulnerable to the extreme temperature hazard. Updated population and building stock statistics were used in the current risk assessment. Further, exposure for both the population and critical facilities was analyzed. These updated datasets provide a more accurate exposure analysis to the extreme temperature hazard.

Section 10. Earthquakes

Key Changes from 2018 DP3:

- The earthquake hazard is now its own hazard profile and no longer grouped with other land- or soil-based hazards.
- The discussion on the hazard description, including location, extent, previous occurrences, and future probability, has been updated.
- The vulnerability assessment has been combined with the hazard description.
- Identification of how climate change will impact earthquake events.
- Integration of cascading and compounding impacts.
- The vulnerability assessment of population, structures, and natural, historic, and cultural resources impacted by earthquake events have been updated and expanded.
- Discussion on future changes that may impact vulnerability.

10.1 Description

Severe earthquakes can have significant risk on sudden loss of life and property. Out-of-state earthquakes can even have severe impacts on Baltimore City. In fact, Marylanders are more likely to feel out-of-state earthquakes than one within the state (Reger 2023).

Key Terms

- Earthquake— A trembling of the ground caused by the sudden movement of large sections of the earth's outer most crust (USGS n.d.).
- Tectonic Plates— A massive, irregularly shaped slab of solid rock, generally composed of both continental and oceanic lithosphere (USGS 1999).
- Tectonic Deformation— The changing of the earth's surfaces caused by tectonic forces that are accumulated in the crust and then cause earthquakes.

An earthquake is caused by the buildup of stresses stored as energy within the tectonic plates, also referred to as tectonic deformation, that is suddenly released as movement. This movement causes fractures, also known as faults in the Earth's crust. These faults generate shock waves which contribute to the devastating damage seen to communities during an earthquake event (Reger 2023).

An earthquake event is any disruption associated with an earthquake that may affect residents' normal activities. Earthquakes in Baltimore City can lead to the collapse of buildings and bridges, disrupt gas lines, electricity lines, and phone services. The severity of these impacts can be determined by a number of factors resulting from severe earthquakes, such as the amount of seismic energy released; duration of shaking; depth of focus (hypocenter); distance from epicenter; geological, geographic, and topographic setting; population and building density; and even time of day (Reger 2023).

Earthquakes often create secondary hazards such as dam failure, fire, hazardous materials release, landslide, flash flooding, avalanches, and tsunamis (USGS n.d.). Due to secondary hazards, the likelihood of deaths, injuries and extensive property damage is very high.

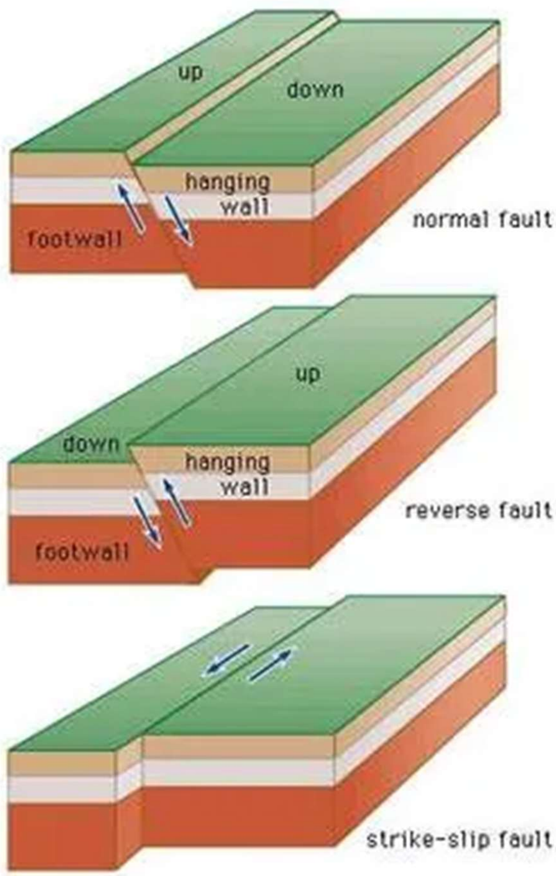
Earthquake events include surface faulting, ground motion (shaking), liquefication, tectonic deformation, tsunamis, and seiches, which are further described below.

10.1.1 Surface Faulting

Surface faulting is the differential movement of a fault line that reaches the Earth's surface. Figure 10-1 illustrates the three types of surface faults, categorized below (USGS n.d.):

- Strike-slip fault: A vertical fracture with mostly horizontal movement. A right lateral strike-slip fault is when the hanging wall (block opposite an observer) moves right of the footwall. A left lateral strike-slip fault is when the hanging wall moves left of the footwall.
- Normal fault: A vertical fracture with mostly vertical movement. Is characterized when a hanging wall moves downward relative to the footwall. The fault surface dips steeply from 45 to 90 degrees.
- Reverse (or thrust) fault: Opposite of a normal fault. A vertical fracture with mostly vertical movement. Is characterized when a hanging wall moves upwards relative to the footwall. The fault surface dips steeply from 45 to 90 degrees.

Figure 10-1. Surface Fault Types



Source: Encyclopedia Britannica, Inc., 1994

While surface faulting can result from landslides, they are more commonly caused by deep-seated forces within the Earth's crust. Some examples of these types of tectonic forces include sedimentary deposits towards the Gulf of Mexico or faulting that is associated with salt domes (USGS n.d.). Maryland does not contain any tectonic plate boundaries like other states with high seismic activity. The closest tectonic plate boundary to the State is located in the middle of the Atlantic Ocean. However, Maryland does contain old fault zones, which were created hundreds of millions of years ago during the formation of the continent. Earthquakes which occur in the state typically originate from these old fault zones (MDNR 2019).

10.1.2 Ground Motion (Shaking)

Ground motion, or ground shaking, is used to describe the vibration of the ground during an earthquake event. Generally, the severity of ground motion increases as magnitude increases and will decrease as one moves farther away from the fault line. Ground motion is caused by seismic waves and can be explained through these different types as defined below (USGS n.d.):

- Body/Surface waves: Cause the ground and buildings to vibrate.
- P waves: Propagate at a speed of 15 thousand miles per hour and are the first waves to cause vibrations in a building.
- S waves: Are the second waves following P waves. They cause buildings to vibrate from side to side, causing the most damage to structures.
- Rayleigh/Love waves: Are the last waves, following S waves. These mainly cause the ground to vibrate in a complex manner.

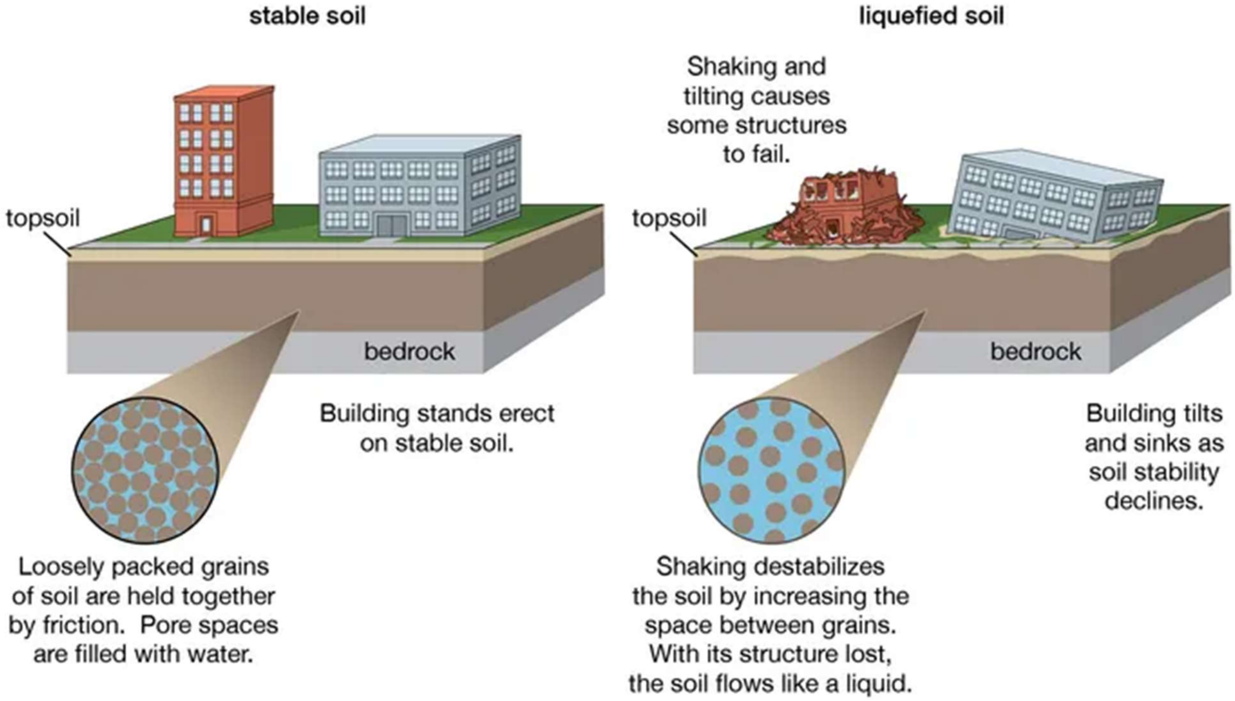
10.1.3 Liquefaction

Liquefaction occurs when loose, water-logged, sediments are displaced due to ground surface movement and the sediment loses its strength. Ground motion can cause this effect. Liquefaction susceptibility is determined by the geological history, depositional setting, and topographic position of the soil. Liquefaction effects may occur along the shorelines of the ocean, rivers, and lakes and they can also happen in low-lying areas away from water bodies in locations where the ground water is near the Earth's surface. Earthquakes can cause liquefaction beneath buildings and structures, resulting in devastating damage to property and even loss of life (USGS n.d.). Figure 10-2 illustrates the process of liquefaction due to ground movement (shaking).

10.1.4 Tectonic Deformation

Tectonic deformation, or crustal deformation, is the changing of the Earth's surface caused by the tectonic forces that occur in the crust. The Earth's lithosphere includes the crust and upper mantle, which is comprised of tectonic plates which slowly move over a period of time (NOAA n.d.). The deformation occurring on the boundaries of these tectonic plates causes earthquake events to occur (USGS 2019). There are three types of plate tectonic boundaries: divergent, convergent, and transform plate boundaries.

Figure 10-2. Process of Liquefaction

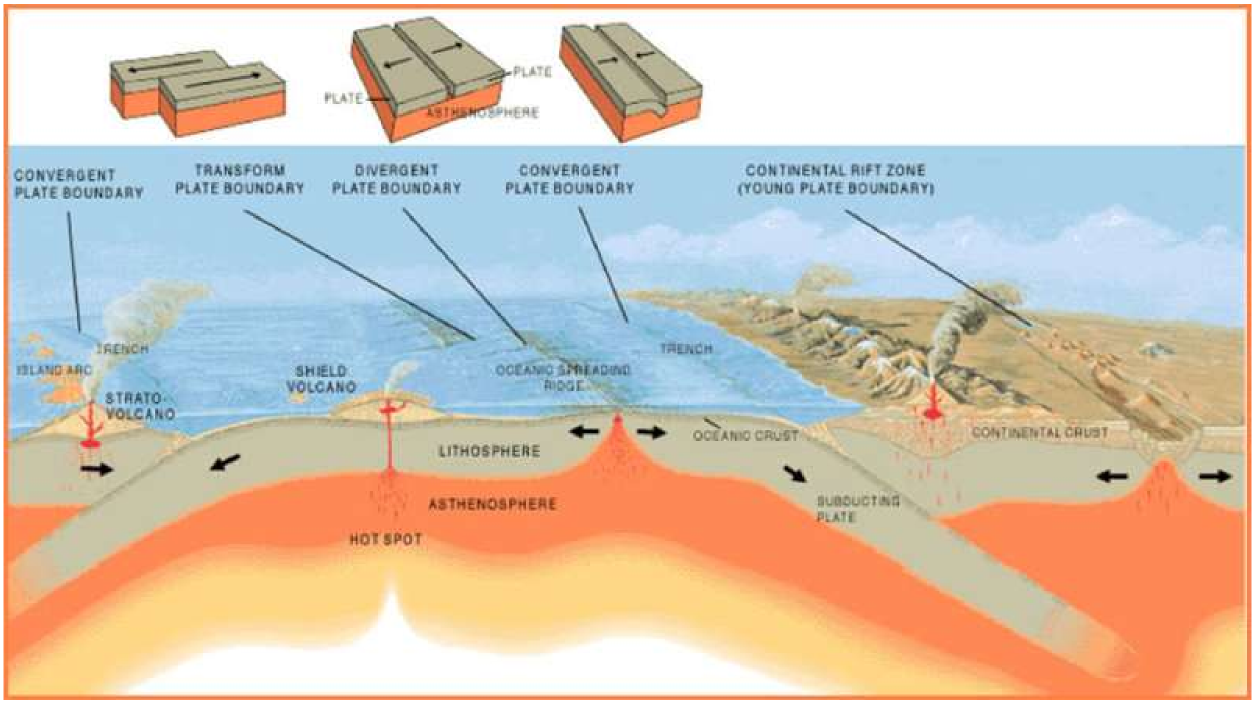


Source: Britannica, 2021

Figure 10-3 illustrates the formation of the three types of plate tectonic boundaries categorized below:

- Divergent boundary: When two tectonic plates move away from each other. Earthquakes are common along this boundary as magma rises from the Earth's mantle to the surface, solidifying into new oceanic crust. The Mid-Atlantic Ridge is a common example of a divergent plate boundary (NOAA n.d.).
- Convergent boundary: When two tectonic plates come together. The colliding plates can cause one or more plates to buckle up into a mountain range; or for one plate to bend down creating a seafloor trench. Generally, a chain of volcanoes is formed parallel to convergent plate boundaries. Powerful earthquakes are common along these boundaries. The Pacific Ring of Fire is a common example of a convergent plate boundary (NOAA n.d.).
- Transform plate boundary: When two plates slide past each other, causing the Earth's crust to crack and break at transform margins without creating or destroying lithosphere. Earthquakes are common along these fault lines. The San Andreas fault zone is a common example of a transform plate boundary (NOAA n.d.).

Figure 10-3. Types of Plate Tectonic Boundaries



Source: USGS, n.d.

10.1.5 Tsunami

Tsunamis are large waves that are caused by undersea earthquakes, major sub-marine slides, or exploding volcanic islands. An undersea earthquake is essentially the vertical movement of the sea floor causing ground motion. This ground motion of the sea floor generates large amounts of water to be displaced and rise resulting in a large wave. Tsunamis are commonly mistaken as tidal waves. Unlike tidal waves, tsunamis are not caused by tidal action of the moon or sun. Generally, the height of a tsunami is approximately 3.3 feet with a distance between wave crests of more than 60 miles. Tsunamis can cause destruction both locally and far away from the event location (USGS n.d.).

10.1.6 Seiche

A seiche is a standing wave oscillating in a body of water (NOAA 2023). It can be described as the sloshing of a closed body water, such as lake or bay, resulting from ground motion. They are generally caused when strong winds and rapid changes in the atmospheric pressure push water from one end to the other. A seiche can also result from an undersea earthquake along ocean shelves or harbors. They are often mistaken as tide events, because of the high and low characteristics of water levels during a seiche event. Seiches are also different from a meteotsunamis event, as their water oscillations occur for longer periods of time, generally more than three hours long. While meteotsunamis are progressive and last a range from two minutes to two hours in length (NOAA 2023).

10.2 Location

The State of Maryland averages less than one earthquake event per year. However, earthquakes can happen in adjacent areas, which can be felt throughout Maryland. Surrounding areas that have significantly more seismic activity that Maryland include southwestern and central Virginia and the Atlantic seaboard northward from Wilmington, Delaware (MGS n.d.).

Earthquake activity is monitored and evaluated by the Maryland Seismic Network, which provides real-time data on local earth movements and earthquakes in Maryland and other distant earthquakes around the World. Seismic data from the network are analyzed by the Lamont-Doherty Earth Observatory and included in the Lamont-Doherty Cooperative Seismic Network database. There are two monitoring stations in Maryland; they are located at Garrett College in Garrett County and Soldier's Delight in western Baltimore County (MGS n.d.).

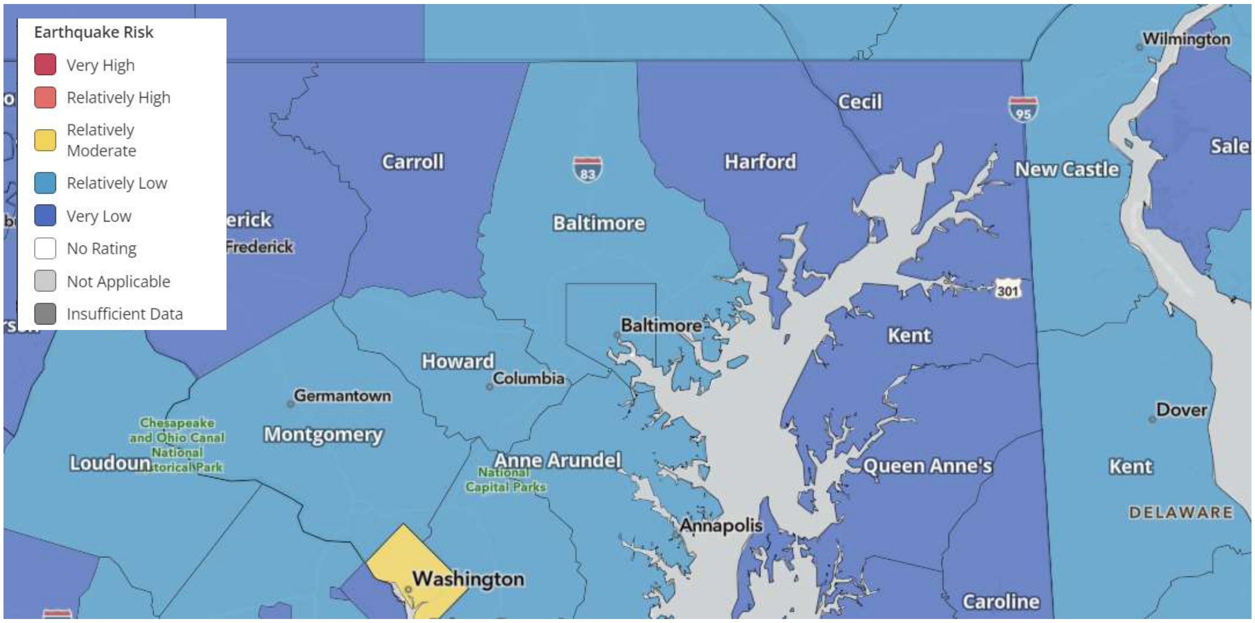
Figure 10-4 displays the Earthquake Risk Index for the United States (the black circle is representative of Baltimore City vicinity). According to the National Risk Index, on the county scale, Baltimore City has a relatively low risk to earthquakes; on the census tract scale Figure 10-5), Baltimore City ranges from a very low risk to a relatively low risk for earthquakes (FEMA 2023).

Figure 10-6 illustrates the epicenters of historic earthquakes that have occurred in and outside of the state.

National maps of earthquake shaking hazards provide information for creating and updating seismic design requirements for building codes, insurance rate structures, earthquake loss studies, retrofit priorities, and land use planning. After thorough review of the studies, professional organizations of engineers update the seismic-risk maps and seismic design requirements contained in building codes (Brown 2001). The USGS updated the National Seismic Hazard Maps in 2018. New seismic, geologic, and geodetic information on earthquake rates and associated ground shaking were incorporated into these revised maps. The 2018 map represents the best available data, as determined by the USGS. Figure 10-7 illustrates the long-term national seismic hazard map from the 2018 updated data created by the Earthquake Hazards Program (USGS 2022).

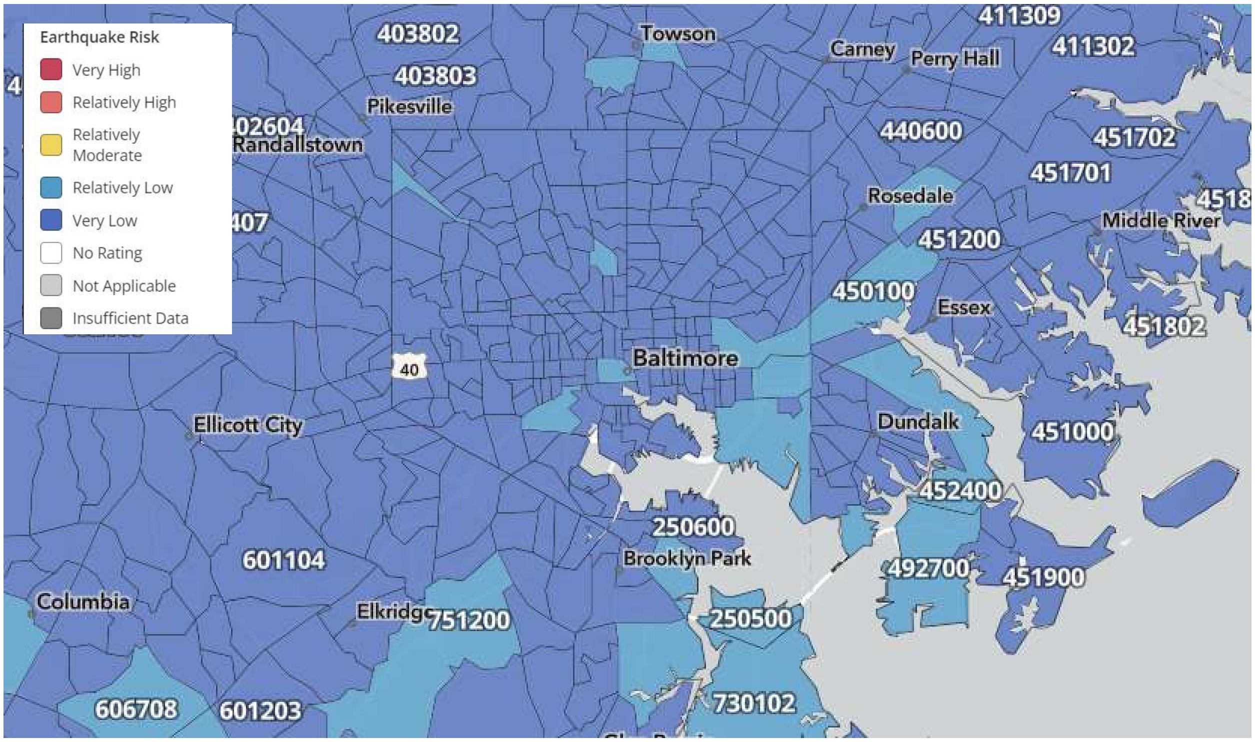
The black circle located on Figure 10-7 indicates the general area of Baltimore City, which ranks on the scale of lowest hazard to highest hazard as the second and third rating.

Figure 10-4. National Risk Index, Earthquake Hazard Risk Index Score Using the County Scale



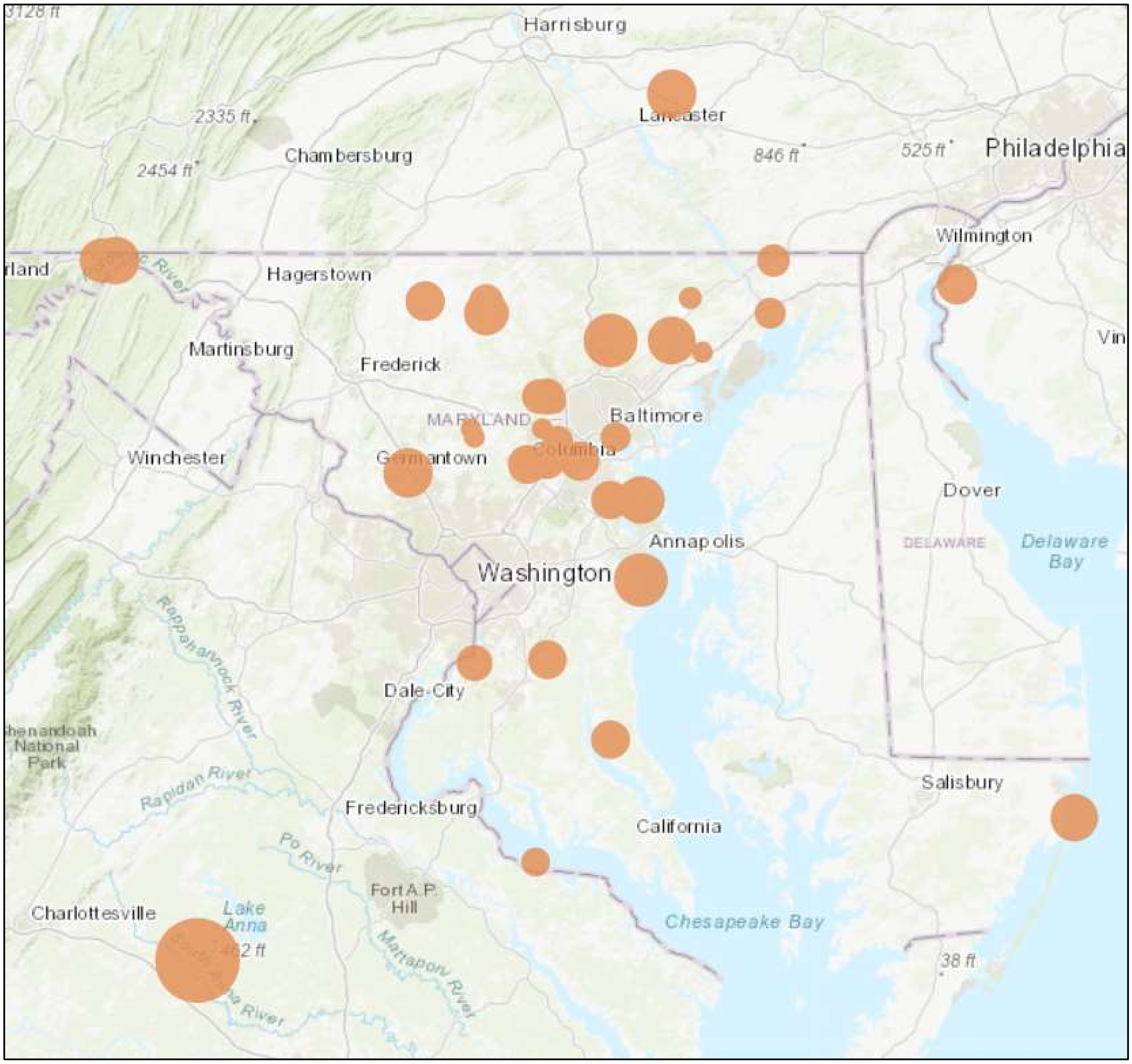
Source: FEMA 2023
Note: The vicinity of Baltimore City is within the black circle

Figure 10-5. National Risk Index, Earthquake Risk Index Score Using the Census Tract Scale



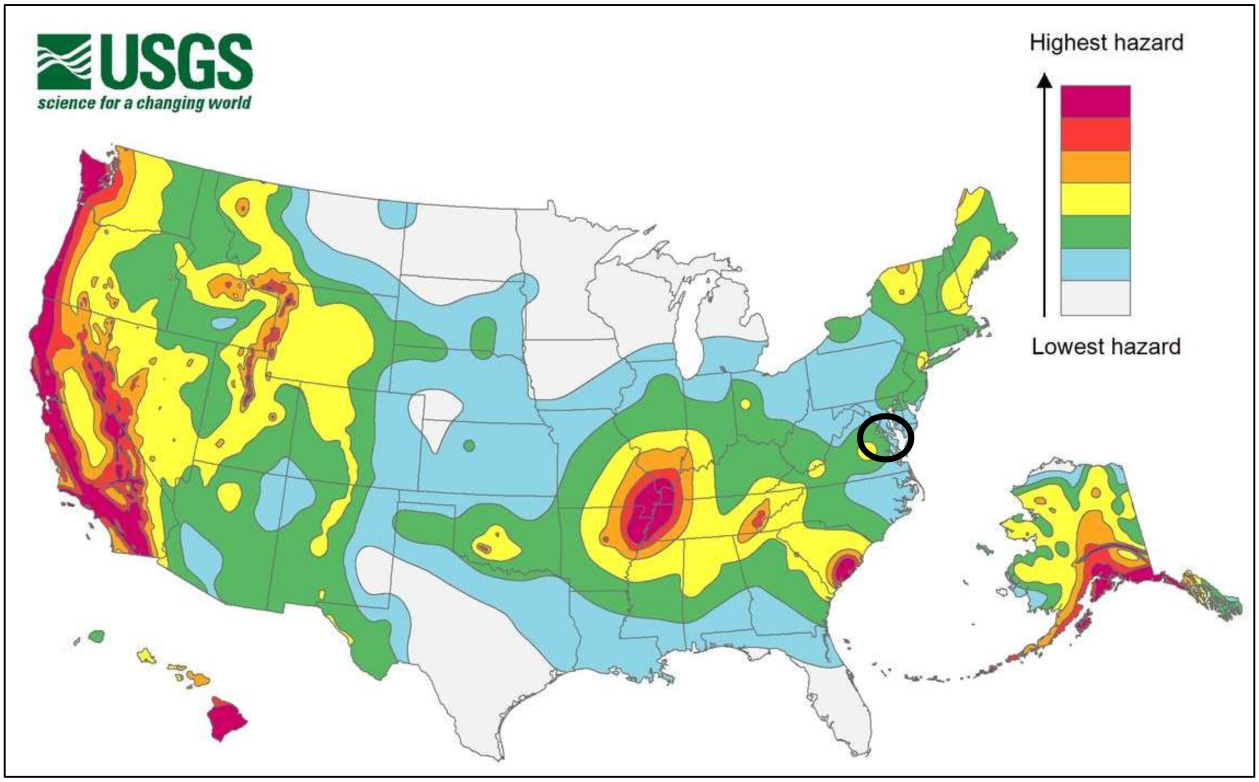
Source: FEMA 2023
Note: The vicinity of Baltimore City is within the black circle

Figure 10-6. Approximate Epicenters of Historic Earthquakes in and near Maryland



Source: MGS, n.d.

Figure 10-7. 2018 Long-Term National Seismic Hazard Map



Source: USGS 2018
Note: Black circle indicates the vicinity of Baltimore City

10.3 Extent

Earthquakes are measured in terms of their intensity and magnitude. 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 total destruction. The earthquake's magnitude is a measure of the energy released at the source of the earthquake.

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 10-1 identifies the Modified Mercalli Intensity Scale and includes the associated damage commonly seen by an earthquake's intensity (USGS n.d.).

The modified Mercalli intensity scale is generally represented visually using shake maps, which show the expected ground shaking at any given location produced by an earthquake with a specified magnitude and epicenter. An earthquake has only one magnitude and one epicenter, but it produces a range of ground shaking at sites throughout the region. This shaking depends on the distance from the earthquake, the rock and soil conditions at sites, and variations in the propagation of seismic waves from the earthquake due to complexities in the structure of the earth's crust. Figure 10-8 shows the probability of the intensity of an earthquake with a 500-year return period (10 percent probability of occurring in 50 years). For the entire City, the intensity would be rated as I – Not Felt.

Figure 10-8. 500-Year Earthquake in Baltimore City

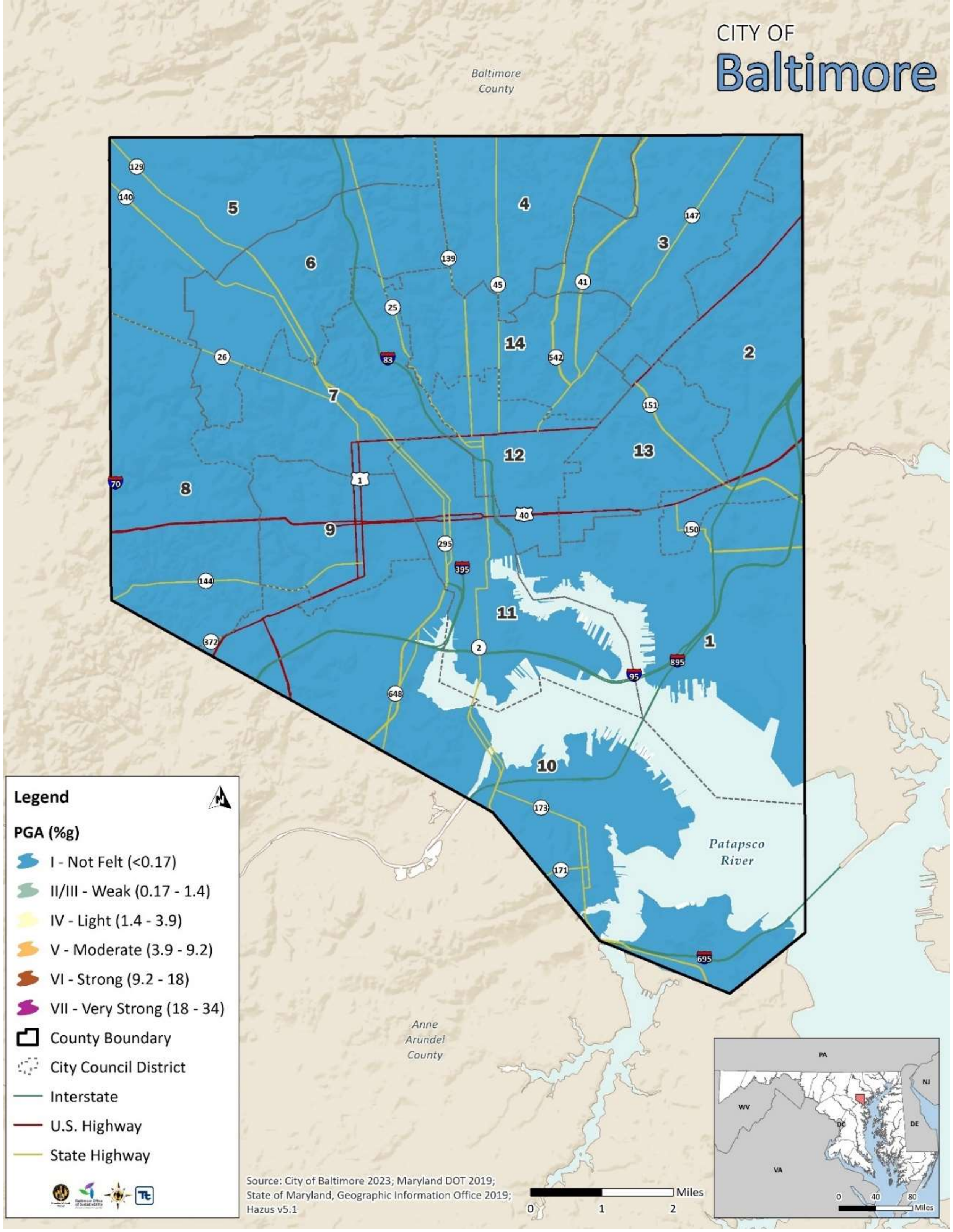


Table 10-1. Modified Mercalli Intensity Scale

Intensity	Description
I – Not Felt	Not felt, except under especially favorable conditions.
II – Weak	Felt only by a few, especially on upper floors of buildings.
III – Weak	Felt by people outdoors and on upper floors of buildings. Often not recognized as an earthquake event. Automobiles may rock slightly. Vibrations are like that of a passing truck.
IV – Light	Felt indoors by many people and outdoors by few during the day. At night, some people may wake up. Dishes, windows, and doors are disturbed. Walls will make cracking sound. Vibrations are like a heavy truck hitting a building. Automobiles will be moved noticeably.
V – Moderate	Felt by almost everyone, and many will wake up if occurrence is at night. Some dishes and windows are broken. Unstable objects are overturned, and pendulum clocks may stop.
VI – Strong	Felt by all and may be frightening event. Some heavy furniture will move. Fallen plaster may occur. Slight damage will be seen.
VII – Very Strong	Damage negligible in well-designed buildings. Considerable damage to ordinary buildings with partial collapse. Substantial damage seen to poorly built and designed structures. Some chimneys are broken.
VIII – Severe	Slight damage to specially designed structures. Considerable damage to ordinary buildings. Substantial damage seen to poorly built and designed structures. Falling of chimneys, factory stacks, columns, monuments, and walls. Heavy furniture is overturned.
IX – Violent	Considerable damage to specially designed structures. Well-designed structures thrown. Substantial damage to ordinary and poorly built structures. Partial collapse and shifting off of foundations for many buildings.
X – Extreme	Destruction of well-built wooden structures. Many masonry and frame structures are destroyed. Rails will be bent.

Source: USGS n.d.

An earthquake’s magnitude is measured based on the ground acceleration as it shakes during an earthquake. The U.S. currently utilizes the Richter Magnitude Scale to measure an earthquakes magnitude, and ranges from 1.0 (micro) to 9.9 (extreme) (Reger 2023). Table 10-2 shows the relationship between the Richter Magnitude Scale to the Modified Mercalli Intensity Scale and the associated annual incidence and distance felt in miles.

The strongest earthquake felt in the Baltimore region was a Virginia earthquake that measured on the Richter Scale as 5.8 magnitude, 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 damage (E. H. Program 2019).

The ground movement, or peak ground acceleration (PGA), during an earthquake is a measure of how hard the Earth shakes in each geographic area. It is expressed as a percentage of the acceleration due to gravity (percent g). Horizontal and vertical PGA varies with soil or rock type (USGS 2019).

Table 10-2. Relationship among Earthquake Magnitude, Intensity, Worldwide Occurrence, and Area Affected

Description	Richter Magnitude	Modified Mercalli Intensity	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, n.d.

10.4 Previous Occurrences and Losses

Many sources provided historical information regarding previous occurrences and losses associated with earthquakes throughout Baltimore City. With so many sources reviewed for the DP3, loss and impact information for many events could vary. Therefore, the accuracy of monetary figures discussed is based only on the available information in cited sources.

10.4.1 FEMA Major Disaster and Emergency Declarations

Between 1950 and 2022, the State of Maryland was not included in any earthquake-related major disaster (DR) or emergency (EM) declaration.

10.4.2 Previous Events

Although Baltimore City has not been included in a FEMA major disaster declaration for this hazard, effects of earthquake events in other areas of the state or region may still cause impacts. Table 10-3 lists the earthquake event impacts felt within a 200-mile radius of Baltimore City.

Table 10-3. Earthquake Events Felt Within 200 Miles of Baltimore City

Date of Event	Event Type	Description
September 7, 1962	Earthquake	Located in Hancock with a recorded magnitude of 3.1 on the Richter Scale.
April 26, 1978	Earthquake	Located in Hancock with a recorded magnitude of 3.3 on the Richter Scale.
April 23, 1984	Earthquake	Located in Lancaster County, Pennsylvania. A recorded magnitude of 4.4 on the Richter Scale.
May 23, 1986	Earthquake	Located in Accokeek, with a recorded magnitude of 2.5 on the Richter Scale.
January 13, 1990	Earthquake	Located in Randallstown with a recorded magnitude of 2.6 on the Richter Scale.
April 4, 1990	Earthquake	Located in Granite with a recorded magnitude of 1.7 on the Richter Scale.

Date of Event	Event Type	Description
September 28, 1991	Earthquake	Located in Granite, with a recorded magnitude of 2.4 on the Richter Scale.
March 10, 1993	Earthquake	Located in Columbia, with a recorded magnitude of 2.5 on the Richter Scale.
March 12, 1993	Earthquake	Located in Columbia, with a recorded magnitude of 2 on the Richter Scale.
March 15, 1993	Earthquake	Located in Columbia, with a recorded magnitude of 2.7 on the Richter Scale.
March 16, 1993	Earthquake	Located in Columbia, with a recorded magnitude of 1.8 on the Richter Scale.
March 17, 1993	Earthquake	Located in Columbia, with a recorded magnitude of 1.0 on the Richter Scale.
March 19, 1993	Earthquake	Located in Columbia, with a recorded magnitude of 1.0 on the Richter Scale.
March 21, 1993	Earthquake	Located in Aberdeen, with a recorded magnitude of 1.5 on the Richter Scale.
March 26, 1993	Earthquake	Located in Ellicott City, with a recorded magnitude of 1.5 on the Richter Scale.
April 4, 1993	Earthquake	Located in Columbia, with a recorded magnitude of 1.5 on the Richter Scale.
April 8, 1993	Earthquake	Located in Columbia, with a recorded magnitude of 1.5 on the Richter Scale.
April 9, 1993	Earthquake	Located in Columbia, with a recorded magnitude of 1.9 on the Richter Scale.
September 12, 1993	Earthquake	Located in Columbia, with a recorded magnitude of 2.1 on the Richter Scale.
November 17, 1993	Earthquake	Located in Columbia, with a recorded magnitude of 1.5 on the Richter Scale.
November 27, 1993	Earthquake	Located in Columbia, with a recorded magnitude of 1.7 on the Richter Scale.
January 16, 1994	Earthquake	Located in Pennsylvania, with a recorded magnitude of 4.6 on the Richter Scale.
October 28, 1994	Earthquake	Located in Glen Burnie, with a recorded magnitude of 2.7 on the Richter Scale.
August 2, 1996	Earthquake	Located in Perryville, with a recorded magnitude of 2.2 on the Richter Scale.
October 17, 1996	Earthquake	Located in Rising Sun, with a recorded magnitude of 2.3 on the Richter Scale.
December 6, 1996	Earthquake	Located in Columbia, with a recorded magnitude of 1.5 on the Richter Scale.
December 14, 1996	Earthquake	Located in Columbia, with a recorded magnitude of 1.5 on the Richter Scale.
December 16, 1996	Earthquake	Located in Ellicott City, with a recorded magnitude of 1.0 on the Richter Scale.
December 22, 1996	Earthquake	Located in Columbia, with a recorded magnitude of 2.3 on the Richter Scale.
September 25, 1998	Earthquake	Located in Pennsylvania, with a recorded magnitude of 4.5 on the Richter Scale.

Date of Event	Event Type	Description
December 18, 2001	Earthquake	Located in Columbia, with a recorded magnitude of 2.0 on the Richter Scale.
March 22, 2002	Earthquake	Located in Columbia, with a recorded magnitude of 2.0 on the Richter Scale.
August 26, 2003	Earthquake	Located in New Jersey, with a recorded magnitude of 3.8 on the Richter Scale.
December 9, 2003	Earthquake	Located in Virginia, with a recorded magnitude of 4.5 on the Richter Scale.
February 23, 2005	Earthquake	A magnitude 2.1 earthquake occurred in southeast Baltimore, near Fort McHenry, Dundalk, Glen Burnie, Pasadena, and Gambrills. The earthquake had a recorded intensity of IV on the Modified Mercalli Scale.
July 1, 2009	Earthquake	Located in southwest New Jersey, with a recorded magnitude of 2.8 on the Richter Scale.
September 29, 2009		Located in Bel Air, with a recorded magnitude of 1.6 on the Richter Scale.
July 16, 2010	Earthquake	Located in the Potomac Region with a recorded magnitude of 3.4 on the Richter Scale.
August 23, 2011	Earthquake	A 5.8 magnitude earthquake occurred in Virginia, causing damage and ground shaking in Baltimore City. The Baltimore Basilica had damage up to $5 million.
October 30, 2017	Earthquake	Located in Glenelg with a recorded magnitude of 1.52 on the Richter Scale.
November 11, 2017	Earthquake	Located 0.5 miles east of Roxbury. Recorded with a magnitude of 1.5 on the Richter Scale.

Source: MGS, n.d.; 2018 Baltimore DP3
Note: With so many sources reviewed for this plan update, loss and impact information for many events could vary. Therefore, the accuracy of monetary figures discussed is based only on the available information in cited sources in relation to Baltimore City specifically.

10.5 Probability of Future Hazard Events

For the 2023 DP3 update, the most up-to-date data was collected to calculate the probability of future occurrence of earthquake events for Baltimore City. Table 10-4 shows the probability of future earthquake events in Baltimore City. Information from the Maryland Geological Survey (MGS) database and the 2018 Baltimore DP3 were used to identify the number of earthquake events that occurred between 1962 and 2017. It is important to note that these are probabilities and even though a hazard may show no probability of occurrence, this does not mean it cannot or will not still occur in the hazard area.

Table 10-4. Occurrence of Earthquake Events and Impacts Felt

Hazard Type	Number of Occurrences Between 1962 and 2017	% Chance of Occurrence in Any Given Year
Earthquake	0	0%
Earthquake Impacts Felt	41	56.9%

Source: MGS, n.d.; 2018 Baltimore DP3.
Note: With so many sources reviewed for this plan update, loss and impact information for many events could vary. Therefore, the accuracy of monetary figures discussed is based only on the available information in cited sources in relation to Baltimore City specifically.

Earthquakes cannot be accurately predicted and can occur any time of the day or year. Major earthquakes are infrequent in Baltimore City and can occur once every few hundred years or longer. However, the consequences of major earthquakes can be very high; and although not many occur within Baltimore City itself, earthquakes located in other regions have a high likelihood of impacting Baltimore City.

Landslides and land slumping may contribute to, or heighten, the probability of earthquake events in Baltimore. Landslides often occur along steep slopes, karst terrain 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. Refer to Section 11 (Soil Movement) for more information on landslide events.

In Section 3, the identified hazards of concern for Baltimore City were ranked. The probability of occurrence, or likelihood of the event, is one parameter used for hazard rankings. Based on historical records and input from the Planning Committee, the probability of occurrence for soil movement events is considered ‘rare’ (10 to 100-percent chance occurring in any given year).

10.6 Potential Impacts of Climate Change

Climate temperatures are rising due to high amounts of greenhouse gases in the atmosphere absorbing the sun’s energy and warming the environment. The Intergovernmental Panel on Climate Change (IPCC) provides evidence for this phenomenon in the latest IPCC report on global warming (IPCC 2021). Global temperatures are expected to rise by 2.7 degrees Celsius by the end of the century. In fact, the seven warmest years on record have all occurred in the last decade. The year 2020 is the second warmest year, with 2016 being the warmest. Although the climate is always changing, the rate at which global warming is taking place is unprecedented.

The impacts of global climate change on earthquake probability are unknown. Some scientists say that melting glaciers could induce tectonic activity (Simon 2021). Large land-based ice sheets and mountain glaciers are melting at alarming rates due to rising global temperatures. As ice melts and water runs off, tremendous amounts of weight are shifted on the earth’s crust. As newly freed crust returns to its original, pre-glacier shape, it could cause seismic plates to slip and stimulate volcanic activity. NASA and USGS scientists found that retreating glaciers in southern Alaska may be opening the way for future earthquakes (NASA 2004).

Secondary impacts of earthquakes can also be magnified by climate change. Soils saturated by repetitive storms may experience liquefaction during seismic activity due to increased saturation. Dams storing increased volumes of water due to changes in the hydrograph could fail during these seismic events. However, there are currently no models available to estimate these impacts.

10.7 Vulnerability Assessment

To understand risk, a community must evaluate what assets are exposed or vulnerable in the hazard area. The entire City has been identified as exposed for the earthquake hazard.

Therefore, all assets in Baltimore City (population, structures, critical facilities, and lifelines), as described in Baltimore City Profile (Section 2), are exposed and potentially vulnerable.

10.7.1 Impacts on Population

The entire population of Baltimore City is vulnerable to the impacts of earthquake events due to the high population density. Risk and vulnerability for earthquake hazards are dependent upon the population density, critical infrastructure, and mitigation actions and plans implemented within the community. Areas near the Patapsco River, which is a major waterbody adjacent to the coastal areas of Baltimore City, are also at risk for secondary hazard events such as flood and storm surge. There is higher risk for those located inside buildings, due to structural damage, or people walking below buildings ornamentation and chimneys that may be loose and fall as a result of an earthquake.

Residents may be displaced or require temporary or long-term sheltering. The number of people requiring shelter is generally less than the number displaced as some displaced persons use hotels or stay with family or friends following a disaster event.

Table 10-5 shows the total population for Baltimore City and for each City Council District. There are 591,489 people who are exposed to earthquake hazards in Baltimore City. District 11 has the highest population with over 48 thousand vulnerable to earthquake hazards. Table 10-5 also breaks down the population into groups who may have a higher vulnerability due to economic and social factors, such as: Persons over the age of 65; under the age of 5; non-English speaking; and those with disabilities. These populations may have a higher overall vulnerability to earthquake events than the general population, refer to subsection 9.15.1.1 Impacts on Socially Vulnerable Populations and Underserved Communities for more information.

Table 10-5. Total Population for Baltimore City

City Council District	Total Population	Over 65 Years	Under 5 Years	Non-English Speaking	Disability
1	43,739	4,481	3,344	1,141	4,200
2	45,252	5,528	3,009	1,376	5,394
3	42,257	5,988	1,669	470	5,485
4	45,027	6,401	3,113	371	5,601
5	43,601	8,122	3,762	1,176	6,613
6	41,604	8,355	2,356	546	7,741
7	39,638	6,177	1,895	349	7,764
8	46,396	7,799	2,947	392	8,376
9	35,869	4,927	2,024	641	8,523
10	41,521	4,755	3,468	1,054	7,685
11	48,022	5,774	2,182	907	6,231
12	37,130	4,203	1,690	575	6,388
13	38,768	4,701	2,684	582	6,814
14	42,664	6,316	2,324	702	5,891
Baltimore City (Total)	**591,489**	**83,527**	**36,468**	**10,283**	**92,707**

Source: U.S. Census Bureau 2021, ACS
Note: Persons per household = 2.32. Number used to calculate Non-English-Speaking population.

Impacts on Socially Vulnerable Populations and Underserved Communities

Populations most at risk are those located in the built environment, particularly near unreinforced masonry construction. In addition, the vulnerable population includes persons over 65, which account for 14.5 percent of Baltimore City population and individuals experiencing economic hardships, which accounts for 19.5 percent of Baltimore City population (U.S. Census 2021). These socially vulnerable populations are most susceptible, based on a number of factors including their physical and financial ability to react or respond during a disaster, and the location and construction quality of their homes.

Table 10-5 shows the total population of groups who may have a higher vulnerability due to economic and social factors, such as: Persons over the age of 65; under the age of 5; non-English speaking; and those with disabilities. In Baltimore City there are over 83 thousand peoples over the age of 65, and 36,468 who are under the age of 5 years old. For those with disabilities, there are over 92 thousand; and 10,283 of the population is considered non-English speaking. This population may have increased vulnerabilities due to need for careful transportation and medical supplies, or lack of communication for safety measures during a hazard event.

Homelessness in Baltimore City is a great concern, as these populations are significantly at risk from hazards due to their exposure and general lack of a structurally sound structure. The Point-in-Time (PIT) Count is a federally mandated survey conducted annually that seeks to determine how many people are experiencing homelessness on any given night in Baltimore City. In 2022, the PIT Count revealed a total of 1,597 people were counted in emergency shelters, transitional housing, and unsheltered spaces such as encampments. This is down from 2,193 people in 2020 and follows a four-year downward trend (Baltimore City 2022). The 2023 PIT occurred in January of 2023; however, the results have not yet been made public.

10.7.2 Impacts on Structures

General Building Stock

All buildings are exposed to the earthquake hazard. Refer to Section 3 (Risk Assessment), which summarizes the building inventory in Baltimore City. Earthquakes often create secondary hazards such as landslides, sink holes, coastal flooding/waves that will impact buildings within Baltimore City. In major earthquake events, buildings will be demolished and impacted by falling debris. Secondary hazards following an earthquake, such as landslides and sinkholes, will also create disturbances from falling debris or unstable ground. Additionally, property located within underserved communities has a higher potential for total loss during earthquake events. Underserved communities may not have the resources and materials to build structures strong enough to withstand severe earthquake events, as well as to rebuild after an event occurs.

For the purpose of this DP3 update, the general building stock was categorized in four major occupancy classes: residential (single and multi-family dwellings); commercial buildings; industrial buildings; government, religion, agricultural, and education buildings. Table 10-6 shows the total number of buildings by occupancy class with the severity of expected damage as a result of a 500-year earthquake.

Table 10-6. Total Buildings in Severity of Expected Damage for a 500-year Earthquake

Occupancy Class	Total Number of Buildings in Occupancy	Severity of Expected Damage - Minor	Severity of Expected Damage - Moderate	Severity of Expected Damage - Severe
Residential Exposure (Single and Multi-Family Dwellings)	211,043	648	29	0
Commercial Buildings	13,970	117	22	2
Industrial Buildings	746	22	8	1
Government, Religion, Agricultural, and Education Buildings	2,096	25	7	1

Source: Hazus v5.1

According to the Hazus data, residential dwellings had the highest total number of buildings damaged: 211,043 buildings for a 500-year earthquake. Residential dwellings also had the highest total number of buildings with minor damage (648) and buildings with moderate damage (29). Commercial buildings had the highest total number of buildings experiencing severe damage due to a 500-year earthquake out of all the occupancy classes identified.

Critical Facilities, Infrastructure, and Community Lifelines

Critical Facilities

All critical facilities are exposed to earthquake hazards. Destruction of facilities, which are vital to the safety of residents, could result in delayed impacts after the hazard event. For example, structural damage to hospitals or safety shelters within Baltimore City, could result in untreated injuries or even loss of life. Damage to first responder facilities could also lead to delayed emergency responses, increasing the overall risk for the community.

For the purpose of the DP3, the critical facilities that were identified are: medical facilities; emergency operation center (EOC); police stations; fire stations; and schools. Table 10-7 shows the percent of critical facilities with a probability of damage severity for a 500-year earthquake. According to the Hazus data, all four critical facilities identified had up to 0.04% probability of extensive damage. Medical facilities, fire stations, and schools had the highest probability of up to 0.5% for moderate damage; and medical facilities and fire stations had the highest probability of up to 1.8% for slight damage due to a 500-year earthquake.

Table 10-7. Percent of Critical Facilities with a Probability of Severity to a 500-Year Earthquake

Type	Slight	Moderate	Extensive
Medical Facilities	0.03% - 1.8%	0% - 0.5%	0.0% - 0.04%
Emergency Operation Center (EOC)	1.1% - 1.6%	0.3% - 0.4%	0.02% - 0.04%
Police Stations	0.8% - 1.6%	0.2% - 0.43%	0.01% - 0.04%
Fire Stations	0.8% - 1.8%	0.2% - 0.5%	0.01% - 0.04%
Schools	0.8% - 1.7%	0.2% - 0.5%	0.01% - 0.04%

Source: Hazus v5.1

Critical Infrastructure

All critical infrastructure is exposed to earthquake hazards. Impacts on transportation infrastructure include blockages, road closures, and road washouts. Secondary impacts to transportation networks are increased commute times, traffic congestion in re-routed areas, and prevention of emergency personnel from responding to incidents. For the purpose of the DP3, critical infrastructure that was identified includes: highway bridges; light rail; communication (phone towers and lines); electrical power (power lines and boxes); oil facilities; potable water; and wastewater.

Table 10-8 shows the percent of critical infrastructure with a probability of damage severity for a 500-year earthquake. Electrical power has the highest probability of extensive damage as a result from a 500-year earthquake event at up to 0.08%. Communication has the highest probability for moderate damage, at up to 0.9% and up to 2.1% for slight damage.

Table 10-8. Percent of Critical Infrastructure with a Probability of Severity to a 500-Year Earthquake

Type	Slight	Moderate	Extensive
Highway Bridges	0%	0%	0%
Light Rail	0.2% - 0.5%	0% - 0.01%	0%
Communication	0.8% - 2.1%	0.2% - 0.9%	0.01% - 0.06%
Electrical Power	0.5% - 1.0%	0.2% - 0.6%	0.03% - 0.08%
Oil Facilities	0.6% - 0.9%	0.3% - 0.5%	0.04% - 0.07%
Potable Water	1.2% - 1.3%	0.30%	0.02%
Wastewater	0.8% - 1.8%	0.2% - 0.5%	0.01% - 0.04%

Source: Hazus v5.1

Community Lifelines

Community lifelines enable the continuous operation of critical business and government functions and are essential for human health and safety as well as economic security (FEMA 2019). Community lifelines can be defined as any structure which is critical to the safety of the people within Baltimore City during and after a hazard event. This could include transportation measures such as major highways, ports, and railways; it could also include communication systems such as phone towers, satellites, radios, and mass notification systems. When a community lifeline is down, risk to the hazard event is increased. Earthquake impacts have the potential to damage or interrupt a community lifeline from functioning properly, increasing Baltimore City's overall risk to the hazard during and after an event.

Table 10-9 shows the level of severity based on the average time of day for a 500-year earthquake event. When community lifelines are down, there are higher chances of injuries and hospitalizations which can go untreated. According to the Hazus data, injuries and hospitalizations are more likely to occur in the early afternoon. This could be due to community lifeline interruptions resulting in impacts seen to the communities after the event has occurred.

Table 10-9. Average Time of Day for Level of Severity for a 500-Year Earthquake

Level of Severity	2:00 AM	2:00 PM	5:00 PM
Injuries	2	11	4
Hospitalizations	0	1	0

Source: Hazus v5.1

10.7.3 Impacts on the Economy

Earthquake events have significant economic impacts by resulting in substantial damage costs and interruption to daily business activity. According to the Hazus results, the total cost of economic building loss to a 500-year earthquake event is over $23 million. Other additional costs include over $4 million in rental losses, $1.7 million in capital-related losses, over $2 million in wages lost, and almost $7.5 in relocation losses for a 500-year earthquake event. These estimated costs are high total business interruption losses and can result in a longer timeframe for Baltimore City to bounce back economically from an earthquake.

10.7.4 Impacts on Natural, Historic, and Cultural Resources

Earthquakes can impact the environment because they can cause destructive ground movement resulting in organic and inorganic debris. Debris from buildings and structures which are inorganic can negatively impact the environment by polluting critical habitat. Destructive ground shaking can also cause mass destruction of Baltimore City's historical infrastructure. Many of the historical buildings and homes are not built with strong foundations to withstand earthquakes and are more vulnerable than other infrastructure.

Due to the developed nature of Baltimore City, all historic and cultural resources are susceptible to impacts from earthquakes. These resources may be impacted in the same manner as the general building stock and critical facilities. In 2011, the Basilica of the Assumption was damaged by a 5.8 magnitude earthquake resulting in repairs to dome of the Basilica. The repairs took two years.

Tree canopy is also affected by earthquake events through high intensity ground movement. The downing of trees and flattening of foliage due to debris can limit the shade area available in Baltimore City, further exacerbating other hazards such as extreme temperature (refer to section 9).

10.7.5 Cascading and Compounding Impacts

Earthquake hazard events can exacerbate soil movement events such as landslides and sinkholes and increase the chance of flooding events. Earthquakes create debris which will move into nearby rivers, bays, creeks, and other bodies of water which will create blockage and spill over onto roadways, causing road blockages and closures.

10.7.6 Future Changes that May Impact Vulnerability

It is important to understand future projections that may impact Baltimore City's overall vulnerability to earthquakes. This understanding could benefit the future development planning efforts within Baltimore City and ensure that sound mitigation and preparedness measures are in place.

Changes in Land Use and Development

All land use and development areas within Baltimore City are at risk from earthquake events. Updates to building codes and regulations may help to lessen risk to development. As well, new development and land use practices should consider incorporating response action plans or integrative technology into their plans to lessen impacts from extreme earthquake and ground shaking aftermath events. The continuation of high-rise building development in urban areas may increase the vulnerability to this hazard.

Changes in Population

Baltimore has experienced a decrease in its population since 2010. According to the U.S. Census Bureau, Baltimore City's population decreased by approximately 4.75 percent between 2010 and 2021 (U.S. Census 2021). Estimated population projections provided by the Maryland Department of Planning indicate that Baltimore City's population will begin to increase going into 2030, reaching a total population of approximately 596,390 persons and continue to increase into 2040 to a population of 599,220 (Maryland Department of Planning 2020).

The overall anticipated increase in population for Baltimore City will heighten the threat of earthquake hazards and the impact on life. As the population continues to grow, Baltimore City may need to increase available resources and assess ways to implement more foundationally sound infrastructure. The groups most vulnerable to the hazard will likely increase, especially if total population of Baltimore City increases. The geographic and topographic areas most vulnerable to the earthquakes will remain the same, but the population exposed will increase.

Climate Change

Climate change is affecting both people and resources in Baltimore City, and these impacts are projected to grow. Although impacts of climate change on earthquake probability are unknown, climate change still influences other hazards such as sea level rise induced flooding, extreme temperatures, or drought. If co-occurring, these hazards have the potential to increase the general population's overall vulnerability to earthquake hazard events. The likelihood of a population's ability to bounce back after an earthquake event is lessened when also exposed to other hazard events influenced by climate change. An example would be the lack of resources and first response aid which are common following a hazard event.

10.7.7 Change in Vulnerability Since 2018 DP3

Baltimore City continues to be vulnerable to earthquake hazards. Updated population and building stock statistics were used in the current risk assessment. Further, exposure for both the population and critical facilities was analyzed. These updated datasets provide a more accurate exposure analysis for the hazard.

Section 11. Soil Movement

Key changes reflected in the 2023 DP3 update:

- This section now includes the following types of soil movement: land subsidence, landslide, and sinkhole. Earthquake is now a standalone hazard addressed in Section 10.
- The hazard description, including location, extent, previous occurrences, and future probability, has been updated.
- The vulnerability assessment has been combined with the hazard description. The vulnerability assessment addresses the impacts to population, structures, and natural/historic/cultural resources.
- Information has been added about integration of cascading and compounding impacts.
- Information has been added about how climate change will impact the soil movement hazard.

11.1 Description

Baltimore City, while not overtly susceptible to extreme soil movement occurrences, has experienced significant landslide and sinkholes events in the past, with a single event costing more that $18.5 million in repairs to Baltimore City (NBC Washington 2014).

Key Terms

- Land Subsidence—Gradual settling or sinking of the Earth's surface (USGS n.d.).
- Landslide—Movement of a mass of rock, debris, or earth down a slope (USGS n.d.).
- Sinkhole—A depression in the ground that has no natural external surface drainage (USGS n.d.).
- Urban Karst—Networks of human-made subsurface pathways (e.g., stormwater and sanitary sewer pipes) and associated high permeability trenches (Bonneau, et al. 2017).
- Karst Aquifers—Vital groundwater resource in the United States. About 40% of the groundwater used for drinking comes from karst aquifers (USGS 2021).

Soil movement refers to the movement of soils from one location to another. This movement may be gradual or sudden and can range in extent. Due to the varying range of extent, the various types of soil movement are often measured through global positioning systems (GPS) that track changes in the soil height. Additionally, ground and water sensors are utilized to track changes. Soil movement is often caused by aquifer system compaction, drainage of organic soils, underground mining, hydro-compaction, natural compactions, sinkholes, and thawing permafrost. Soil movement can also be caused by natural events such as earthquakes, soil compaction, glacial isostatic adjustments, erosion, and adding water to fine soils deposited by wind (loess deposits) (NOAA n.d.).

For the purpose of the DP3, and as deemed appropriate by the CPT, soil movement includes land subsidence, landslides, sinkholes, and urban karst. These types of soil movement are discussed below.

11.1.1 Land Subsidence

Land subsidence is a gradual settling or sudden sinking of the Earth's surface due to removal and displacement of subsurface earth materials. Subsidence is one of the most diverse forms of ground failure, ranging from small or local collapses to broad regional lowering of the Earth's surface. The principal causes are mostly due to human activities and include but are not limited to:

- Aquifer-system compaction associated with groundwater withdrawals
- Drainage of organic soils
- Fracking and underground mining
- Earthquakes and erosion
- Natural compaction or collapse
- Expansive soils
- Mining activities (USGS 2019)

Consequences of land subsidence include:

- Reduces the ability to store water in an aquifer
- Partially or completely submerges land
- Collapses water well casings
- Disrupts collector drains and irrigation ditches
- Alters the flow of creeks, which may increase the frequency and severity of flooding
- Damages roadways, bridges, building foundations, and other infrastructure

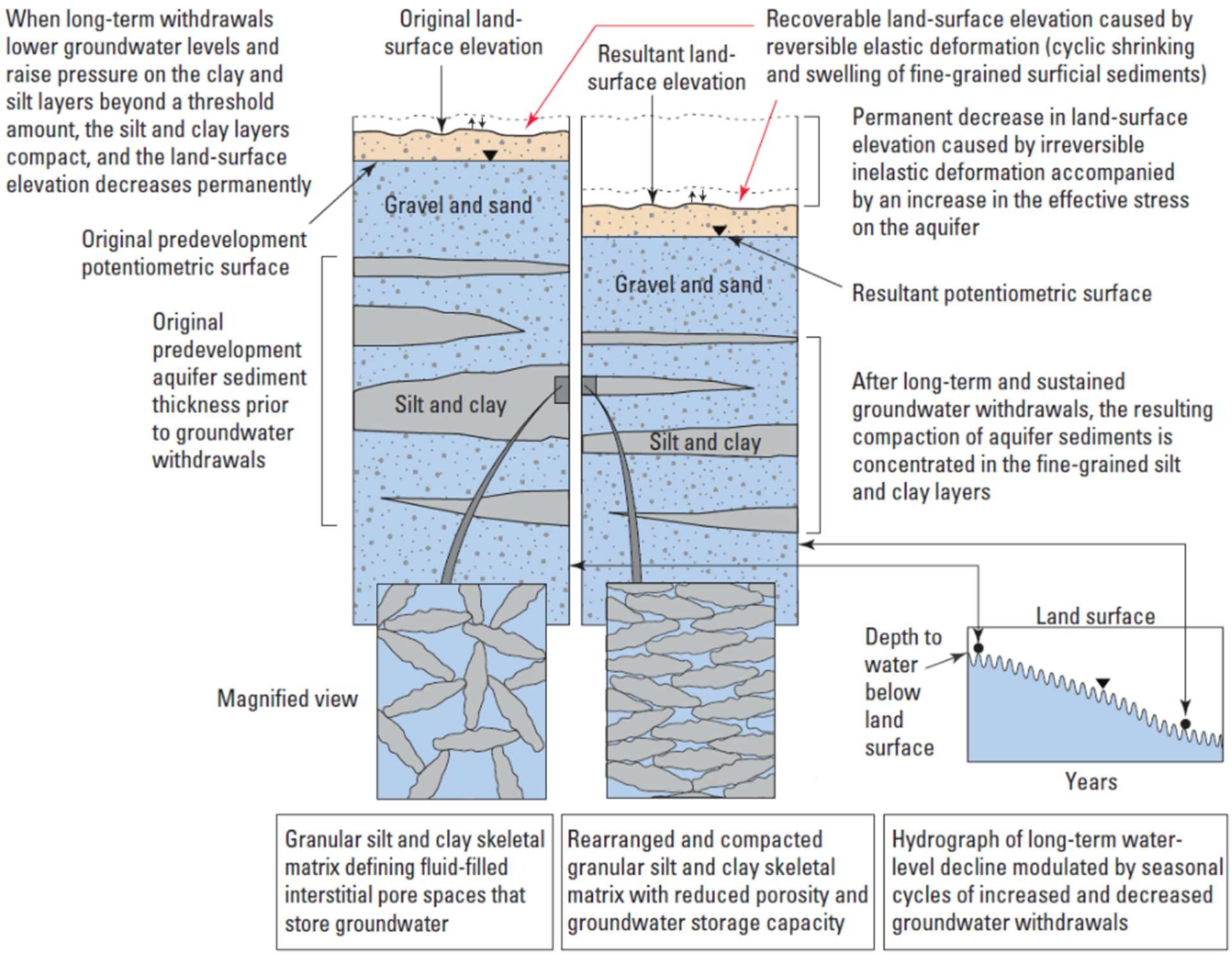
Land subsidence occurs on karst terrain, which is generally underlain by limestone or dolomite, in which the topography is formed chiefly by the dissolving of rock which may be characterized by sinkholes, sinking streams, closed depressions, subterranean drainage, and caves (USGS 2018). Figure 11-1 below illustrates the land subsidence process, wherein soil layers become compacted and unstable due to the loss of groundwater.

11.1.2 Landslides

A landslide consists of mass movements of soil and/or rock down a slope due to gravity and usually water. Slips, slumps, rock falls, slides, flows, and creep are terms used by geologists to identify specific mechanisms and velocities for mass movement (USGS 2022). Many factors cause landslides and rockfalls, but water and human activity are the most prevalent in Baltimore City.

- **Water:** Intense rainfall, changes in groundwater level, and water level changes along coastlines, earthen dams, and the banks of lakes, reservoirs, and rivers are the primary triggers of landslides.
- **Seismic Activity:** Earthquakes in landslide-prone areas greatly increase the likelihood that landslides will occur, either due to ground shaking alone or shaking-caused dilation of soil materials.

Figure 11-1. The Subsidence Process



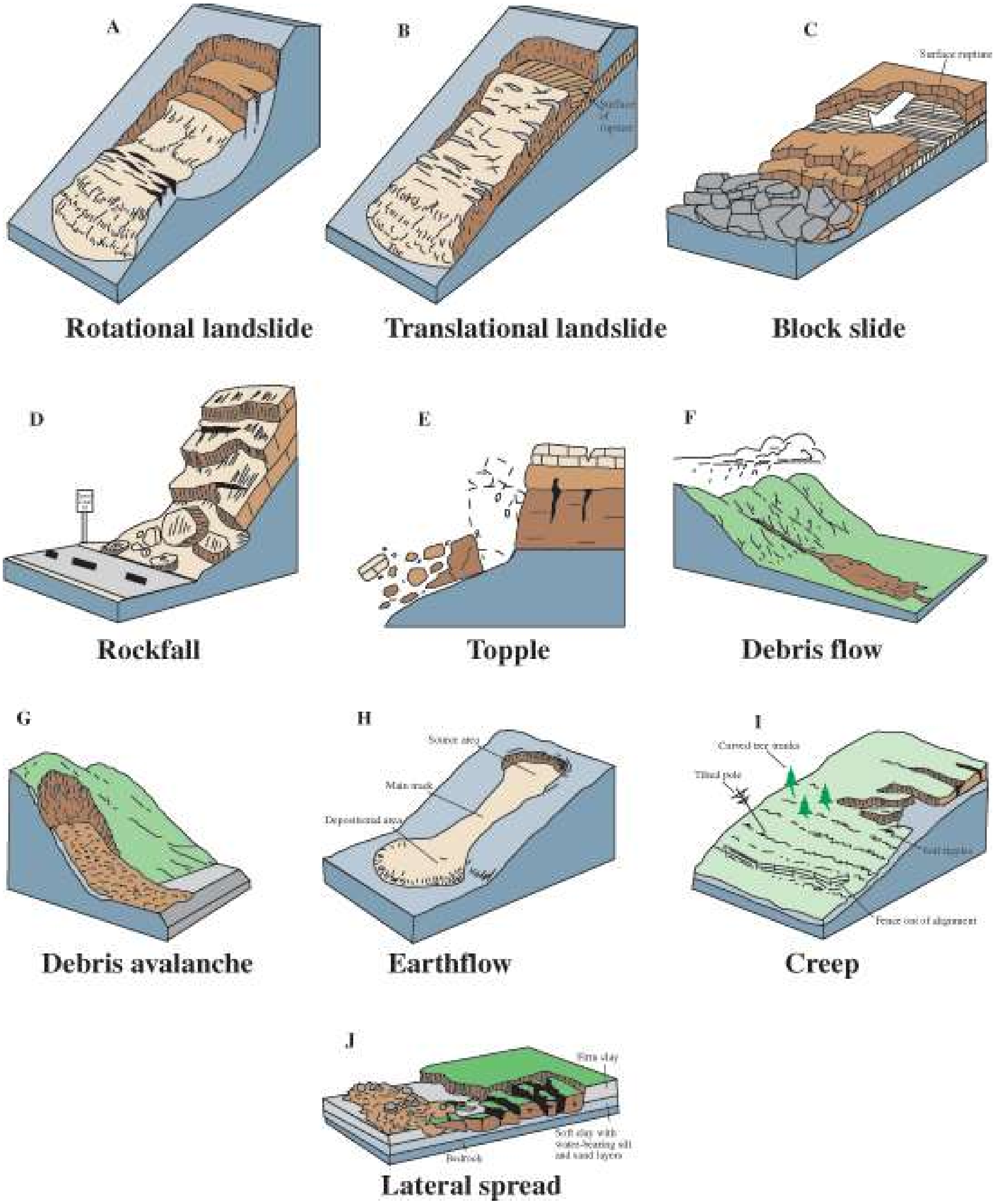
Source: USGS n.d.

- **Mining:** Huge amounts of vibrations, including blasting, reach yards under the soil surface, which poses a greater threat to areas that are already at risk of sliding.
- **Human Activity:** Landslides may result directly or indirectly from human activities. Construction activity that undercuts or overloads dangerous slopes or that redirects the flow of surface or groundwater can trigger slope failures (USGS 2004).

According to the United State Geological Survey, (USGS), there are numerous types of landslides, as described below and visualized in Figure 11-2:

- **Slides:** Translational or rotational movement of material downslope. Slides travel at a range of rates, displacing forests and infrastructure as they move.
- **Rotational slide:** This is a slide in which the surface of rupture is curved upward, and the slide movement rotates parallel to the ground surface.
- **Translational slide:** In this type of slide, the landslide mass moves along a roughly flat surface with little rotation.

Figure 11-2. Major Types of Landslide Movement



Source: USGS 2004

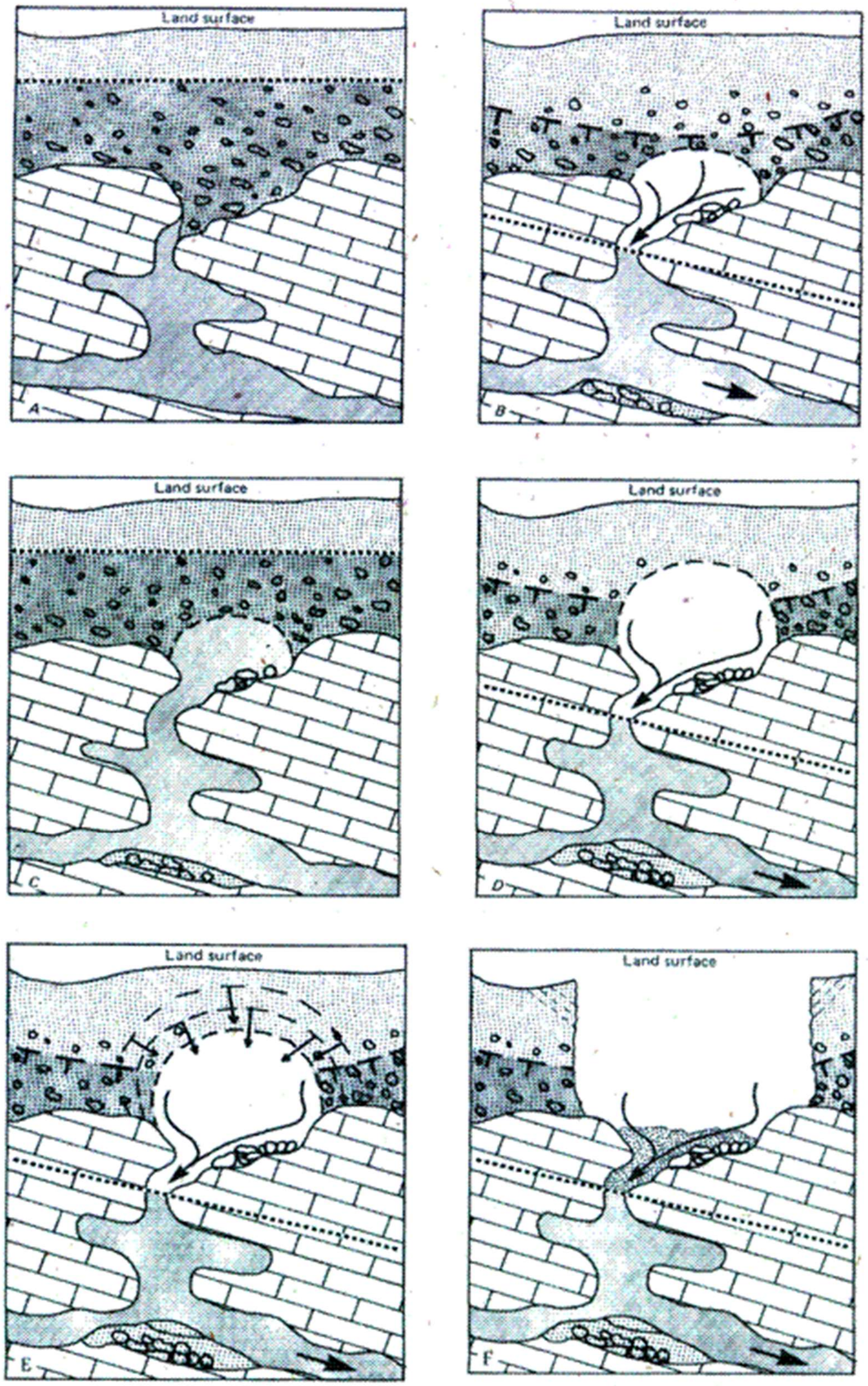
- **Falls:** Falls are abrupt movements of geologic materials, such as rocks and boulders, that become detached from steep slopes or cliffs. Falls are strongly influenced by gravity, weathering, and the presence of water in a mineral's pores.
- **Topples:** Toppling failures are distinguished by the forward rotation of a unit about some point under the actions of gravity and forces exerted by surrounding objects or by fluids in cracks.
- **Flows:** There are five basic categories of flows that differ from one another in fundamental ways.
- **Debris flow:** A debris flow is a form of rapid mass movement in which a combination of loose soil, rock, organic matter, air, and water mobilize as a slurry that flows downslope. Debris flows are commonly caused by intense surface-water flow, due to heavy precipitation or rapid snowmelt, that erodes and mobilizes loose soil or rock on steep slopes.
- **Debris avalanche:** This is a variety of very rapid to extremely rapid debris flow.
- **Earthflow:** Earthflows have a characteristic "hourglass" shape. The slope material liquefies and runs out, forming a bowl or depression at the head.
- **Mudflow:** A mudflow is an earthflow consisting of material that is wet enough to flow rapidly and that contains at least 50 percent sand-, silt-, and clay-sized particles.
- **Creep:** Creep is the slow, steady, downward movement of slope-forming soil or rock. Creep is indicated by curved tree trunks, bent fences, or retaining walls, tilted poles or fences, and small soil ripples or ridges.
- **Lateral spreads:** Lateral spreads are distinctive because they usually occur on very gentle slopes or flat terrain. The failure is caused by liquefaction, the process whereby saturated, loose, sediments are transformed from a solid into a liquefied state. The failure starts suddenly in a small area and spreads rapidly (USGS 2004).

11.1.3 Sinkholes

According to the USGS, a sinkhole is a depression in the ground with no natural external surface drainage. This means that when it rains, all the water stays inside of the sinkhole and drains into the ground. Sinkholes can be problematic, as the land may stay intact for a period of time until the underground spaces become too large and cause the land above it to collapse, as the support from underneath has become minimal (USGS 2021); see Figure 11-3 for a visual on how sinkholes form. This circular, funnel-shaped soil movement is most common in karst terrain (Maryland Geological Survey n.d.). In populated and developed areas, such as Baltimore City, sinkholes are more likely to cause problems. Sinkholes present two hazards:

- The physical danger of falling into them, as well as the danger to structures — buildings, roads, airport runways, etc.
- The threat to ground and surface water quality by the potential for direct introduction of contaminants (Maryland Geological Survey n.d.).

Figure 11-3. Sinkhole Formation



Source: Maryland Geological Survey n.d.

Some common features that may warn of eventual sinkhole collapse include:

- Circular and linear cracks in soil, asphalt, and concrete paving or floors.
- Depressions in soil or pavement that result in the ponding of water.
- Slumping, sagging, or tilting of trees, roads, rails, fences, pipes, poles, or other structures.
- Downward movement of small diameter vertical structures such as poles or posts.
- Fractures in foundations and walls, often accompanied by jammed doors or windows.
- Small holes appearing on the surface of the ground during a short period of time.
- Sudden muddying of water in a well that has been producing clear water.
- Sudden draining of a pond or creek (Maryland Geological Survey n.d.).

According to the USGS, sinkholes have been correlated to land-use practices, especially from groundwater pumping, construction, and development practices. Sinkholes can also form when natural water-drainage patterns are changed, and new water-diversion systems are developed. Some sinkholes form when the land surface is changed, such as when industrial and runoff-storage ponds are created. The weight of the new material can trigger a collapse of supporting material, causing a sinkhole (USGS 2018).

The overburden sediments that cover underground areas in the aquifer systems are balanced by groundwater pressure. The water below ground helps keep the surface soil in place. Groundwater pumping for urban water supply can produce new sinkholes. If pumping results in the lowering of groundwater levels, then underground structural failure, such as sinkholes, can occur (USGS 2018).

11.1.4 Urban Karst

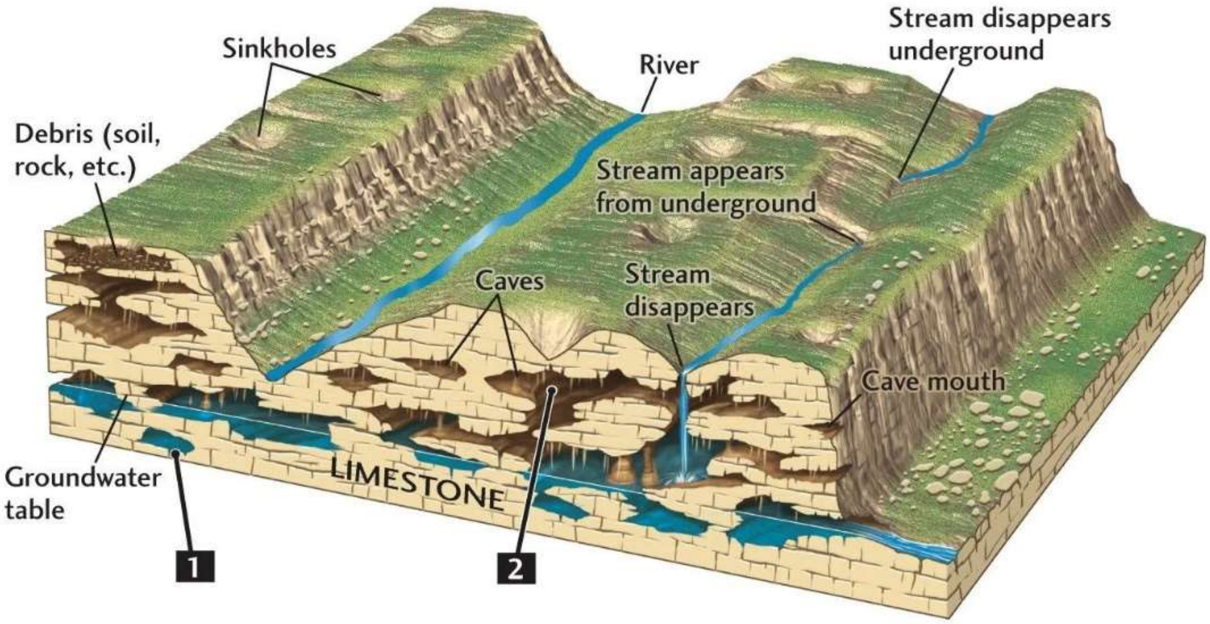
Karst is a type of topography formed on carbonate rock such as limestone or dolomite and characterized by sinkholes, caves, and open-channel groundwater flow (refer to Figure 11-4). In Maryland, karst areas occur in Baltimore, Carroll, Washington, and Frederick Counties, with less extensive areas in Allegany County (Maryland Geological Survey n.d.).

Karst aquifers are a vital groundwater resource in the United States. In the United States, about 40% of the groundwater used for drinking comes from karst aquifers. The State of Maryland is included in three karst aquifers, the Valley and Ridge, Piedmont, and Blue Ridge Aquifers (USGS 2021). People living and working in karst regions need to be particularly sensitive to issues of land use and water quality protection.

11.2 Location

Soil movement can occur as a result of geological settings, and in some instances as a result of other hazards and stressors like flooding and failing infrastructure. Within Baltimore City geologic conditions, such as steep slopes, are present contributing to the occurrence of some types of land slide. Human-caused conditions, such as failing infrastructure have also contributed to soil movement with Baltimore City.

Figure 11-4. Karst Terrains



Source: Obi 2016

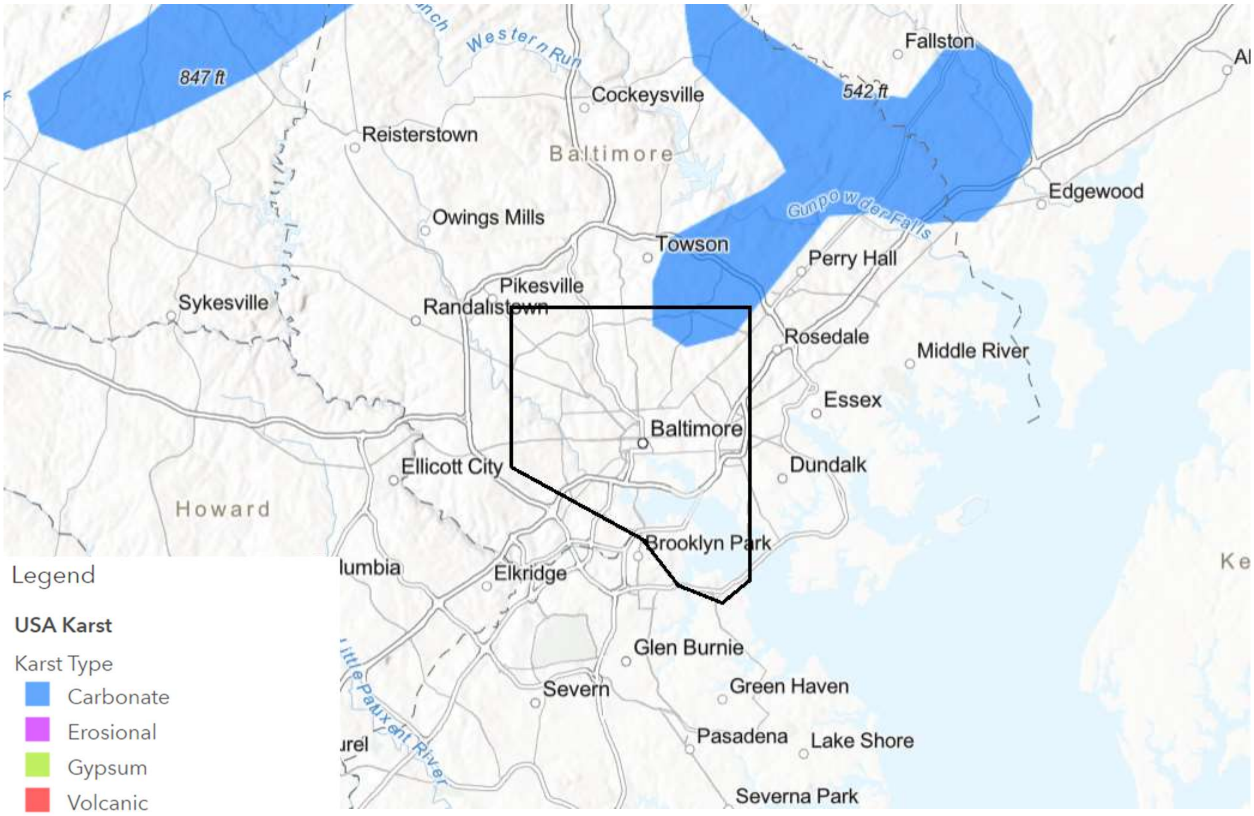
11.2.1 Land Subsidence

The US Geological Survey (USGS) notes that "subsidence is a global problem and, 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" (USGS 2018).

While Baltimore City does not have much karst terrain (as shown in Figure 11-5) Baltimore City may still be susceptible to land subsidence. Decades of groundwater withdrawals from confined coastal plain aquifers in Maryland have resulted in significant drawdown of groundwater levels. Water levels have declined in some aquifers to more than 170 feet below sea level. Projected increases in population mean greater withdrawal amounts. Withdrawing water from a confined aquifer reduces the hydrostatic pressure, a measure of pressure on fluid, in the pumped aquifer and in the adjacent confining layers of soil. Reduction of hydrostatic pressure in the aquifer system from the drawdowns will increase the weight on the soil, which may lead to compaction and land subsidence (Maryland Geological Survey n.d.).

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. Ever since the ice sheets retreated, the elevated area has been subsiding. Land subsidence has been observed since the 1940s in the southern Chesapeake Bay region at rates of 1.1 to 4.8 millimeters per year. Recent climate assessments have reported Baltimore's rate of land subsidence to have been roughly half a foot in the last century. When coupled with rising waters, local land subsidence can exacerbate relative sea level rise (USGS 2013).

Figure 11-5. Karst Map of Baltimore City and Surrounding Areas



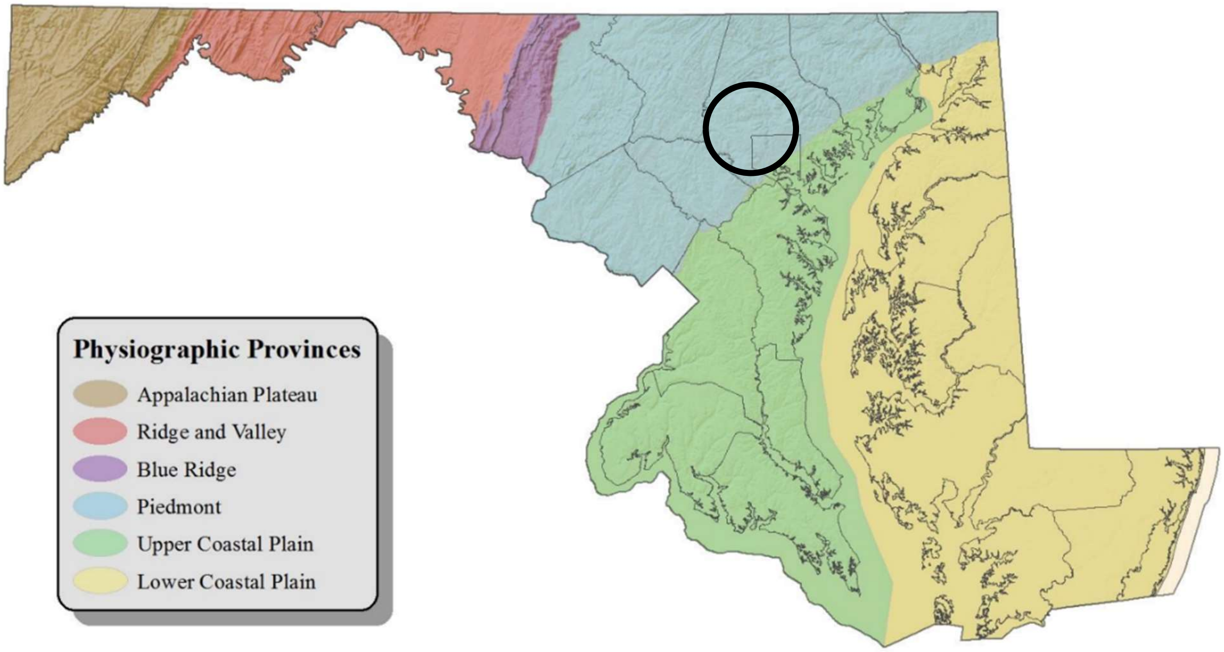
Source: ArcGIS 2021

11.2.2 Landslides

While landslides are considered to be rare in the State of Maryland, they are most likely to occur in the Western portion of the state due to mountainous terrain and changing slope (Maryland Emergency Management Agency 2021). However, landslides can still occur outside of the mountainous regions of the State.

In Maryland's Coastal Plain province, the Marlboro Clay is one of the geologic formations highly susceptible to slope failure. Other formations highly susceptible include clays of the Potomac Group and the St. Mary's Formation; the Potomac Group is present in the Piedmont province (Maryland Geological Survey 2000). Both slumps and earthflows can occur associated with the Marlboro Clay (Maryland Geological Survey n.d.). Baltimore City is located in both the Coastal Plain and Piedmont provinces, as shown in Figure 11-6, located within the black circle.

Figure 11-6. Physiographic Provinces of Maryland



Source: Maryland Department of Natural Resources 2016
Note: Baltimore is located within the black circle

Figure 11-7 displays the Landslide Risk Index for Baltimore City. According to the National Risk Index, on the county Scale, Baltimore City has a relatively moderate risk to landslide; on the census tract scale (Figure 11-8), Baltimore City ranges from a very low risk to a relatively high risk for landslide. The locations most at risk from landslide in Baltimore City include areas near Gwynns Falls trails, near the University of Maryland and just north of the Inner Harbor, and near John Hopkins University (FEMA 2023). See Figure 11-9 below, which shows the steep slope with over 30% grade locations in Baltimore City.

11.2.3 Sinkholes

Sinkholes typically form in areas with karst soils (see Figure 11-5 for locations in Baltimore City). Sinkholes in Baltimore City generally are human-caused, not produced naturally. In many cases, they have occurred over or under infrastructure, such as water mains.

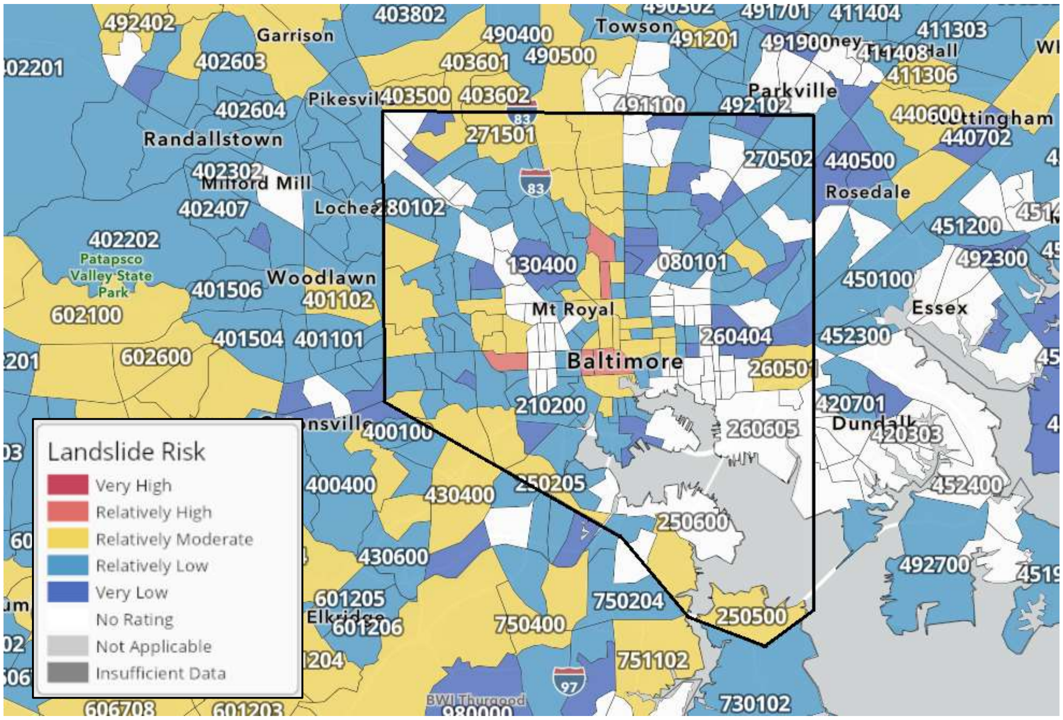
11.2.4 Urban Karst

Karst features of soil are a good indicator of for determining sinkhole risk and location. The most common type of bedrock in karst terranes is carbonate rock, which includes limestone (calcium carbonate), dolostone (calcium-magnesium carbonate), and marble (calcium carbonate). There are a few other kinds of rock (e.g., gypsum, which is composed of calcium sulfate) that can be involved in karst, but in Maryland karst terranes are limited to areas underlain by carbonate rocks (Maryland Geological Survey n.d.). Figure 11-5 shows the distribution of karst features of soil in Baltimore City and its surrounding areas. As displayed below, Baltimore City has a small section of carbonate soil, a type of karst soil, in the northwestern portion of Baltimore City.

Figure 11-7. National Risk Index, Landslide Risk Index Score Using the County Scale

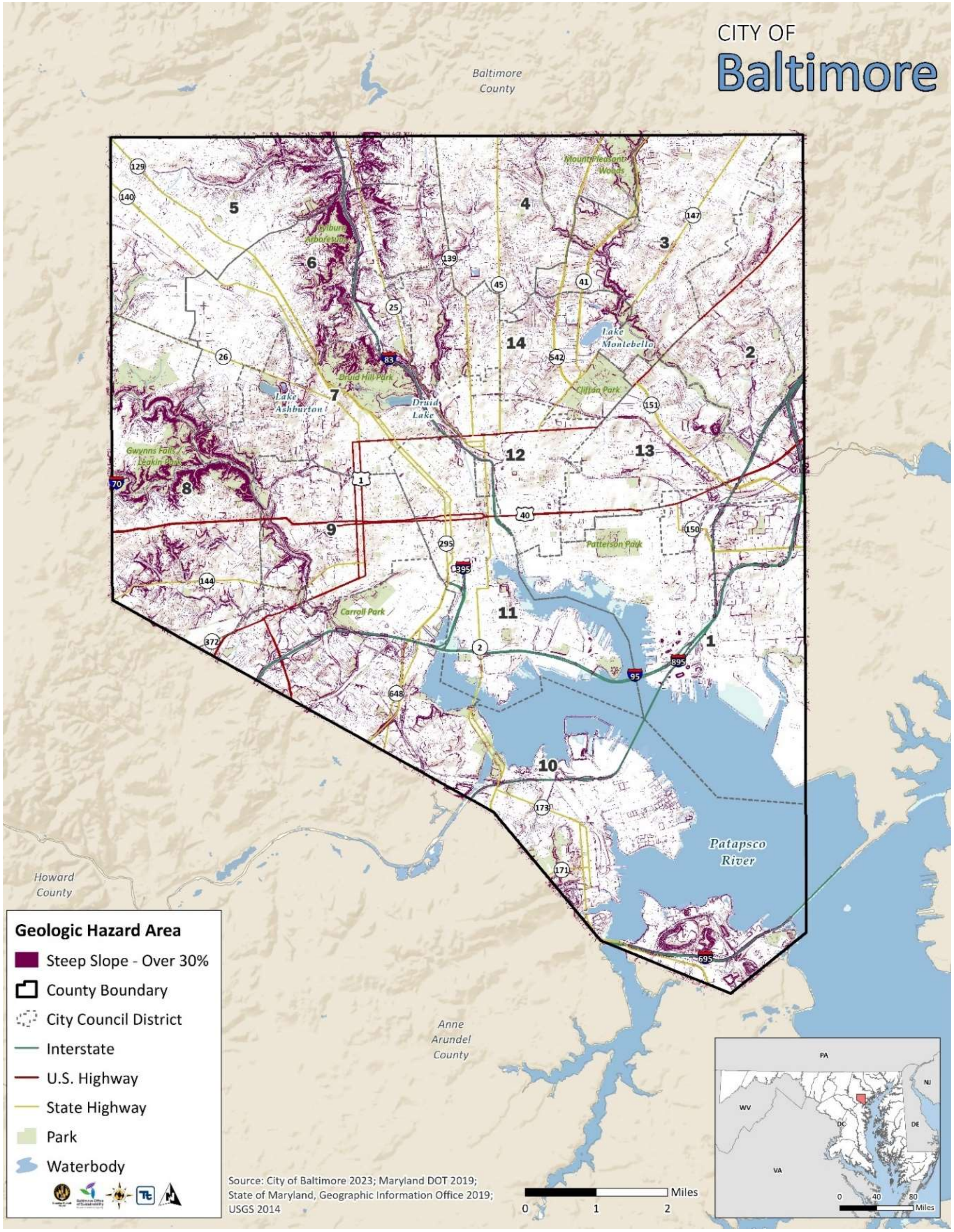
Source: FEMA 2023

Figure 11-8. National Risk Index, Landslide Risk Index Score Using the Census Tract Scale



Source: FEMA 2023

Figure 11-9. Steep Slope – Over 30% Grade Locations in Baltimore City



11.3 Extent

11.3.1 Land Subsidence

Human activity can often be the cause of a subsidence area. Leaking water pipes or structures that convey stormwater runoff may also result in areas of subsidence as the water dissolves substantial amounts of rock over time. In some cases, construction, land grading, or earth-moving activities that cause changes in stormwater flow can trigger subsidence events. Subsidence events may occur during mining activities, especially in areas where the cover of a mine is thin or in areas where bedrock is not necessarily conducive to their formation. Subsurface (i.e., underground) extraction of materials such as oil, gas, coal, metal ores (i.e., copper, iron, and zinc), clay, shale, limestone, or water may result in slow-moving or abrupt shifts in the ground surface (Whittaker and Reddish 1989).

The occurrence of subsidence is not as obvious as other geologic hazards. The detection of subsidence is gradual and is typically from the identified movement of key benchmarks or landmarks, such as a statue or tree appearing to have moved or sunk into the ground. Scientists will use radar images from Earth-orbiting satellites to monitor subsidence by mapping the land-surface deformation. This tool is called InSAR or interferometric synthetic aperture radar. Once subsidence is identified and mapped, assessments of the InSAR data can be done to improve our understanding of the subsidence processes (USGS 2019).

11.3.2 Landslides

Landslides can be measured using the size/volume of the debris that was moved during the landslide events. In the western areas of Maryland where landslides are most prevalent, boulders as large as 60 feet and 900 tons in weight have been displaced. The velocity of a landslide is determined by the debris flow – sometimes referred to as mudslides, mudflows, lahars, or debris avalanches – generally occur during periods of intense rainfall or rapid snowmelt. These events are typically about 10 miles per hour (MPH) but can exceed 35 miles per hour in extreme cases (USGS 2022).

11.3.3 Sinkholes

Factors such as urban development, quarrying, and highway construction can upset the soil-bedrock equilibrium and cause sinkhole development. A common site for sinkhole development is within stormwater basins or ponds constructed near business parks or housing developments. During the construction of such features, soil is stripped away, commonly exposing underlying bedrock and often soil-filled voids and inactive sinkholes. When these ponds become filled during periods of rainfall, the plugged sinkholes are flushed by the deluge. Additionally, these catch basins are often constructed along existing drainage lowlands, which are already susceptible to sinkhole activation (MDOT 2004).

Another common location for active sinkhole occurrence is within unlined road drainage ways. Like stormwater management areas, road drainages remove soil cover from inactive or filled sinkholes so that during subsequent periods of rainfall, these features become activated. Sinkhole activation in areas of unlined drainage is not restricted to roads or highways; in some parts of Maryland, sinkholes were identified along railroad rights-of-way (MDOT 2004).

11.3.4 Urban Karst

Soil movement is the product of natural hazards and human-man hazards. Landslides, sinkholes, and urban karst are three contributing factors in soil movement and how it impacts Baltimore City. As mentioned above, karst conditions are not naturally present in Baltimore City; however, human-made issues, such as failing underground infrastructure, are a contributing factor to the sinkholes and landslides within Baltimore City.

11.4 Previous Occurrences and Losses

Various sources provide historical information regarding previous occurrences and losses associated with geologic hazards throughout the State of Maryland and Baltimore City; therefore, the loss and impact information for many events varies depending on the source. The accuracy of monetary figures discussed is based only on the available information in cited sources.

11.4.1 FEMA Major Disaster and Emergency Declarations

Between 1950 and June 2023, the State of Maryland was not included in any soil movement related major disaster declaration (DR) or emergency declaration (EM). Generally, these disasters cover a wide region of the State of Maryland; therefore, they may have impacted many counties. However, not all counties were included in the disaster declaration. Baltimore City has not been included in any declarations (FEMA 2022).

11.4.2 Previous Events

For the 2023 DP3 update, known soil movement events that impacted Baltimore City between 1950 and 2023 are discussed below in Table 11-1. Due to limited sources of information, data from the 2018 Baltimore DP3 and news reports were used to identify various soil movement events that occurred between 2008 and 2023.

Table 11-1. Soil Movement Events in Baltimore City, 2008–2023

Date(s) of Event	Event Type	FEMA Declaration Number (if applicable)	Baltimore City included in Declaration?	Location Impacted	Description
2008	Sinkhole	N/A	N/A	Race and West Street	Details regarding this event were not identified during the planning process.
2009	Sinkhole	N/A	N/A	2238 East Monument Street	Details regarding this event were not identified during the planning process.
2009	Sinkhole	N/A	N/A	2100 South Cliton Street	Details regarding this event were not identified during the planning process.
2011	Sinkhole	N/A	N/A	600 Cathedral Street	Details regarding this event were not identified during the planning process.
2012	Sinkhole	N/A	N/A	I-83 and 29th Street	Details regarding this event were not identified during the planning process.
2012	Sinkhole	N/A	N/A	2300 block of East Monument Street	Details regarding this event were not identified during the planning process.
2013	Sinkhole	N/A	N/A	West 37th and Keswick Road	Details regarding this event were not identified during the planning process.
2013	Sinkhole	N/A	N/A	721 Gorsuch Avenue	Details regarding this event were not identified during the planning process.
2014	Sinkhole	N/A	N/A	1000 Block of Riverside Avenue	Details regarding this event were not identified during the planning process.
April 30, 2014	Landslide	N/A	N/A	East 26th Street	In April 2014, a sudden landslide occurred along East 26th Street. The side of East 26th Street collapsed onto the CSX tracks below the street; the landslide plummeted eight cars, trees, a street lamp, and a large swath of sidewalk and buried the railroad tracks below in debris (CBS News Baltimore 2014). The estimated cost to repair the street collapse was $18.5 million. The landslide came after roughly five inches of rain had fallen in Baltimore City. The landslide came after roughly five inches of rain had fallen in Baltimore City. Residents living along the stretch of road which collapsed were temporarily relocated for about two months (WTOP News 2014).
2015	Sinkhole	N/A	N/A	Eutaw Street	Details regarding this event were not identified during the planning process.

Date(s) of Event	Event Type	FEMA Declaration Number (if applicable)	Baltimore City included in Declaration?	Location Impacted	Description
2016	Sinkhole	N/A	N/A	100 Center Street	Details regarding this event were not identified during the planning process.
2016	Sinkhole	N/A	N/A	500 Mulberry Street	Details regarding this event were not identified during the planning process.
2016	Sinkhole	N/A	N/A	2400 East Monument Street	Details regarding this event were not identified during the planning process.
2016	Sinkhole	N/A	N/A	700 Cathedral Street	Details regarding this event were not identified during the planning process.
2018	Sinkhole	N/A	N/A	North Howard and West Lexington Street	Details regarding this event were not identified during the planning process.
2018	Sinkhole	N/A	N/A	East 26th Street	Details regarding this event were not identified during the planning process.
2019	Sinkhole	N/A	N/A	York Road	Details regarding this event were not identified during the planning process.
2019	Sinkhole	N/A	N/A	Pratt and Howard Street	Details regarding this event were not identified during the planning process.
July 2019	Sinkhole	N/A	N/A	Convention Center near Camden Yards	In July 2019, a sinkhole on swallowed part of a Light Rail platform next to the Convention Center near Camden Yards. The sinkhole is a consequence of a massive water main break that happened near Howard and Pratt streets just two days before (WBALTV 2019).
2021	Sinkhole	N/A	N/A	Guilford Avenue	Details regarding this event were not identified during the planning process.
November 2022	Sinkhole	N/A	N/A	Montebello 1 Water Treatment Plant	In November 2022, a sinkhole formed in Lake Montebello near the water filtration plant. Repairs cost $10 million, took about 4 months to conclude, and temporarily interrupted water services to portions of Baltimore City (The Baltimore Banner 2023).
July 2022	Sinkhole	N/A	N/A	700 block of North Avenue	In July 2022, the 700 block of E. North Avenue was closed to traffic because of a sinkhole in the sidewalk; a portion of the roadway did not partially reopen for roughly 6 months (City of Baltimore 2022).
2022	Sinkhole	N/A	N/A	North Wolfe Street	Details regarding this event were not identified during the planning process.

Date(s) of Event	Event Type	FEMA Declaration Number (if applicable)	Baltimore City included in Declaration?	Location Impacted	Description
2023	Sinkhole	N/A	N/A	3900 block of Mannasota Avenue	Details regarding this event were not identified during the planning process.
May 2023	Sinkhole	N/A	N/A	Parkside neighborhood of northeast Baltimore	In May 2023, a water main break created a sinkhole in Parkside neighborhood of northeast Baltimore but did not interrupt any utility services for residents (Fox 5 News 2023).

Source: Baltimore City 2018; CBS News Baltimore 2014; Baltimore City 2022; Fox 5 News 2023; The Baltimore Banner 2023; WBALTV 2019; WMAR News 2019; Baltimore City 2019; CBS News 2021; CBS News 2022

11.5 Probability of Future Hazard Events

Predicting future soil movement events in Baltimore City is difficult based upon risk factors and past occurrences. Table 11-2 summarizes data regarding the probability of occurrences of soil movement events in Baltimore City based on historic record. The information used to calculate the probability of occurrences is based on news reports and USGS.

Table 11-2. Probability of Future Soil Movement Events

Hazard Type	Number of Occurrences Between 1950 and 2023	% Chance of Occurring in Any Given Year
Landslide	1	1.36 %
Sinkhole	23	31.51 %
Urban Karst	0	0 %
Total	**24**	**32.87 %**

Sources: City 2018; CBS News Baltimore 2014; City 2022; Fox 5 News 2023; The Baltimore Banner 2023; WBAL-TV 2019; WMAR News 2019; City 2019; CBS News 2021; CBS News 2022
Note: Disaster occurrences include federally declared disasters since the 1950 Federal Disaster Relief Act, and selected events since 1950. Due to limitations in data, not all soil movement events occurring between 1954 and 1996 are accounted for in the tally of occurrences. As a result, the number of hazard occurrences is underestimated.

In Section 3, the identified hazards of concern for Baltimore City were ranked. The probability of occurrence, or likelihood of the event, is one parameter used for hazard rankings. Based on historical records and input from the Planning Committee, the probability of occurrence for soil movement events is considered "occasional."

11.6 Potential Impacts of Climate Change

Climate temperatures are rising due to high amounts of greenhouse gases in the atmosphere absorbing the sun's energy and warming the environment. The Intergovernmental Panel on Climate Change (IPCC) provides evidence for this phenomenon in the latest IPCC report on global warming. Global temperatures are expected to rise by 2.7°C by the end of the century. The seven warmest years on record have all occurred in the last decade: 2020 was the second warmest year on record; 2016 was the warmest year on record. (IPCC 2021).

Although the climate is always changing, the rate at which global warming is taking place is unprecedented. As temperatures are rising, so are sea levels. Sea level rise is a result of two phenomena: glacial ice melts and thermal expansion. Large land-based ice sheets and mountain glaciers are melting at alarming rates due to rising global temperatures. These permafrost areas store much of the Earth's water and carbon through carbon sequestration. As these ice sheets melt, they add to the ocean's volume of about 2 mm per year on average (NASA 2020). As well, glacial ice sheets are a natural form of carbon sequestration, and as a result, release greenhouse gases into the atmosphere when they melt (Wadham, et al. 2019). Another phenomenon contributing to sea level rise is thermal expansion. Thermal expansion is when water molecules expand due to a rise in temperature. Higher temperatures result in greater distance between water molecules as the cohesive forces holding them together expand. This thermal expansion contributes to an overall increase in global sea levels. In fact, approximately 1/3 of the global sea level rise recorded since 2004 has been caused by thermal expansion (NASA 2021).

Climate change will significantly impact soil movement hazard events. As discussed throughout this hazard profile, precipitation is a significant factor in the movement of soil. As precipitation infiltrates the soil, it moves downward from the saturated zone to an unsaturated zone. Excess moisture reduces the stability of soil, especially on a slope. The projected increase in rainfall accumulations, and particularly the intense downpours, may cause the occurrence of soil movement events to be more frequent (University of Maryland 2023).

Projections for increased rain will contribute to the rise in frequency of soil movement events. Baltimore City, and the State of Maryland as a whole, is projected to experience increased annual rainfall and more intense rainfall and severe storms. These increases will influence the movement of soils via water erosion, cause an influx of water in underground pipes, and oversaturate soils (University of Maryland 2023).

11.7 Vulnerability Assessment

To understand risk, a community must evaluate what assets are exposed or vulnerable in the hazard area identified. Portions of Baltimore City have been identified as being exposed to the soil movement hazard. For this analysis, assets in the steep slope >30% grade (population, structures, critical facilities, and lifelines) were evaluated in the sections below.

11.7.1 Impacts on Population

Generally, soil movement events are isolated incidents and impact the populations within the immediate area of the event. Populations in the hazard area are particularly vulnerable to this hazard. Health threats from soil movements include: (1) trauma caused by rapidly moving water and debris; (2) broken electrical, water, gas, and sewage lines that can lead to injury or illness; and (3) disrupted roadways that can endanger motorists and disrupt transport and access to health care (CDC 2018). In addition, residents may be displaced or require temporary or long-term shelter. The number of people requiring shelter is generally less than the number displaced, as some displaced persons use hotels or stay with family or friends following a disaster event.

To estimate population exposure to the soil movement hazard, the steep slope >30% grade boundaries was used. Based on the spatial analysis, there are an estimated 25,424 residents living in the landslide (steep slope >30% grade) hazard area, or 4.3 percent of Baltimore City's total population. City Council District 4 has the greatest number of residents living in the landslide (steep slope >30% grade) hazard area, with approximately 3,031 residents, respectively. Table 11-3 summarizes the population exposed to the soil movement hazard by City Council District.

Table 11-3. Estimated Number of Persons Living in the Landslide (Steep Slope >30% Grade) Hazard Area

City Council Districts	Total Population (American Community Survey 2021)	Estimated Population Located in the Landslide (Steep Slope >30% Grade) Hazard Area	
		Number of Persons	Percent of Total
1	43,739	581	1.3%
2	45,252	1,992	4.4%
3	42,257	1,470	3.5%
4	45,027	3,031	6.7%
5	43,601	2,778	6.4%
6	41,604	2,037	4.9%
7	39,638	2,055	5.2%
8	46,396	2,889	6.2%
9	35,869	1,566	4.4%
10	41,521	1,964	4.7%
11	48,022	1,329	2.8%
12	37,130	760	2.0%
13	38,768	661	1.7%
14	42,664	2,310	5.4%
Baltimore City (Total)	**591,489**	**25,424**	**4.3%**

Source: U.S. Census Bureau 2021, ACS; USGS 2014

The aftermath of soil movement events may present threats to public health and safety similar to flooding events, as many of these events are exacerbated by precipitation and excess runoff. These threats may include unsafe food; contaminated drinking and washing water and poor sanitation; mosquitoes and animals; mold and mildew; carbon monoxide poisoning; and mental stress and fatigue. Furthermore, in instances of longer recovery periods, mental stress and fatigue may be exacerbated in communities and groups experiencing heighted social vulnerability. Additional outcomes may include downed utility lines, large debris such as vehicles, trees, and utility poles, excess soil erosion, and uneven and unstable ground.

Current loss estimation models such as Hazus are not equipped to measure public health impacts. The best preparation for these effects includes awareness that they can occur, education of the public on prevention, and planning to deal with them during responses to soil movement events.

Impacts on Socially Vulnerable Populations and Underserved Communities

Socially vulnerable populations are most susceptible based on many factors, including their physical and financial ability to react or respond during a hazard and the location and construction quality of their housing. Economically disadvantaged populations are likely to evaluate their risk and make decisions based on the major economic impact on their family and may not have funds to evacuate. Vulnerable populations include:

- People who are experiencing homelessness
- People who are elderly (over 65 years old)

- People with low income
- People who are linguistically isolated
- People with life-threatening illnesses
- People who may struggle to evacuate.

These groups may require extra time to evacuate or need assistance to evacuate and are more likely to seek or need medical attention.

Homelessness in Baltimore City is a great concern, as the populations are significantly at risk from hazards due to their exposure and general lack of a structurally sound structure. The Point-in-Time (PIT) Count is a federally mandated survey conducted annually that seeks to determine how many people are experiencing homelessness on any given night in Baltimore City. In 2022, the night of the PIT Count revealed a total of 1,597 people were counted in emergency shelters, transitional housing, and unsheltered spaces such as encampments. This is down from 2,193 people in 2020 and follows a four-year downward trend (Baltimore City 2022). The 2023 PIT occurred in January of 2023; however, the results have not yet been made public. As it is unknown where the homeless are located at any given time, it is assumed the entire population is exposed to the soil movement hazard.

Table 11-4 displays the total population data for Baltimore City-by-City Council District. According to the 2021 American Community Survey, there are roughly 84,000 persons over age 65 (14.1 percent of the total population); approximately 36,000 persons (6.2-percent of the total population) under the age of 5; just over 10,000 persons (1.7-percent of the total population) which do not speak English; an estimated 93,000 persons (15.7-percent of the total population) who have a disability; and about 116,000 persons (19.5-percent of the total population) living at or below the poverty level.

11.7.2 Impacts on Structures

General Building Stock

All buildings are exposed to the soil movement hazard. Refer to Section 2 (City Profile), which summarizes the building inventory in Baltimore City. Soil movement (land subsidence, landslide, sinkholes, urban karst) heavily impacts buildings within Baltimore City. In major landslide and sinkhole events, buildings will be swept away completely, impacted by falling debris, partially impacted by sinkholes. Additionally, property located within underserved communities has a higher potential for total loss during soil movement events.

Table 11-5 shows a spatial analysis for the soil movement hazard, which determined there are 9,320 buildings located in the landslide hazard area. The greatest number of buildings is located in City Council District 4 (973 buildings), while City Council District 10 has the highest replacement cost value ($2.059 billion).

Table 11-4. Baltimore City Total Population by City Council District

City Council District	Total Population (American Community Survey 2021)	Percent of City Total	American Community Survey 5-Year Population Estimates (2021)									
			Over 65	Percent of Jurisdiction Total	Under 5	Percent of Jurisdiction Total	Non-English Speaking	Percent of Jurisdiction Total	Disability	Percent of Jurisdiction Total	Poverty Level	Percent of Jurisdiction Total
1	43,739	7.4%	4,481	10.2%	3,344	7.6%	1,141	2.6%	4,200	9.6%	5,851	13.4%
2	45,252	7.7%	5,528	12.2%	3,009	6.6%	1,376	3.0%	5,394	11.9%	6,530	14.4%
3	42,257	7.1%	5,988	14.2%	1,669	4.0%	470	1.1%	5,485	13.0%	3,539	8.4%
4	45,027	7.6%	6,401	14.2%	3,113	6.9%	371	0.8%	5,601	12.4%	6,218	13.8%
5	43,601	7.4%	8,122	18.6%	3,762	8.6%	1,176	2.7%	6,613	15.2%	7,155	16.4%
6	41,604	7.0%	8,355	20.1%	2,356	5.7%	546	1.3%	7,741	18.6%	7,910	19.0%
7	39,638	6.7%	6,177	15.6%	1,895	4.8%	349	0.9%	7,764	19.6%	9,082	22.9%
8	46,396	7.8%	7,799	16.8%	2,947	6.4%	392	0.8%	8,376	18.1%	8,014	17.3%
9	35,869	6.1%	4,927	13.7%	2,024	5.6%	641	1.8%	8,523	23.8%	11,821	33.0%
10	41,521	7.0%	4,755	11.5%	3,468	8.4%	1,054	2.5%	7,685	18.5%	12,283	29.6%
11	48,022	8.1%	5,774	12.0%	2,182	4.5%	907	1.9%	6,231	13.0%	8,651	18.0%
12	37,130	6.3%	4,203	11.3%	1,690	4.6%	575	1.5%	6,388	17.2%	9,815	26.4%
13	38,768	6.6%	4,701	12.1%	2,684	6.9%	582	1.5%	6,814	17.6%	11,673	30.1%
14	42,664	7.2%	6,316	14.8%	2,324	5.4%	702	1.6%	5,891	13.8%	7,086	16.6%
Baltimore City (Total)	**591,489**	**100.0%**	**83,527**	**14.1%**	**36,468**	**6.2%**	**10,283**	**1.7%**	**92,707**	**15.7%**	**115,625**	**19.5%**

Table 11-5. Estimated General Building Stock Located in the Landslide (Steep Slope >30% Grade) Hazard Area

City Council Districts	Total Number of Buildings	Total Replacement Cost Value (RCV)	Estimated Number and Total Replacement Cost Value of Structures Located in the Landslide (Steep Slope >30% Grade) Hazard Area			
			Number of Buildings	Percent of Total	Total RCV of Buildings	Percent of Total
1	22,781	$42,726,169,218	304	1.3%	$667,768,191	1.6%
2	12,746	$19,773,061,274	553	4.3%	$728,611,473	3.7%
3	14,274	$14,195,099,773	506	3.5%	$631,939,874	4.5%
4	14,536	$12,686,748,697	973	6.7%	$861,773,452	6.8%
5	12,637	$18,575,913,421	789	6.2%	$935,475,036	5.0%
6	15,009	$19,159,968,457	737	4.9%	$1,126,354,048	5.9%
7	17,409	$18,007,600,793	898	5.2%	$811,944,600	4.5%
8	14,350	$14,208,439,442	887	6.2%	$915,586,785	6.4%
9	21,371	$21,990,875,897	930	4.4%	$938,939,314	4.3%
10	16,334	$33,621,448,750	796	4.9%	$2,059,370,332	6.1%
11	17,184	$62,344,674,213	434	2.5%	$1,063,968,580	1.7%
12	15,436	$33,041,741,651	327	2.1%	$828,949,949	2.5%
13	18,095	$19,432,245,395	331	1.8%	$577,907,832	3.0%
14	15,694	$17,744,799,580	855	5.4%	$1,136,567,419	6.4%
Baltimore City (Total)	**227,856**	**$347,508,786,561**	**9,320**	**4.1%**	**$13,285,156,888**	**3.8%**

Source: Maryland Department of Planning 2020, 2022; RS Means 2023; USGS 2014

Critical Facilities, Infrastructure, and Community Lifelines

Critical facilities and lifelines in Baltimore City exposed to the soil movement hazard are discussed below in Table 11-6. There are 199 critical facilities located in the steep slope >30% grade hazard area, with the greatest number of critical facilities and lifelines being located in City Council District 10 (40 critical facilities, 39 lifelines), while City Council District 13 has the number of critical facilities and lifelines (4 critical facilities, 3 lifelines).

Critical facilities will experience similar issues as described above for general building stock. Additionally, it is essential that critical facilities remain operational during natural hazard events. Soil movement events can cause long periods of utility failures due to infrastructure damage. Backup power is recommended for critical facilities and infrastructure so that continuity of operations can occur during hazard events.

Soil movement hazards have the potential to destabilize the foundation of infrastructure, including water treatment plants, dams, and levees, which may result in monetary losses to businesses and governmental organizations. These events can expose the underlying bedrock adjacent to structures, which can erode and threaten the structural integrity and safety of the structure above.

Table 11-6. Critical Facilities, Infrastructure, and Lifelines Located in the Landslide (Steep Slope >30% Grade) Hazard Area

City Council District	Total Critical Facilities Located in Jurisdiction	Total Lifelines Located in Jurisdiction	Number of Critical Facilities and Lifeline Facilities Located in the (Steep Slope >30% grade) Hazard Area			
			Critical Facilities	Percent of Total Critical Facilities	Lifelines	Percent of Total Lifelines
1	217	190	11	5.1%	11	5.8%
2	142	119	15	10.6%	13	10.9%
3	115	106	10	8.7%	10	9.4%
4	132	112	5	3.8%	5	4.5%
5	142	120	16	11.3%	16	13.3%
6	190	148	13	6.8%	10	6.8%
7	205	146	17	8.3%	17	11.6%
8	114	94	9	7.9%	7	7.4%
9	197	122	17	8.6%	11	9.0%
10	252	219	40	15.9%	39	17.8%
11	353	283	21	5.9%	18	6.4%
12	254	174	7	2.8%	5	2.9%
13	151	113	4	2.6%	3	2.7%
14	134	96	14	10.4%	11	11.5%
Baltimore City (Total)	**2,598**	**2,042**	**199**	**7.7%**	**176**	**8.6%**

Source: City 2023; Maryland Department of Transportation (MDOT) 2023; Baltimore City Department of Public Works 2023; HILFD 2018, 2021, 2022; USGS 2014
Notes: (HIFLD) Homeland Infrastructure Foundation-Level Data); USGS (United States Geological Survey)

Additionally, impacts to transportation infrastructure may be incurred, including road washouts, blockages, road closures, and prevention of emergency personnel from responding to incidents. Secondary impacts to transportation networks are increased commute times and traffic congestion in re-routed areas.

- **Roads:** Access to major roads is crucial to life-safety after a disaster event and to response and recovery operations. Soil movements can block egress and ingress on roads, causing isolation for neighborhoods, traffic problems, and delays for public and private transportation.
- **Bridges:** Soil movements can significantly impact road bridges. Mass movements can knock out bridge abutments or significantly weaken the soil supporting them, making them hazardous for use.
- **Power Lines:** Power lines are generally elevated above steep slopes, but the towers supporting them can be subject to landslides. A soil movement could trigger failure of the soil underneath a tower, causing it to collapse and ripping down the lines.
- **Rail Lines:** Similar to roads, rail lines are important for response and recovery operations after a disaster. Soil movements can block travel along the rail lines, which would become especially troublesome because it would not be as easy to detour a rail line as it is on a local road or highway.

Community lifelines enable the continuous operation of critical business and government functions and are essential for human health and safety as well as economic security (FEMA

2023). It is essential that community lifelines remain operational during soil movement events so that the lifelines may address any issues affecting health, safety, and economic security.

Table 11-7 lists the number of lifelines within the landslide (steep slope >30 % grade) hazard area. Of the 176 lifelines located in the hazard area, the greatest number (99) are transportation facilities.

Table 11-7. Lifelines Located in the Landslide (Steep Slope >30% Grade) Hazard Area

FEMA Lifeline Category	Number of Lifelines	Number of Lifelines Located in the Landslide Hazard Area (Steep Slope >30% Grade)
Communications	307	20
Energy	70	1
Food, Hydration, and Shelter	127	3
Hazardous Materials	0	0
Health and Medical	802	31
Safety and Security	290	22
Transportation	446	99
Baltimore City (Total)	**2,042**	**176**

Source: City 2023; Maryland Department of Transportation (MDOT) 2023; Baltimore City Department of Public Works 2023; HILFD 2018, 2021, 2022

11.7.3 Impacts on the Economy

Soil movement can impact property values, cause disruptions to businesses, impact tourism, and result in individuals being burdened with displacement and relocation costs. In areas prone to frequent soil movement activity individuals may experience financial losses due to the need to repair damage caused by soil movement, face difficulty selling their homes due to the occurrence of soil movement activity, and in instances when a structure has been damaged and is inhabitable individuals may incur costs related to relocating. Baltimore City may face increased cost due to response and recovery activities for emergency efforts related to soil movement.

11.7.4 Impacts on Natural, Historic, and Cultural Resources

Soil movement hazards can potentially alter rivers or streams, potentially harming water quality, fisheries, and spawning habitat; they can also create new depressions that can fill with water, creating new aquatic habitats. Soil movement can also cause erosional issues surrounding waterways, causing them to expand and potentially encroach and damage properties. In other instances, a soil movement event may block the movement of water and disrupt the natural flow of water.

Soil movement hazards may also impact historic and cultural sites by destabilizing the foundation of buildings and structures. There are no areas prone to natural subsidence in Baltimore City. However, historic and cultural resources may be impacted by soil movement as a result of failing infrastructure and excess rain.

11.7.5 Cascading and Compounding Impacts

Soil movement events can be exacerbated by flood hazard events. For example, debris from a landslide or sinkhole event can move into nearby rivers, bays, and creeks causing the water to rise and spill over onto roadways throughout the town. Additionally, continued landslides and sinkholes will create an environment for more frequent and severe landslide and sinkhole events due to loosening of soil, ground, and vegetation.

11.7.6 Future Changes that May Impact Vulnerability

Understanding future changes that impact vulnerability in Baltimore City can assist in planning for future development and ensuring that appropriate mitigation, planning, and preparedness measures are in place. Baltimore City considered the following factors to examine potential conditions that may affect hazard vulnerability:

- Potential or projected development
- Projected changes in the population
- Other identified conditions as relevant and appropriate, including the impacts of climate change

Changes in Land Use and Development

It is anticipated that the human exposure and vulnerability to soil movement hazard impacts in newly developed areas will be similar to those that currently exist. Any areas of growth located in the hazard areas (land subsidence, landslide, sinkhole, or urban karst) could be potentially impacted. It may be beneficial for Baltimore City to examine the current state and integrity of its underground stormwater systems and prioritize projects which may decrease the likelihood of soil movement hazards, particularly the hazard of sinkholes.

Changes in Population

Baltimore has experienced a decrease in its population since 2010. According to the U.S. Census Bureau, Baltimore City's population decreased by approximately 4.75 percent between 2010 and 2021 (U.S. Census 2021). Estimated population projections provided by the Maryland Department of Planning indicate that Baltimore City's population will begin to increase going into 2030, reaching a total population of approximately 596,390 persons and continue to increase into 2040 to a population of 599,220 (Maryland Department of Planning 2020).

The overall anticipated increase in population for Baltimore City will heighten the threat of the soil movement hazard and its impact on life. As the population continues to grow, Baltimore City may need to assess the age and integrity of its infrastructure to determine its risk of contributing to the soil movement hazard. The groups most vulnerable to the hazard will likely increase, especially if populations increase in dense, urbanized locations of Baltimore City. The geographic and topographic areas most vulnerable to the soil movement hazard will remain the same, but the population exposed will increase.

Climate Change

As discussed previously, Baltimore City is projected to experience an increase in the frequency and severity of extreme storms and rainfall. This can lead to a higher vulnerability in soil movement hazards occurring because changes in precipitation and groundwater increase the likelihood of land subsidence, landslide, sinkholes, and urban karst incidents occurring in Baltimore City.

11.7.7 Change in Vulnerability Since 2018 DP3

Overall, Baltimore City's vulnerability to soil movement hazards remains unchanged from the 2018 DP3.

Section 12. Human-Caused

Key changes reflected in the 2023 DP3 update:

- Human-caused is a new hazard of concern included in the 2023 DP3 update.

12.1 Description

Though human-caused events are considered rare, the impacts could be detrimental to Baltimore City's economy, public health and safety, transportation, and in some cases, the environment.

Human-caused hazards have elements of human intent, negligence, or error involving a failure of a manufactured system. These hazards differ from natural disasters, which result from natural hazards. Almost all human-caused hazards result from deliberate, intentional actions taken to threaten or harm the well-being of others. The Core Planning Team (CPT) has defined human-caused hazards to include cyber-attack and hazardous materials.

Key Terms

- Cyberwarfare—A series of cyber-attacks against a nation-state, causing it significant harm. This harm could include disruption of vital computer systems up to the loss of life.
- Cyberterrorism—The politically motivated use of computers and information technology to cause severe disruption or widespread fear in society.
- Superfund—A U.S. federal government program designed to fund the cleanup of toxic wastes.
- CERCLA—The Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) authorizes the President to respond to releases or threatened releases of hazardous substances into the environment.

12.1.1 Cyber-Attack

A cyber-attack is an intentional effort to steal, expose, disrupt, disable, or destroy data, applications, or other assets through unauthorized access to a network, computer system, or digital device (NIST n.d.). Cyber-attacks can disrupt, damage, and destroy businesses or organizations. These types of attacks can occur for various reasons, which may range from small scale, such as petty theft, to a much larger scale, such as an act of war. There are three main categories for motivations behind cyber-attacks (IBM 2022):

- **Criminally motivated** attackers seek financial gain through monetary theft, data theft, or business disruption. Criminals may hack into a bank account to steal money or use scams to trick people into sending money. Hackers may steal data and use it to commit identity theft, sell it on the dark web, or hold it for ransom.
- **Politically motivated** attackers are associated with cyberwarfare or cyberterrorism. In cyberwarfare, nation-state actors often target their enemies' government agencies or critical infrastructure. Activist hackers, called "hacktivists," may not cause extensive damage. Instead, attention is typically sought for causes by making the attacks known to the public.

- **Personally motivated** attackers primarily seek retribution for some perceived slight. Money or sensitive data may be stolen, or disruption to an organization's systems could occur.

Less common cyber-attack motivations include corporate espionage, in which hackers steal intellectual property to gain an advantage over competitors, and vigilante hackers, who exploit a system's vulnerabilities to warn others about them. Some hackers enjoy the challenge of breaking into an organization's data and will perform the action to show intellectual superiority (IBM 2022).

12.1.2 Hazardous Materials

Hazardous materials are considered severely harmful to human health and the environment, as defined by the United States Environmental Protection Agency (USEPA) Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) (Superfund Law). Many are commonly used materials that are harmless in their normal uses but are quite dangerous if released. The Superfund law designates more than 800 substances as hazardous and identifies many more as potentially hazardous due to their characteristics and the circumstances of their release (USEPA 2013). Superfund's definition of a hazardous substance includes the following:

- Any element, compound, mixture, solution, or substance designated as hazardous under section 102 of CERCLA.
- Any hazardous substance designated under section 311(b)(2)(a) of the Clean Water Act (CWA) or any toxic pollutant listed under section 307(a) of the CWA. There are over 400 substances designated as either hazardous or toxic under the CWA.
- Any hazardous waste having the characteristics identified or listed under section 3001 of the Resource Conservation and Recovery Act.
- Any hazardous air pollutant listed under section 112 of the Clean Air Act, as amended. There are over 200 substances listed as hazardous air pollutants under the Clean Air Act (CAA).
- Any imminently hazardous chemical substance or mixture which the U.S. Environmental Protection Agency (EPA) Administrator has "taken action under" section 7 of the Toxic Substances Control Act (USEPA 2023).

If released or misused, hazardous materials can cause death, serious injury, long-lasting health effects, and damage to structures and other properties as well as the environment. Many products containing hazardous materials are used and stored in homes, and these products are shipped daily on highways, railroads, waterways, and pipelines.

- **Highways** - Transportation of hazardous materials on highways involves tanker trucks or trailers, which are responsible for the greatest number of hazardous material release incidents. Baltimore City is composed of approximately seven (7) miles of interstate highways and 2,000 miles of roadway in total; many of which are used to transport hazardous materials (Baltimore City DOT 2023). These roads cross rivers and streams at many points; hazardous material spills on roads have the potential to pollute watersheds that serve as domestic water supplies for parts of Baltimore City.

- **Railroads** - Potential also exists for hazardous material releases to occur along rail lines as collisions and derailments of train cars can result in large spills. Commercial railroads in Baltimore City are operated by CSX Transportation and Norfolk Southern Railway. Discussed further in this profile is a case study on the train derailment in the Howard Street Tunnel.
- **Waterways** - Hazardous materials in intermodal containers are shipped to and from Baltimore City through the Port of Baltimore. The Port of Baltimore is one of the 20 largest ports in the nation and handles both coal and petroleum products.
- **Pipelines** - Pipelines in Baltimore City also transport hazardous liquids and flammable substances such as natural gas, oil, and petroleum. Incidents can occur when pipes corrode, are damaged during excavation, are incorrectly operated, or are damaged by other forces.

In March 2018, former Baltimore Mayor Catherine Pugh signed the Crude Oil Terminal Prohibition into law. The law bans the construction of new crude terminals, helping to prevent a surge in the transport of crude oil trains through the City. The ban, which applies to new crude oil terminals, does not impact current terminals. Oil is transported by rail and ship in Baltimore City. Crashes, spills of materials, and fires on vessels can pose a hazard. Oil imports are able to be transported via rail or pipeline from the terminals.

12.2 Location

12.2.1 Cyber-Attack

Cyber-attacks are unpredictable and typically occur without warning. Cyber-attacks can cause severe disruptions to computers and electronics associated with critical infrastructure, transportation, data centers, public safety, and utility services. The entirety of Baltimore City, including those who live, work, and visit Baltimore City, are vulnerable to a cyber-attack.

12.2.2 Hazardous Materials

Hazardous Substances Fixed Site

Historically, wastes were dumped on the ground, in rivers, or left out in the open. As a result, thousands of uncontrolled or abandoned contaminated sites were created. These sites included abandoned warehouses, manufacturing facilities, processing plants, and landfills. In response to concerns regarding health and environmental risks, Congress established the Superfund program in 1980 to clean up these sites. The Superfund program is administered by the USEPA in cooperation with individual states. In Maryland, the Department of Environment, Land Restoration Program oversees the Superfund program (State of Maryland n.d.).

Federal regulations, such as the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) and the Superfund Amendments and Reauthorization Act (SARA), which was signed into law in 1986, require that a National Priorities List (NPL) of sites throughout the United States be maintained and revised at least annually (USEPA 1989). Fixed-site facilities in Baltimore City that use, manufacture, or store hazardous materials pose risk and must comply with Title III of the federal SARA.

The USEPA Hazardous Waste Report, which is a biennial report, collects data on the generation, management, and minimization of hazardous waste. This report provides detailed data on the generation of hazardous waste from large-quantity generators and data on waste management practices from treatment, storage, and disposal facilities. The 2019 report lists 51 facilities in Baltimore City (USEPA 2021).

Superfund is a program administered by the USEPA to locate, investigate, and clean up the worst hazardous waste sites throughout the U.S. Data from the Comprehensive Environmental Response, Compensation, and Liability Information System database indicated that there are three Superfund sites located throughout Baltimore City (USEPA 2023).

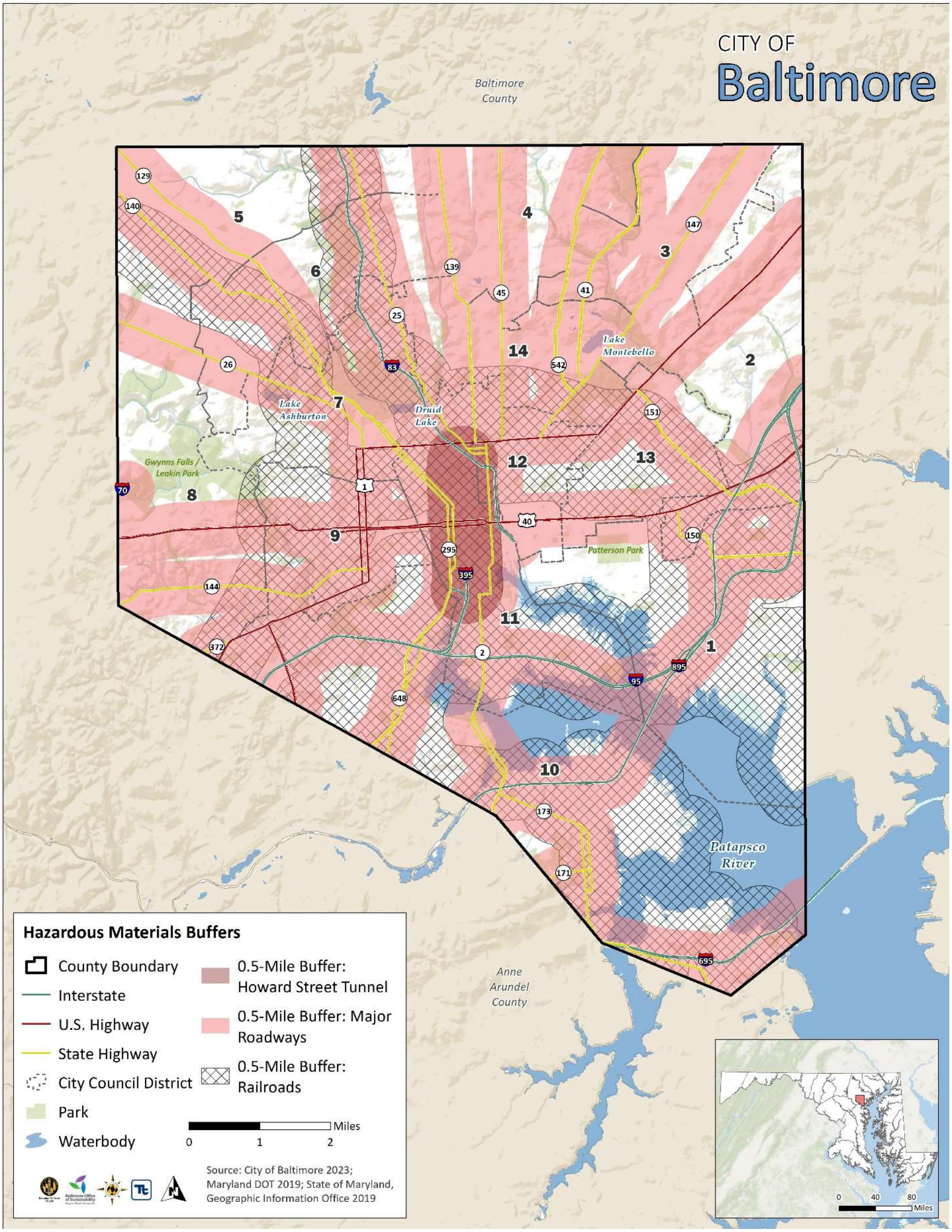
Hazardous Materials In-Transit

Incidents involving hazardous materials in transit can occur anywhere in Baltimore City. Baltimore City has dense and connective road networks, with major roadways such as I-83, I-95, I-295, the Baltimore–Washington Parkway (Maryland Route 295), US Route 1, US Route 40, US Route 40 Bypass, and Maryland Route 2. Highway transportation routes in the area where hazardous materials are shipped on a regular basis include Interstates 70, 83, 95, 97, 395, 695, and 795 (FIREHOUSE 2008). Figure 12-1 shows the major transportation routes in Baltimore City.

CSX coal explosion on December 20, 2021

Source: Fox 5 News 2022

Figure 12-1. Major Transportation Routes in Baltimore City



Hazardous materials can also be transported via pipeline in Baltimore City. Baltimore City has a relatively small network of natural gas and petroleum pipelines. According to the U.S. Energy Information Administration, natural gas is transported via pipeline into Baltimore City from the Gulf Coast and the Southwest (USEIA 2022). Hazardous materials in intermodal containers are shipped to and from Baltimore City through the Port of Baltimore. Colonial Pipeline Co. has a pipeline system that terminates in the Curtis Bay area in the southeast side of Baltimore City, where there is a major concentration of petroleum and chemical facilities. Some of the chemicals found in the industrial areas include uranium-hexafluoride, anhydrous ammonia, chlorine, petroleum products, and ethanol produced in Baltimore City (FIREHOUSE 2008). Figure 12-2 shows the extent and locations of pipelines throughout Baltimore City.

Transportation of hazardous materials in Baltimore City is also conducted by rail lines, which are used by CSX and Norfolk Southern. The CSX line, which runs below Howard Street, was the site of a major hazardous materials spill and fire on July 18, 2001 (see Previous Occurrences and Losses). In 2022, CSX reported 42,494 loaded shipments of hazardous materials were handled, including intermodal shipments, in Baltimore City. Within these shipments were a variety of 171 products, 15.32 percent were classified as Alcohols Not Otherwise Specified, 11.82 percent were Freight of All Kinds-Hazardous Materials, and 11.55 percent were Molten Sulfur.

The Baltimore City Fire Department's Hazardous Materials (HazMat) Team was formed in 1985 as a result of newly passed federal legislation requiring specialized operations and training for hazardous materials response. The HazMat Team responds to calls involving fuel spills, gas leaks, odor investigations, and carbon monoxide alarms. Absorbent materials are carried on all apparatus, and first-due companies can handle fuel spills up to 50 gallons but have the option to call in the HazMat Team any time they need additional resources. If a spill enters the sewer system, the HazMat Team is called automatically. Truck companies and squads carry five-gas meters and photo ionization detectors. All companies carry radiation meters, and all firefighters are trained to a minimum of the operations level (FIREHOUSE 2008).

12.3 Extent

12.3.1 Cyber-Attack

Cyber-attacks have been more frequent in recent years, impacting individuals, businesses, institutions, local governments, and state agencies. The Federal Bureau of Investigations reported that in 2022, approximately 800,944 complaints regarding internet scams were received from across the globe. The total losses associated with internet scams accumulated to $10.3 billion (FBI 2023).

Impacts from a cyber-attack could disrupt or potentially threaten Baltimore City's economy. The magnitude of a cyber-attack varies based on the extent of systems effect, the duration of the attack, and the type of attack. Furthermore, the magnitude of the cyber-attack is dependent upon the system being impacted by the attack, and its ability to pre-empt and address any emerging issues (Maryland Emergency Management Agency 2021). Table 12-1 describes common forms of cyber-attack.

Figure 12-2. Location of Pipelines in Baltimore City

Source: PHMSA n.d.

Note: Red lines indicate petroleum pipelines; blue lines indicate natural gas pipelines

Table 12-1. Common Forms of Cyber-Attack

Threat	Description
Trojan Horses	A form of malware that tricks users into installation by posing as a useful program or by hiding within legitimate software.
Ransomware	A form of malware that utilizes strong encryptions to hold data or systems storage. The individuals behind this type of attack will demand payment in exchange for releasing the system and restoring its functionality.
Scareware	A form of malware that uses fake messages to frighten victims into passing sensitive information.
Spyware	A form of malware that gathers usernames, passwords, and credit card numbers for the perpetrator to utilize.
Worms	A form of malware that uses a self-replicating code to automatically spread between apps and devices without human action.
Phishing	A socially engineered scam that uses fake emails or text messages to steal an individual's credentials, exfiltrate sensitive data, or spread malware. These messages are designed to look as though it is sent from a reputable source.
Denial-of-Service	Denial-of-service (DoS) and distributed denial-of-service (DDoS) attacks flood a system's resources with fraudulent traffic. The difference between DoS attacks and DDoS attacks is simply that DoS attacks use a single source to generate fraudulent traffic, while DDoS attacks use multiple sources. DDoS attacks are often carried out with a botnet, a network of internet-connected, malware-infected devices under a hacker's control.
SQL Injection	A Structured Query Language (SQL) injection occurs when an attacker inserts malicious code into a server that uses SQL and forces the server to reveal information it normally would not. An attacker could carry out an SQL injection simply by submitting malicious code into a vulnerable website search box.
DNS Spoofing	Attackers will covertly edit domain name system (DNS) records to replace a website's real IP address with a fake one. When victims try to visit the real site, the malicious site that steals data or spreads malware.

Source: IBM 2022; Maryland Emergency Management Agency 2021

12.3.2 Hazardous Materials

The extent of a hazardous material release will depend on whether it is from a fixed or mobile source, the size of impact, the toxicity and properties of the material, the duration of the release, and the environmental conditions (for example, wind and precipitation, terrain, etc.).

Hazardous material releases can contaminate air, water, and soils, possibly resulting in death and/or injuries. Dispersion can take place rapidly when the hazardous material is transported by water and wind. While often accidental, releases can occur as a result of human neglect, intentional acts, or natural hazards. When caused by natural hazards, these incidents are known as secondary events. Hazardous materials can include toxic chemicals, radioactive substances, infectious substances, and hazardous wastes. Such releases can affect nearby populations and contaminate critical or sensitive environmental areas.

With a hazardous material release, whether accidental or intentional, several potentially exacerbating or mitigating circumstances will affect its severity or impact. Mitigating conditions are precautionary measures taken in advance to reduce the impact of a release on the surrounding environment. Primary and secondary containment or shielding by sheltering-in-place measures protects people and property from the harmful effects of a hazardous material release. Exacerbating conditions, characteristics that can enhance or magnify the effects of a hazardous material release, include:

- Weather conditions, which affect how the hazard occurs and develops
- Micro-meteorological effects of buildings and terrain, which alter dispersion of hazardous materials in compliance with applicable codes (such as building or fire codes)
- Maintenance failures (such as fire protection and containment features), which can substantially increase the damage to the facility itself and to surrounding buildings.

As discussed earlier, the severity of the incident is dependent not only on the circumstances described above but also on the type of material released and the distance and related response time for emergency response teams. The areas proximate to the releases are generally at greatest risk; however, depending on the agent, a release can travel great distances or remain present in the environment for a long period of time (i.e., centuries to millennia).

12.4 Previous Occurrences and Losses

12.4.1 FEMA Major Disasters and Emergency Declarations

Between 1953 and 2022, Baltimore City was not included in any disaster declarations (DR) or emergency declarations (EM) for human-caused events (FEMA 2023).

12.4.2 Previous Events

A number of incidents related to hazardous materials releases have impacted Baltimore. A selection of notable events is detailed below.

In December of 2021, a coal dust explosion was reported at a CSX coal plant in south Baltimore. The explosion was due to the accumulation of methane combined with inadequate ventilation. Shockwaves from the explosion could be felt across Baltimore City. The Baltimore City Council hosted a hearing to investigate the explosion and provide community members an opportunity to share input on the impact. MDE subsequently acknowledged the lack of methane monitoring was a regulatory gap. MDE sent a notice of violation to CSX Transportation Inc. on July 20, 2022, outlining a regulatory violation under the Code of Maryland Regulations (COMAR) that led to the December 2021 explosion. The notice mentioned the unpermitted release of carbon dioxide (CO2), carbon monoxide, (CO), nitrous oxides, volatile organic compounds, and sulfur dioxide (SO2). Though no initial injuries were reported, the coal explosion refocused ongoing concerns about the environmental justice burdens associated with the CSX coal operations placed on the Curtis Bay community. MDE has begun air quality monitoring in collaboration with Johns Hopkins University researchers. State officials have committed to bringing the CSX facility into compliance and preventing future hazardous events related to the coal operations.

For the 2023 DP3 update, known human-caused events that impacted individuals, agencies, organizations, or institutions in Baltimore City since 2001 are discussed in Table 12-2.

Table 12-2. Human-Caused Incidents Impacting Baltimore City (2001 to 2023)

Date(s) of Event	Event Type	FEMA Declaration Number (if applicable)	Baltimore City Included in Declaration?	Location(s) Impact	Description
July 18, 2001	Howard Street Tunnel Hazardous Materials Incident	N/A	N/A	Howard Street Tunnel	On Wednesday, July 18, 2001, an eastbound CSX freight train derailed 11 of its 60 cars while passing through the Howard Street Tunnel in Baltimore, Maryland. Four of the 11 derailed cars were tank cars: 1 contained tripropylene, a flammable liquid; 2 contained hydrochloric acid; and 1 contained di(2-ethylhexyl) phthalate, which is a plasticizer and an environmentally hazardous substance. The derailed tank car containing tripropylene was punctured, and the escaping chemical ignited. The fire spread to several adjacent cars, creating heat, smoke, and fumes that restricted access to the tunnel for several days. Details regarding this event is discussed further below.
June 1, 2004	Hazardous Material Incident – Rail	N/A	N/A	Chemical Road	An operator was unloading a railcar when they discovered sulfuric acid spraying onto the top of the railcar from a ruptured acid unloading hose. The operator activated the emergency stop and reported the release. This made it unsafe to approach the railcar, and site remediation was required. This resulted in approximately $283,000 in damage (includes material lost, carrier damage, property damage, response costs, and remediation clean-up costs).
December 15, 2004	Hazardous Material Incident – Air Pollution	N/A	N/A	Curtis Bay	MDE reports that Curtis Bay Energy (formerly Phoenix Services), a commercial medical waste incinerator, has repeatedly violated legal limits for mercury, soot, and other air pollutants. A Consent Order between MDE and Curtis Bay Energy imposed a $225,000 penalty against Curtis Bay Energy. The Consent Order also included the installation of air pollution control equipment as well as provisions for mercury Supplemental Environmental Projects (SEP) in the amount of $125,000.
June 12, 2006	Hazardous Material Incident – Materials Release	N/A	N/A	Fairfield Road	A non-permitted released of benzene occurred at the facilities of Sasol North American, Inc., a chemical manufacturer. Sasol failed to notify the National Response Center, State Emergency Response Commission, and the Local Emergency Planning Commission. A Consent Order was executed requiring Sasol to pay a combined penalty for the violations.

Date(s) of Event	Event Type	FEMA Declaration Number (if applicable)	Baltimore City Included in Declaration?	Location(s) Impact	Description
April 20, 2007	Hazardous Material Incident - Highway	N/A	N/A	West Lafayette Street	A driver delivering fuel oil to a home delivered to a wrong address, and approximately 14 gallons of fuel oil was released into the basement. Remediation was completed. This resulted in over $120,000 in damage (includes material lost, carrier damage, property damage, response costs, and remediation clean-up costs).
January 29, 2008	Hazardous Material Incident – Highway	N/A	N/A	East Monument Street	A fuel oil truck driver hooked up the truck to a home that had the fuel tank removed. As a result, approximately 120 gallons of fuel oil was released into the basement of the home. This resulted in over $500,000 in damage (includes material lost, carrier damage, property damage, response costs, and remediation clean-up costs).
June 10, 2008	Hazardous Material Incident – Highway	N/A	N/A	Underpass of MD Route 2	A cargo tank rolled to its right side on Route 2 near Hanover Street. The tank was damaged and began releasing gasoline onto the road and the ground beneath the ramp. This incident resulted in over $70,000 in damage (includes material lost, carrier damage, property damage, response costs, and remediation clean-up costs).
April 9, 2009	Hazardous Material Incident – Highway	N/A	N/A	4th Street and North Bridge Road	A tractor-trailer driver lost control, and the trailer rolled over, resulting in the release of 700 liquid gallons of gasoline. This incident resulted in over $9 million in damage (includes material lost, carrier damage, property damage, response costs, and remediation clean-up costs).
April 28, 2009	Hazardous Material Incident – Highway	N/A	N/A	Baltimore Beltway	A car failed to yield from an entrance ramp on to I-695. A tanker truck tried to avoid the car, which caused the truck to roll over. This broke open the tank and released 5,000 gallons of an elevated temperature liquid. This incident resulted in $69,785 in damage (includes material lost, carrier damage, property damage, response costs, and remediation clean-up costs).
October 14, 2009	Hazardous Material Incident – Highway	N/A	N/A	West Patapsco Avenue	A stored trailer was vented to release 5,000 gallons of diesel fuel. This incident resulted in $55,000 in damage (includes material lost, carrier damage, property damage, response costs, and remediation clean-up costs).
August 24, 2010	Hazardous Material Incident – Water	N/A	N/A	Broening Highway	Six gallons of furfuryl alcohol leaked from a storage box that led to decontamination and site remediation. This incident resulted

Date(s) of Event	Event Type	FEMA Declaration Number (if applicable)	Baltimore City Included in Declaration?	Location(s) Impact	Description
					in $110,119 in damage (includes material lost, carrier damage, property damage, response costs, and remediation clean-up costs).
February 2014	Cyber-Attack	N/A	N/A	Citywide	The personal information of more than 309,000 students, staff, and alumni of the University of Maryland was compromised in a cyber-attack that exposed names, Social Security numbers, dates of birth, and university identification numbers.
August 22, 2016	Hazardous Material Incident – Highway	N/A	N/A	I-95	A tractor-trailer driver lost control, resulting in the trailer rolling over. This damaged the saddle tank and released approximately 50 gallons of fuel oil. The cargo inside the trailer was damaged and released 270 gallons of polyether-modified polysiloxane. This incident resulted in $78,832 in damage (includes material lost, carrier damage, property damage, response costs, and remediation clean-up costs).
September 3, 2016	Hazardous Material Incident – Materials Release	N/A	N/A	Fort Armistead	A non-permitted release of 6,339 pounds of ferrous chloride occurred at Kemira Water Solutions, Inc.'s facility. The EPA filed a Consent Agreement and Final Order which consisted of a penalty of $20,129 for the notification violation and additional reporting violations.
December 26, 2017	Hazardous Material Incident – Highway	N/A	N/A	I-83	A tractor-trailer driver lost control and hit a guard wall, causing 2,800 gallons of fuel oil to be released. This incident resulted in $136,000 in damage (includes material lost, carrier damage, property damage, response costs, and remediation clean-up costs).
March 2018	Cyber-Attack	N/A	N/A	Citywide	Baltimore Police Department's computer-aided dispatch was hit with a cyber-attack that put the 911 and 311 systems down for 17 hours.
May 2019	Cyber-Attack	N/A	N/A	Citywide	Baltimore City endured the infamous ransomware attack that shut down City services for months and cost Baltimore City millions of dollars. Details regarding this event is discussed further below.

Date(s) of Event	Event Type	FEMA Declaration Number (if applicable)	Baltimore City Included in Declaration?	Location(s) Impact	Description
June 2021	Cyber-Attack	N/A	N/A	Citywide	Turning Point Clinic, Baltimore's largest substance abuse treatment clinic, experienced a cyber-attack that exposed patients' information.
December 2021	Cyber-Attack	N/A	N/A	Citywide	The Maryland Health Department was hit with a ransomware attack that shut down services, including the Baltimore City government's COVID-19 tracker.
December 30, 2021	CSX Coal Explosion	N/A	N/A	South Baltimore	A notice of violation was issued by MDE to CSX regarding the Maryland Air Quality Act, Maryland Code, Environmental Article §2-101 et seg that occurred on December 30, 2021. A $100,000 settlement was reached.
June 22, 2022	Hazardous Material Incident – Lead Paint	N/A	N/A	Woodberry, Medfield, and Hampen	Skyline Tower Painting and Communication Tower Painting was contracted to power wash and paint a large TV antenna in the Woodberry neighborhood. Paint chips from the tower that fell throughout the neighborhood were tested and were positive for lead. MDE issued a stop work order and the company removed paint debris from the surrounding area.
May 2023	Cyber-Attack	N/A	N/A	Citywide	John Hopkins University and Health System were alerted to a widespread cyber-attack that placed the personal information of community employees, students, and patients at risk; Johns Hopkins officials say the cyber-attack did not impact patient medical records. The attackers targeted a previously unknown vulnerability in the widely used software MOVEit. The investigation into this cyber-attack is ongoing.

Source: U.S. DOT Pipeline and Hazardous Materials Safety Administration 2023; Technical.ly 2022; Baltimore Sun 2004; Baltimore Brew 2022; EPA 2019; Fox45 News 2022

12.4.3 Additional Event Details

May 2019 Baltimore City Cyber-Attack

In May 2019, Baltimore City fell victim to a cyber-attack which lasted for over one month. The Robbinhood ransomware was identified as being responsible. The hackers got ahold of Baltimore City's entire online infrastructure and held it for ransom. They demanded that Baltimore City pay 3 Bitcoin for each system to be unlocked or 13 Bitcoin for the whole lot of them. This amounted to approximately $76,280 in total. The cyber-attack impacted Baltimore City's servers and email system and rendered Baltimore City's official card payment system and debt checking application inaccessible. Restoration processes began in June. By June 4, 35 percent of the over 10,000 municipal employees regained access to accounts; roughly three weeks later, 95 percent of the accounts could be accessed. Throughout the cyber-attack, Baltimore City refused to pay the $76,280 ransom, which was heavily criticized. Baltimore City spent a total of $18.2 million instead on restoration and mitigation efforts; this total also includes $8.2 million of revenue loss (Heimdel 2020).

Signs indicating a cyber-attack began on May 7 when the Department of Public Works tweeted about its email service being down. Later the same day, the same institution announced to the public that its phone lines had also been affected. The Department of Transportation was the second organization to suffer damage that day when employees found themselves unable to process vehicles at one of the impound lots. Furthermore, most of Baltimore City's departments found their email systems unresponsive.

With assistance from the local FBI unit, City investigators managed to quarantine the strain, which they identified as the Robbinhood ransomware. The hackers were able to hold Baltimore City's online infrastructure and demanded Baltimore City to pay 3 Bitcoin for each system to be unlocked, amounting to approximately $76,280 in total.

The newly appointed Mayor, Bernard Young, released a statement noting that all City employees were forced to replace computerized work with manual processes, including any payments due to Baltimore City which would otherwise be completed with a card payment system and debt checking application.

One week following the cyber-attack, it was revealed 15 City agencies, departments, and offices were impacted. An official statement was posted on the Baltimore City website, though the statement did not provide clarity on the ongoing situation or provide a timeframe for repairs.

Beginning in June, efforts to resolve the issues associated with the cyber-attack ramped up. Security researchers were able to identify a Twitter account associated with the ransomware attacker, who had already released personal documents belonging to City employees. The Twitter account was suspended on June 3.

On the following day, it was announced that 35 percent of the over 10,000 municipal employees regained access to accounts. It took another two weeks before the restoration process would reach 65 percent; at this point, water billing, e-permit systems, and real estate transactions were still impacted. Over a month and a half after the cyber-attack, it was announced that 95 percent of the accounts could be accessed; however, other system functions, such as billing, were still impacted (Heimdel 2020).

Baltimore City incurred a total of $18.2 million in damage from the cyber-attack. This cost included $4.6 million on restoration, $5.4 million in mitigation efforts, and $8.2 million in revenue loss.

Throughout the cyber-attack, Baltimore City refused to pay the hacker the demanded $76,280 ransom, which was heavily criticized by the public. However, Mayor Young stated

> "... We've been advised by both the Secret Service and the FBI not to pay the ransom. Second, that's just not the way we operate. We won't reward criminal behavior. If we paid the ransom, there is no guarantee they can or will unlock our system. There's no way of tracking the payment or even being able to confirm who we are paying the money to. Because of the way they requested payment, there's no way of knowing if they are leaving other malware on our system to hold us for ransom again in the future. Ultimately, we would still have to take all the steps we have taken to ensure a safe and secure environment..." (Heimdel 2020).

Howard Street Tunnel Hazardous Materials Incident

On Wednesday, July 18, 2001, an eastbound CSX freight train derailed 11 of its 60 cars while passing through the Howard Street Tunnel in Baltimore, Maryland. Four of the 11 derailed cars were tank cars: 1 contained tripropylene, a flammable liquid; 2 contained hydrochloric acid; and 1 contained di(2-ethylhexyl) phthalate, which is a plasticizer and an environmentally hazardous substance. The derailed tank car containing tripropylene was punctured, and the escaping chemical ignited. The fire spread to several adjacent cars, creating heat, smoke, and fumes that restricted access to the tunnel for several days. A 40-inch-diameter water main directly above the tunnel broke in the hours following the accident and flooded the tunnel with millions of gallons of water. Five emergency responders sustained minor injuries while involved with the on-site emergency. Total costs associated with the accident, including response and clean-up costs, were estimated at about $12 million (NTSB 2005).

On the day of the accident, 11 trains went through the Howard Street Tunnel before the accident train. The crewmembers of the accident train reported that their train entered the west end of the tunnel below the timetable speed of 25 mph. About a quarter of a mile into the tunnel, the track grade changes from slightly descending to slightly ascending. The event recorders showed that at the dip, the train's speed was 24 mph; as the train passed through the dip, the train started the ascending grade. While the train was moving about 21 mph, the locomotive tractive effort increased, and the train slowed to 18 mph. At 3:08 p.m., an un-commanded emergency air brake application was recorded, and the lead locomotive stopped in the tunnel. Unknown to the crew at the time, the train had derailed. The emergency application of the train air brakes had occurred when the train became uncoupled ahead of the first car to derail, causing the train air brake line to separate.

The derailment also resulted in the puncturing of a derailed tank car carrying tripropylene and the subsequent ignition of this product. Post-accident inspection of the tank car indicated that a braking system linkage bar had disconnected and that the disconnected end of the linkage bar, when lifted upward, aligned with the hole in the tank. The fire spread to cargo in adjacent cars, which included paper and wood products, and generated heavy smoke and fumes that quickly filled the tunnel. Additionally, 2,554 gallons of hydrochloric acid were released from another derailed tank car (NTSB 2005).

At 3:26 p.m., the director of security at a hotel near the derailment site called 911 and reported a disturbance near his facility. The security director then called the Baltimore Department of Public Works to report the disturbance. About 10 minutes later, he called the CSX communications center to advise them of a strong "rumbling" that had occurred at his building, noting it sounded like the rumbling originated in the Howard Street railroad tunnel.

The CSX chief dispatcher contacted the Baltimore trainmaster to advise and inquire if the train was transporting hazardous materials. He was told that the train did include hazardous materials cars. Baltimore Fire Department was dispatched to the scene, identifying smoke to be coming from the west tunnel; responders were unable to enter the tunnel due to excessive fire and smoke.

Roughly an hour after arriving on scene, a shelter-in-place was ordered for several blocks on either side of the tunnel path; other precautionary measures included evacuating the Camden Yards baseball stadium, activating the public alert siren system, and employing local television and radio outlets for public notifications.

For the next 2 days, several groups of firefighters and railroad employees equipped with self-contained breathing apparatus ventured into the tunnel to determine the extent of the derailment and the status of burning equipment and cargo. The fire lasted for about 5 days as smoke emanated from both ends of the tunnel and several manholes at the Howard Street level. On Monday, July 23, the scene was declared under control (NTSB 2005).

The National Transportation Safety Board (NTSB) conducted an investigation into the accident. The investigation resulted in a 28-page briefing detailing the derailment and fire. Recommendations from the NTSB were as follows:

- CXS Transportation Incorporated
- Maintain historical documentation of maintenance and inspection activities affecting the Howard Street Tunnel.
- Take action necessary to enhance the exchange of information with Baltimore on maintenance and construction activities within and in the vicinity of the Howard Street Tunnel.
- City of Baltimore, Maryland
- Take action necessary to enhance the exchange of information with CSX Transportation on maintenance and construction activities within and in the vicinity of the Howard Street Tunnel.
- Update and revise your emergency preparedness documents to include information on hazardous materials discharge response procedures specific to tunnel environments as well as infrastructure information on the Howard Street Tunnel.

No official determination for the cause of the derailment was identified. Computer simulations indicated that neither train operations nor changes in track conditions alone likely resulted in a derailment. Available physical evidence and computer simulations also showed that the most likely derailment scenario involved an obstruction between a wheel and the rail, in combination with changes in track geometry. However, post-accident fire, flooding, and necessary emergency response activities, including removing burning freight cars from the tunnel, significantly disturbed the accident site. No obstruction was identified that could be convincingly connected to wheel climb, and evidence was insufficient to determine changes in track geometry (NTSB 2005).

12.5 Probability of Future Hazard Events

Predicting future human-caused events, such as cyber-attacks and hazardous material incidents, in Baltimore City is difficult. Incidents can be sudden without any warning or slowly develop.

For cyber-attacks, based on past historical data and trends, the future probability of cyber-attacks occurring in Baltimore City is likely. Cyber-attacks have the potential to impact Baltimore City's computer infrastructure and the systems and services that are provided to the public. Concerns about cyber-attacks throughout the United States are growing as its impacts could have potentially crippling effects. Security experts describe the threat of cyber-attacks as imminent and highly likely to occur in any given year (Maryland Emergency Management Agency 2021).

For hazardous material incidents, small spills, both fixed site and in-transit, occur throughout the year, and the probability of these events is likely. The risk of major incidents in a given year is rare. It is estimated that Baltimore City will continue to experience direct and indirect impacts of hazardous material incidents annually that may induce secondary hazards such as infrastructure deterioration or failure, water quality and supply concerns, and transportation delays, accidents, and inconveniences. Table 12-3 shows the probability of future occurrences in Baltimore City.

Table 12-3. Future Occurrence of Human-Caused Events in Baltimore City

Hazard Type	Number of Occurrences Between 2001 and 2023	% Chance of Occurrence in Any Given Year
Cyber-Attack	6	26.09%
Hazardous Materials	14	60.98%
Total	17	74.07%

Source: U.S. DOT Pipeline and Hazardous Materials Safety Administration 2023; Technical.ly 2022

In Section 3, the identified hazards of concern for Baltimore City were ranked. The probability of occurrence, or likelihood of the event, is one parameter used for hazard rankings. Based on historical records and input from the CPT, the probability of occurrence for human-caused hazards is considered "occasional."

12.5.1 Potential Impacts of Climate Change

Cyber-Attack

Generally, cyber-attacks will not be affected by climate change. However, climate change has many direct and indirect impacts on the human population, and influences on human behavior can be further analyzed.

Hazardous Materials

It can be assumed that the projected increase in temperatures may impact the storage and ultimately transportation of hazardous materials. If stored improperly or if storage methods are not adapted to withstand extreme temperatures, hazardous materials may have an adverse reaction, leading to a potential hazardous materials incident (OSHA 2016).

Similarly, the increase in frequency and magnitude of flood and severe weather events may impact hazardous materials at both fixed sites and during transit. Baltimore City experiences significant flooding events already, and with future climate projections, these events may become more frequent and intense. If not properly stored, hazardous materials could interact with flood waters and cause adverse reactions (US EPA 2021). Hazardous materials in-transit would be at risk, varying by mode of transport. Transport by rail and highway would need to be aware of flooding conditions and visibility during severe storms; transport by water would need to be aware of wave action and water elevation levels; transport by pipeline would need to be aware of potential excess soil saturation, which could influence the integrity of pipelines during extreme conditions.

12.6 Vulnerability Assessment

To understand risk, a community must evaluate what assets are exposed or vulnerable in the hazard area identified. The entire City has been identified as exposed to the human-caused hazard. Therefore, all assets in Baltimore City (population, structures, critical facilities, and lifelines), as described in the Section 3 (Risk Assessment), are exposed and potentially vulnerable.

12.6.1 Impacts on Population

General Population

Cyber-Attack

The entirety of Baltimore City (591,489 people), including those that live, work, and visit Baltimore City, are vulnerable to a cyber-attack. The impact of a cyber-attack can begin at the government-level and trickle down to affecting those in Baltimore City. As seen during the May 2019 Baltimore City Cyber-Attack, programs offered by Baltimore City to its residents had to be performed manually instead of electronically due to systems being down; this caused a lag in real estate sales, bill payments, and permitting.

Hazardous Materials

Depending on the type and quantity of chemicals released and the weather conditions, an incident can affect larger areas that cross jurisdictional boundaries. When hazardous materials are released, they may contaminate the environment and pose greater danger to human health. Exposure may be either acute or chronic, depending upon the nature of the substance and extent of release and contamination.

Due to the varied location of different hazardous substances and waste sites in Baltimore City, the entire City is considered vulnerable to this hazard. Potential losses from hazardous materials incidents include human health and life and property resources. These types of incidents can lead to injury, illnesses, and/or death from both the involved persons and those living in the impacted areas.

To estimate population exposure to the hazardous material hazard, a half-mile buffer was placed around all hazardous material roadway and rail routes in Baltimore City; the population within this buffer is considered exposed. Table 12-4 summarizes the population located with a half-mile of these areas, by City Council District.

Table 12-4. Estimated Population Located in the Hazardous Materials Hazard Areas

City Council Districts	Total Population (American Community Survey 2021)	Estimated Population Located in the Hazardous Materials Hazard Areas			
		Number of Persons Located within 1/2 Mile of Hazardous Materials Roadway Routes	Percent of Total	Number of Persons Located within 1/2 Mile of Hazardous Materials Rail Routes	Percent of Total
1	43,739	17,177	39.3%	20,239	46.3%
2	45,252	26,212	57.9%	3,276	7.2%
3	42,257	36,403	86.1%	0	0.0%
4	45,027	36,388	80.8%	0	0.0%
5	43,601	30,109	69.1%	14,540	33.3%
6	41,604	31,955	76.8%	23,601	56.7%
7	39,638	29,976	75.6%	29,914	75.5%
8	46,396	36,224	78.1%	10,399	22.4%
9	35,869	30,376	84.7%	34,240	95.5%
10	41,521	30,790	74.2%	38,400	92.5%
11	48,022	43,862	91.3%	43,982	91.6%
12	37,130	32,787	88.3%	35,112	94.6%
13	38,768	29,690	76.6%	28,090	72.5%
14	42,664	40,816	95.7%	15,552	36.5%
Baltimore City (Total)	**591,489**	**452,766**	**76.5%**	**297,346**	**50.3%**

Source: U.S. Census 2021, American Community Survey; Maryland Department of Transportation 2019; City of Baltimore 2020

Based on the spatial analysis, there are an estimated 452,766 residents living within a half-mile of a hazardous material roadway route, or 76.5 percent of Baltimore City's total population. There are an estimated 297,346 residents living within a half-mile of a hazardous material rail route, or 50.3 percent of Baltimore City's total population. City Council District 11 has the greatest number of residents living within a half-mile of a hazardous material roadway and rail route, with approximately 43,862 residents and 43,982 residents, respectively.

Socially Vulnerable Populations and Underserved Communities

Socially vulnerable populations are most susceptible based on many factors, including their physical and financial ability to react or respond during a hazard and the location and construction quality of their housing. Economically disadvantaged populations are likely to evaluate their risk and make decisions based on the major economic impact to their family and may not have funds to evacuate if necessary.

Table 12-5 displays the total population data for Baltimore City by City Council District. According to the 2021 American Community Survey, there are roughly 84,000 persons over age 65 (14.1 percent of the total population); approximately 36,000 persons (6.2-percent of the total population) under the age of 5; just over 10,000 persons (1.7-percent of the total population) which do not speak English; an estimated 93,000 persons (15.7-percent of the total population) who have a disability; and about 116,000 persons (19.5-percent of the total population) living at or below the poverty level.

Table 12-5. Baltimore City Total Population by City Council District

City Council District	Total Population (American Community Survey 2021)	Percent of City Total	American Community Survey 5-Year Population Estimates (2021)									
			Over 65	Percent of Jurisdiction Total	Under 5	Percent of Jurisdiction Total	Non-English Speaking	Percent of Jurisdiction Total	Disability	Percent of Jurisdiction Total	Poverty Level	Percent of Jurisdiction Total
1	43,739	7.4%	4,481	10.2%	3,344	7.6%	1,141	2.6%	4,200	9.6%	5,851	13.4%
2	45,252	7.7%	5,528	12.2%	3,009	6.6%	1,376	3.0%	5,394	11.9%	6,530	14.4%
3	42,257	7.1%	5,988	14.2%	1,669	4.0%	470	1.1%	5,485	13.0%	3,539	8.4%
4	45,027	7.6%	6,401	14.2%	3,113	6.9%	371	0.8%	5,601	12.4%	6,218	13.8%
5	43,601	7.4%	8,122	18.6%	3,762	8.6%	1,176	2.7%	6,613	15.2%	7,155	16.4%
6	41,604	7.0%	8,355	20.1%	2,356	5.7%	546	1.3%	7,741	18.6%	7,910	19.0%
7	39,638	6.7%	6,177	15.6%	1,895	4.8%	349	0.9%	7,764	19.6%	9,082	22.9%
8	46,396	7.8%	7,799	16.8%	2,947	6.4%	392	0.8%	8,376	18.1%	8,014	17.3%
9	35,869	6.1%	4,927	13.7%	2,024	5.6%	641	1.8%	8,523	23.8%	11,821	33.0%
10	41,521	7.0%	4,755	11.5%	3,468	8.4%	1,054	2.5%	7,685	18.5%	12,283	29.6%
11	48,022	8.1%	5,774	12.0%	2,182	4.5%	907	1.9%	6,231	13.0%	8,651	18.0%
12	37,130	6.3%	4,203	11.3%	1,690	4.6%	575	1.5%	6,388	17.2%	9,815	26.4%
13	38,768	6.6%	4,701	12.1%	2,684	6.9%	582	1.5%	6,814	17.6%	11,673	30.1%
14	42,664	7.2%	6,316	14.8%	2,324	5.4%	702	1.6%	5,891	13.8%	7,086	16.6%
Baltimore City (Total)	**591,489**	**100.0%**	**83,527**	**14.1%**	**36,468**	**6.2%**	**10,283**	**1.7%**	**92,707**	**15.7%**	**115,625**	**19.5%**

Cyber-Attack

In general, socially vulnerable populations may not be impacted by cyber-attack events to the extent of other social groups and populations. Socially vulnerable populations are often reliant on government or community programs for access to technology, such as laptops and desktops. Access to those items would be indirectly impacted if the agency or organization providing those services were directly impacted. However, certain types of cyber-attacks, such as phishing, often target older adults (AARP 2021).

Hazardous Materials

Those particularly vulnerable to hazardous materials events include populations located along major transportation routes because of the quantities of chemicals transported on these major thoroughfares.

Socially vulnerable populations are particularly vulnerable to impacts from hazardous materials, not just hazardous material events. There is an environmental injustice with the location of hazard material facilities through the United States, and Baltimore City is not an exclusion (Baltimore Corps 2020).

12.6.2 Impacts on Structures

General Building Stock

Cyber-Attack

Potential losses to the general building stock caused by a cyber-attack are difficult to quantify. Potential losses may include inaccessibility and/or loss of service depending on the extent of the attack and whether the access points to the building are electronic or manual.

Hazardous Materials

Potential losses to the general building stock caused by a hazardous substance release, whether in transit or at fixed sites, are difficult to quantify. The degree of damage depends on the scale of the incident. Potential losses may include inaccessibility, loss of service, contamination, and/or potential structural and content losses.

The closure of waterways, railroads, airports, and highways as a result of a hazardous substance incident has the potential to impact the ability to deliver goods and services efficiently. Potential impacts may be local, regional, or statewide, depending on the magnitude of the event and level of service disruptions.

Table 12-6 summarizes the number of structures located within a half-mile of a hazardous material roadway and rail routes by City Council District. In summary, there are 174,170 buildings located within a half-mile of a hazardous material roadway route buffer with an estimated $270 billion of replacement cost value (i.e., building and content replacement costs). In total, this represents approximately 77.8 percent of Baltimore City's total general building stock inventory. In addition, there are 125,698 buildings located within a half-mile of a hazardous material rail route buffer with an estimated $216 billion of building stock and contents exposed. This represents approximately 62.2 percent of Baltimore City's total general building stock inventory.

Table 12-6. Estimated Number and Total Replacement Cost Value of Structures Located Within the 1/2 Mile Hazardous Materials Hazard Area

City Council District	Total Number of Buildings	Total Replacement Cost Value (RCV)	Number of Buildings Located Within 1/2 Mile of Hazardous Materials Roadway Routes				Number of Buildings Located Within 1/2 Mile of Hazardous Materials Rail Routes			
			Number of Buildings	Percent of Total	Total Replacement Cost of Buildings	Percent of Total	Number of Buildings	Percent of Total	Total Replacement Cost of Buildings	Percent of Total
1	22,781	$42,726,169,218	8,758	38.4%	$13,201,333,320	30.9%	10,635	46.7%	$20,196,636,051	47.3%
2	12,746	$19,773,061,274	7,693	60.4%	$15,436,772,252	78.1%	1,346	10.6%	$6,746,870,496	34.1%
3	14,274	$14,195,099,773	12,356	86.6%	$13,139,643,514	92.6%	0	0.0%	$0	0.0%
4	14,536	$12,686,748,697	11,808	81.2%	$11,119,411,557	87.6%	0	0.0%	$0	0.0%
5	12,637	$18,575,913,421	8,780	69.5%	$12,137,285,454	65.3%	4,349	34.4%	$7,674,737,442	41.3%
6	15,009	$19,159,968,457	11,626	77.5%	$16,340,608,492	85.3%	8,630	57.5%	$12,766,925,841	66.6%
7	17,409	$18,007,600,793	13,196	75.8%	$14,049,960,803	78.0%	13,130	75.4%	$13,529,657,856	75.1%
8	14,350	$14,208,439,442	11,263	78.5%	$12,121,565,050	85.3%	3,204	22.3%	$2,314,247,278	16.3%
9	21,371	$21,990,875,897	18,162	85.0%	$19,030,484,766	86.5%	20,427	95.6%	$21,406,198,208	97.3%
10	16,334	$33,621,448,750	12,222	74.8%	$26,398,296,537	78.5%	15,118	92.6%	$31,005,402,940	92.2%
11	17,184	$62,344,674,213	15,610	90.8%	$52,965,073,891	85.0%	15,615	90.9%	$52,343,587,652	84.0%
12	15,436	$33,041,741,651	13,712	88.8%	$30,728,950,663	93.0%	14,175	91.8%	$24,726,505,003	74.8%
13	18,095	$19,432,245,395	13,962	77.2%	$16,584,978,692	85.3%	13,187	72.9%	$15,344,174,102	79.0%
14	15,694	$17,744,799,580	15,022	95.7%	$17,082,631,483	96.3%	5,882	37.5%	$8,028,060,810	45.2%
Baltimore City (Total)	**227,856**	**$347,508,786,561**	**174,170**	**76.4%**	**$270,336,996,474**	**77.8%**	**125,698**	**55.2%**	**$216,083,003,679**	**62.2%**

Source: Maryland Department of Planning 2020, 2022; RS Means 2022; Maryland Department of Transportation 2019; City of Baltimore 2020

Critical Facilities, Infrastructure, and Community Lifelines

Cyber-Attack

While physical structures are generally not at risk, all networked electronic devices are vulnerable to cyber-attacks. Many facilities are essential to the operation of City functions and infrastructure. For example, an attack on the power grid could have detrimental impacts on City services and functions. A coordinated attack could render City-run networks useless, causing major disruptions to infrastructure such as the power grid, water treatment plants, and sewer and wastewater treatment plants. A seemingly minor cyber-attack would be if a perpetrator were to gain access to variable message boards and alter the text to cause disruption and instill fear or worry in the population.

Because computer networks contain sensitive information that is integral to security, networks will likely continue to be the focus of coordinated cyber-attacks. Computer networks are also entrusted with many forms of personal and financial information, including tax filings, birth and death records, Social Security numbers, medical information, and more. Additionally, many critical facilities that are essential to City operations rely upon computer networks to monitor and control critical functions.

Additionally, a large-scale computer breach would likely lead to significant economic costs in lost productivity to the impacted City agencies and potentially related businesses and industries (Maryland Emergency Management Agency 2021).

A significant cyber-attack could impact all seven FEMA community lifelines, as described in Table 12-7.

Hazardous Materials

Potential losses to critical facilities caused by a hazardous materials incident are difficult to quantify. Potential losses may include inaccessibility, loss of service, contamination, and/or potential structural and content losses if an explosion occurs.

If a significant hazardous materials incident occurred, not only would life, safety, and building stock be at risk, but the economy of Baltimore City may be impacted as well. A significant incident in an urban area may force businesses to close for an extended period of time because of contamination or direct damage caused by an explosion if one occurred. Estimating impacts on the economy is difficult to determine, given the uncertain nature of the size and scope of incidents.

Hazardous material incidents have the potential to lead to major transportation route closures in Baltimore City. The closure of waterways, railroads, airports, and highways as a result of hazard material release incidents has the potential to impact the ability to deliver goods and services. Potential impacts may be local, regional, or statewide, depending on the magnitude of the event and the level of services disruptions.

A significant hazardous materials event could impact all seven FEMA community lifelines, as described in Table 12-8.

Table 12-7. Community Lifeline Impacts from a Cyber-Attack Event

Community Lifeline	Impact
Safety and Security	Law enforcement, fire, and government services which rely on computer-based systems to operate are especially at risk. Vulnerabilities in security should be addressed to avoid ransomware attacks, which are the most occurring form of cyber-attack. Corrections facilities should also ensure systems are not vulnerable, as many cell blocks are operated utilizing electronic mechanisms.
Food, Hydration, and Shelter	Water systems in particular may be at risk from a cyber-attack due to interconnected systems. Potable water, wastewater, and sewer treatment plants may all be connected to singular location for operation control; this would mean a perpetrator would just need to access a singular point in order to gain access to multiple locations.
Health and Medical	Health and medical facilities are at a heightened risk of cyber-attacks due to the personal information being held at the facilities.
Energy	Interconnected systems in power grids are convenient but place an increased risk for cyber-attacks without proper security. A cyber-attack on oil and gas pipelines is rare, but extremely costly. The mechanized systems, if not secure, could cut the flow of oil to its original destination until demands are meet.
Communications	If a system is not closed, the infrastructure associated with communications, including responder communications, could be greatly impacted by a cyber-attack. Encrypted channels for responder communications ensures unwanted listeners do not have access; alert and warning messaging systems and 911/dispatch should have security keys to mitigate the risk of a cyber-attack as the operations directly impact life safety.
Transportation	While a cyber-attack would not directly impact transportation infrastructure, it could affect the transportation stations such as ticketing systems at train stations and airports; the mechanics at an airport for security and baggage gathering and claims; and the mechanics at rapid rail lines.
Hazardous Material	A cyber-attack could target a facility that houses hazardous materials (including hospitals), Tier II facilities, and gas stations. Depending to what extent the cyber-attack impacts the facility, there could be a hazardous materials release if the materials are stored with electronic locks.

Table 12-8. Community Lifeline Impacts from a Hazard Material Event

Community Lifeline	Impact
Safety and Security	Hazardous material events directly involve law enforcement and fire services, as these events impact community safety. Government services could be affected during a hazardous material event due to supply chain disruption and the overall response to the event.
Food, Hydration, and Shelter	Contaminants and pollutants are transported via air and water potentially impacting food and water sources. If an evacuation is ordered, shelters may open in Baltimore City.
Health and Medical	Hazardous material events have the potential to expel chemicals into the air and waterways, potentially impacting public health and causing individuals to seek medical care, which may result in patient movement and impact. Additionally, hazardous material events could disrupt the medical supply chain, and the supply chain overall if the event were to occur in a non-fixed-point location, such as rail lines or on a major highway.
Energy	Hazardous materials include petroleum and natural gas, which can be used to power vehicles, houses, and critical facilities. A hazardous materials event could interrupt the flow of transport for these materials, causing delays in delivery and impacting the disbursement of power. An additional potential impact to the Energy community lifeline would be if a hazardous materials incident were severe enough to cause an explosion and interrupt or knock out the power grid.
Communications	A hazardous materials event would have the potential to impact infrastructure more so than responder communications, alerts or warnings, and dispatch. In an industrial area, including the port, this is particularly the case as crude oil and liquid natural gas may be exposed to chemicals which they may be reactive to.
Transportation	Depending on the method of transport, multiple forms of transportation could be impacted. Hazardous materials in Baltimore City are transported in and out of Baltimore City via highway, roadway, railway, maritime, and pipeline. Pipelines often are in close proximity of major highways and roadways; if an event were to occur on or in either of these methods of transport, the other may be impacted.
Hazardous Material	Contaminants and pollutants are transported via air and water impacting the environment and the population; hazardous materials facilities are impacted (depending on event size, multiple facilities in close proximity could cause cascading impacts).

Table 12-9 lists the number of lifelines within a half-mile of a hazardous material roadway and rail routes. Of the 1,686 lifelines located within a half-mile of a hazardous material roadway route buffer, the greatest number are health and medical facilities. Additionally, there are 1,271 lifelines located within a half-mile of a hazardous material rail route buffer, 413 of which are health and medical facilities.

Table 12-9. Lifelines Located within a Half-Mile of Hazardous Materials Routes

FEMA Lifeline Category	Number of Lifelines	Number of Lifelines Located within 1/2 Mile of Hazardous Materials Roadway Routes	Number of Lifelines Located within 1/2 Mile of Hazardous Materials Rail Routes
Communications	307	248	202
Energy	70	49	53
Food, Hydration, and Shelter	127	102	84
Hazardous Materials	0	0	0
Health and Medical	802	647	413
Safety and Security	290	238	168
Transportation	446	402	351
Baltimore City (Total)	**2,042**	**1,686**	**1,271**

Source: City of Baltimore 2023; Maryland Department of Transportation (MDOT) 2023; Baltimore City Department of Public Works 2023; HILFD 2018, 2021, 2022; Maryland Department of Transportation 2019; City of Baltimore 2020

12.6.3 Impact on the Economy

Cyber-Attack

A cyber-attack can have significant impacts on the economy. Investigations into the stock price impact of cyber-attacks show that identified target firms suffer losses of 1%–5% in the days after an attack (Congressional Research Service 2004). The Center for Strategic and International Studies (CSIS) estimated in 2018 that cybercrime cost the world almost $600 billion or 0.8% of global GDP (CSIS 2018).

The 2019 cyber-attack on Baltimore City, discussed above in **May 2019 Baltimore City Cyber-Attack**, cost $18.2 million on restoration and mitigation efforts, including $8.2 million of lost revenue.

Hazardous Materials

Impacts on the economy from hazardous material events can cause major disruption. Not only do these events impact the companies transporting the materials, but the events may also impact facilities surrounding the location of the event. For example, if a hazardous material event occurred on a waterway, water-based recreational facilities and activities, such as the National Aquarium, Baltimore Cruises, and the Living Classrooms Foundation's paddle boats, may experience a financial impact (Chesapeake Bay Foundation 2023).

A hazardous materials event can become costly quickly, between the cost of responders, response equipment, and necessary clean-up. The **Howard Street Tunnel Hazardous Materials Incident**, described earlier in the document, cost an estimated $12 million, including response and clean-up costs.

12.6.4 Impacts on Natural, Historic, and Cultural Resources

Cyber-Attack

Cyber-attacks may have some impact on natural, historic, and cultural resources, depending on the attacker's justification or reasoning behind the attack. As mentioned in Section 12.1, perpetrators may be motivated by political and personal views. An individual may seek retribution for a wrongdoing, by invoking an attack on a natural, historic, and/or cultural resource, including a facility. Similarly, if an individual is seeking to bring attention to a political occurrence or view, a cyber-attack may occur at a historical site which could have significance to the political issue.

Hazardous Materials

Hazardous materials that are released into the environment can be harmful to species and their habitat. Wastes that get into waterways will be disruptive and sometimes deadly to aquatic species. Consequentially, wastes that get into waterways can also contaminate drinking water supplies. Hazardous wastes can also leach into soils and travel with wind, which not only impacts the localized habitat but can create issues for surrounding communities. Strict disposal regulations have been defined by organizations like the EPA to ensure that the environment and community is protected from these types of events (USEPA 2023).

12.6.5 Cascading and Compounding Impacts

Cyber-Attack

Critical infrastructure such as power grids, transportation networks, and water supply systems are vital to Baltimore City's economy and prosperity. The cascading effect of risk beyond a system under attack into allied and interconnected fields can be even more devastating, creating chaos to major economic, food, and health systems and lasting for long periods of time. Interdependencies among critical infrastructure are often necessary to meet design specifications, but also lead to undesirable situations when a fault or attack occurs in one and escalates to other connected locations. Escalations may disrupt the operation of the involved critical infrastructure and create feedback loops that can initiate and propagate disturbances in unforeseen ways due to the complexity of the connected systems (Reddy Palleti, et al. 2021).

When Baltimore City fell victim to a cyber-attack in May 2019, the cyber-attack impacted Baltimore City's servers and email system and rendered Baltimore City's official card payment system and debt checking application inaccessible; nearly all electronic-based programs offered by Baltimore City had to be performed manually instead, causing delays, increased costs, and impacted potential revenue. Restoration processes began in June but were not completed until July 2019 (Heimdel 2020). More information on this event can be found in the event synopsis May 2019 Baltimore City Cyber-Attack.

Hazardous Materials

A hazardous materials event requires an urgent response to contain chemical or material release and protect humans and the environment, or the event could quickly cascade into a public health emergency. There are multiple variables that determine how a hazardous materials event will play out, including the method of transport for the chemicals (or if it occurred at a fixed facility), whether shelter-in-place and/or evacuations were ordered, if any persons became contaminated and were not decontaminated properly, and whether a complete response team was dispatched.

In the worst cases, a hazardous materials event would not be able to be controlled for hours to days, with the identified materials being dispersed into the air and/or absorbed into the groundwater. Persons could inhale the material, which would cause adverse side effects and potable water could become contaminated, leading to a water advisory, declaring individuals should rely on bottled water. Hundreds or thousands of persons, up to a few miles from the incident site, may need medical attention due to the inhalation of the material; responders would need to rotate operational periods and perform decontamination operations to maintain scene security and safe working conditions.

A key part of maintaining control during a hazardous material event is to keep the public calm and share clear, concise, and relevant information to the public through a verified method. A hazardous materials event can quickly escalate to public panic if correct information is not dispersed.

12.6.6 Future Changes that May Impact Vulnerability

Understanding future changes that impact vulnerability in Baltimore City can assist in planning for future development and ensuring that appropriate mitigation, planning, and preparedness measures are in place. Baltimore City considered the following factors to examine potential conditions that may affect hazard vulnerability:

- Potential or projected development
- Projected changes in the population
- Other identified conditions as relevant and appropriate, including the impacts of climate change

Changes in Land Use and Development

Cyber-Attack

Generally, cyber-attacks will not be affected by change in land use and development.

Hazardous Materials

Development near the transit routes for hazardous materials and facilities will increase Baltimore City's overall risk. Therefore, Baltimore City should take precautions with the location of new development and the development's proximity to hazardous material facilities and transit routes. Baltimore City may also want to consider implementing designs into the new development that enables improved evacuation or protection from residual impacts from the hazardous materials.

Changes in Population

Baltimore has experienced a decrease in its population since 2010. According to the U.S. Census Bureau, Baltimore City's population decreased by approximately 4.75 percent between 2010 and 2021 (U.S. Census 2021). Estimated population projections provided by the

Maryland Department of Planning indicate that Baltimore City's population will begin to increase going into 2030, reaching a total population of approximately 596,390 persons and continue to increase into 2040 to a population of 599,220 (Maryland Department of Planning 2020).

Cyber-Attack

An increase in the population will ultimately increase the number of persons who could be impacted by a cyber-attack within Baltimore City. However, as Baltimore City continues to rely on technology and increase its virtual footprint, the likelihood of a cyber-attack will increase.

Hazardous Materials

An increase in the population will ultimately increase the number of persons requiring use of transit routes that may also be used as hazardous materials transit routes. Therefore, it is critical that Baltimore City has alternative evacuation routes in case there is a hazardous material outbreak along one of these routes.

Climate Change

The relationship between cyber-attacks and climate change has not been significantly scientifically assessed to draw conclusions.

Hazardous materials transported by transportation systems could be impacted depending on the method for storing materials. If stored improperly, hazardous materials, particularly those which react with certain temperature ranges, could react to the anticipated increase in extreme temperatures caused by climate change. Additionally, a warm environment combined with moisture can also cause microbial growth in storage tanks resulting in degradation and contamination (Komariah, et al. 2022).

Similarly, climate change may potentially increase the frequency and magnitude of flood and severe weather events, which may lead to an increased release of hazardous substances at both fixed sites and in-transit.

12.6.7 Change in Vulnerability Since 2018 DP3

Human-caused hazards were not included as a hazard of concern in the 2018 DP3. Despite the population decreasing since 2018, given the number of significant human-caused events that have occurred in Baltimore City, it can be assumed that the vulnerability to human-caused hazard events has increased since 2018.

Section 13. Capability Assessment

Key changes from the 2018 DP3:

- Federal, state, and local capabilities have been comprehensively reviewed, updated, and reformatted.

FEMA Planning Policy Element C1: 44 CFR § 201.6(c)(3): The plan must document the jurisdiction's existing authorities, policies, programs, and resources and its ability to expand on and improve these existing policies and programs.

Existing laws, ordinances, plans and programs at the federal, state, and local level can support or impact hazard mitigation actions identified in this plan. The capability assessment evaluates Baltimore City's resources to manage risk, including regulatory, administrative, financial, and staffing capabilities. This aids in identifying gaps and showcasing existing hazard mitigation and resilience measures in Baltimore City.

Mayor Brandon Scott and OEM representatives bringing awareness to flood risk in Hillen Road area during March 2021.

Image provided by OEM.

During the 2023 DP3 update process, Baltimore City was tasked with developing and updating their capability assessment, paying particular attention to evaluating the effectiveness of these capabilities in supporting hazard mitigation and identifying opportunities to enhance local capabilities to integrate hazard mitigation into their plans, programs, and day-to-day operations. The following federal and state programs have been identified as programs that may interface with the actions identified in this plan.

13.1 Update Process Summary

The purpose of the capability assessment is to understand the planning, regulatory, administrative, technical, and financial capabilities present in Baltimore City. This assessment helps the County, and its jurisdictions identify strengths and opportunities that can be used to reduce losses from hazard events and reduce risks throughout Baltimore City.

To complete the capability assessment, representatives from City agencies and stakeholder organizations responded to surveys to document existing capabilities and gaps. In addition, plans and codes/ordinances were reviewed to enhance the information provided by Baltimore City.

13.2 Planning and Regulatory Capability

Planning and regulatory capabilities are based on the implementation of ordinances, policies, local laws, state statutes, and plans and programs that relate to guiding and management growth and development. Planning and regulatory capabilities refer not only to the current plans and regulations, but also to the jurisdiction's ability to change and improve those plans and regulations as needed. Baltimore City has many planning and regulatory capabilities that extend beyond Baltimore City limits having beneficial impacts on the region.

13.2.1 Participation in the National Flood Insurance Program

The National Flood Insurance Program (NFIP) was established through the National Flood Insurance Act of 1968; the NFIP is a federal program enabling property owners in participating communities to purchase insurance as a protection against flood losses. Participation in the NFIP is based on an agreement between communities and the federal government. If a community adopts and enforces a floodplain management ordinance to reduce future flood risk to new construction and substantial improvements in floodplains, the federal government will make flood insurance available within the community. This insurance is designed to provide an alternative to disaster assistance and reduce the escalating costs of repairing damage to buildings and their contents caused by floods (FEMA 2002).

Baltimore City has participated in the NFIP since March of 1978. The City has adopted the NFIP minimum floodplain management criteria and exceeds both federal and state minimum requirements. The City has several areas within floodplain code where higher standards have been adopted. Two ways in which this is most evident can be seen in the fact that Baltimore City considers both the 100-year and 500-year to be one in the same. The city has also adopted 2 feet of freeboard which is applied to any Flood Protection Elevation determined within the City's floodplain district. BFE data is also required for proposed development that involves more than five lots or five acres which is reviewed by the City Floodplain Manager.

FEMA is in the process of implementing new approaches to determining flood risk, calculating insurance premiums, and applying Community Rating System (CRS) discounts (see Community Rating System below), called Risk Rating 2.0, Equity in Action (Risk Rating 2.0). Risk Rating 2.0 is a FEMA-led initiative to transform the NFIP into a complete actuarial rate-based program. Under the previous CRS program, discounts for flood insurance policy holders depended on whether the insured property was within a mapped SFHA. Risk Rating 2.0 gradually phases in rates based on factors related to the insured structure.

Discounts to policyholders in communities who participate in the CRS will continue. Communities can continue earning NFIP rate discounts of 5 to 45 percent based on the CRS classification. However, since Risk Rating 2.0 does not use flood zones to determine flood risk, CRS discounts will be applied uniformly in each jurisdiction, regardless of whether the structure is within the SFHA.

Phase I began on October 1, 2021. Any new policies purchased as of this date were subject to the new rating methodology. Existing policyholders eligible for renewal were able to begin taking advantage of immediate decreases in their premiums. Phase II went into effect on April 1, 2022. All remaining policies renewing on or after April 1, 2022, are subject to the new rating methodology under Risk Rating 2.0. Based on this phased approach, the full impact of this transition on Baltimore City will not be fully known for a few years.

Community Rating System

Baltimore City's adoption of higher standards has earned the City a Community Rating System (CRS) rating of five and Baltimore City is the only community within Maryland to have that high of a rating. The CRS program is a voluntary program that provides flood insurance premium discounts to communities who participate in the program. This allows property owners within the SFHA a 25% flood insurance premium discount to the full-risk premium for all NFIP policies in the Regular Program in a participating community, including policies outside of the SFHA. The City Floodplain Manager within DOP is appointed to implement all of the addressed commitments and requirement of the NFIP to include maintaining and storing current and historic FIRM and FIS reports, supporting and compiling map update requests, tracking Letters of Map Change, provides assistance with local floodplain determinations, issuing permits for all proposed development within the SFHA, reviewing elevation certificates, educating and notifying community members and property owners about flood insurance and any changes to the FIRMs that would impact insurance rates, provide assistance regarding flood insurance issues, and tracking the number of structures within the SFHA.

The City has also adopted the most recent FIRMs as of June 16, 2021, per the City's floodplain code § 2-3(a)(1) which states: The official floodplain map is the most current Flood Insurance Rate Map, as prepared by the Federal Emergency Management Agency (Baltimore Planning Department). The City, through the floodplain manager, supports requests for map updates and compiles and tracks Letters of Map Change as well as tracks all current and historic FIRMs and FIS reports. The City also collects technical data and modeling in two different ways. Currently, the city is undertaking a huge effort to determine the capacity of the stormwater sewer network. This data will be used to develop watershed master plans as well as guide development and improvements to the storm drain network. The first way in which the city collects this data is by gathering the data internally through interagency collaboration. The second way in which the city requires and collects information is when permit applicants are required to complete H&H modeling.

Substantial Damage and Improvement

After an event, the City implements a process to determine substantial improvement and substantial damage. Once a permit is received to complete work on a substantially damaged property, the permit applicant must submit an alternative analysis to determine if the structure can be relocated to a less hazardous site. Substantial damage assessments are conducted in the floodway and DOP staff conduct site visits after suspected substantial damage has occurred after intense weather events. Staff then rely on pictures, information gathered by 311 and other city agencies, along with permit applications to identify substantially damaged properties. Currently there is no written procedure for DOP staff to utilize when doing these assessments, but staff refer to FEMA's *Substantial Improvement/ Substantial Damage Desk Reference FEMA P-758*. The Floodplain Manager may issue a stop work order if any development or person has failed to comply with or otherwise has violated any provision of a rule or regulation adopted under the Floodplain Ordinance. The stop work order may be issued to the person responsible for the violation or that person's authorized agent; the developer or owner of the development or that person's authorized agent; and on-site personnel. The violation notice must be served in person; by certified or registered mail; or if the identity or whereabouts of the person responsible, developer, or owner is unknown, by posting a copy of notice in a conspicuous place in or on the property. The contents of the violation must describe the nature of the violation; describe the remedial action needed to correct the violation; specify a responsible period of time within which to complete the remedial action. The Floodplain Manager may institute or cause to be instituted any appropriate legal proceeding.

Standards and Outreach

Additional standards include requiring elevation certificates for new construction or substantially improved structures. Permit applicants must provide an elevation certificate to the Floodplain Manager within DOP, who is responsible for reviewing the elevation certificate. For commercial structures a Floodproofing Certificate is required by DOP for all new construction and substantial improvements. For residential structures the lowest floor elevation and lowest elevation of machinery serving the structure must be certified on an elevation certificate based on finished construction.

Education about flood insurance and flood maps the community members continues to be a priority for the City since 1,855 structures have been identified within the floodplain through the City's tracking of residential and non-residential structures within the SFHA. The Baltimore Office of Sustainability has a website dedicated to flood-insurance and includes a variety of topics. The City also notifies residents located in the SFHA annually about their status as a resident in the SFHA and flood insurance information. Events are also regularly attended where the Floodplain Manager is available for questions or support. Some flood prone communities have standing quarterly meetings during which multiple agencies interface with the community members and give support for these kinds of issues.

Additional information regarding administration and enforcement of the NFIP is available in Appendix D.

Table 13-1 summarizes the planning and regulatory capabilities available to Baltimore City. Table 13-2 summarizes the planning and regulatory capabilities available to Baltimore City at the Federal and State level.

Table 13-1. Planning and Regulatory Capabilities – City of Baltimore

Capability	Details	
Baltimore City Building, Fire, and Related Codes - Effective as of May 18, 2020.	**Description:**	This Codes Article comprises the following standards and codes, as supplemented, amended, or otherwise modified by the Mayor and City Council of Baltimore. These codes guide new development and redevelopment to be designed to withstands forces from hazard events • Maryland Building Performance Standards / March 2019 • International Building Code / 2018 • National Electrical Code / 2017 • International Fuel Gas Code / 2018 • International Mechanical Code / 2018 • International Plumbing Code / 2018 • International Property Maintenance Code / 2018 • International Fire Code / 2018 • International Energy Conservation Code / 2018 • International Residential Code, 1- and 2- Family Dwellings / 2018 • International Green Construction Code / 2018 • International Swimming Pool and Spa Code / 2018
	Responsible Agency:	Department of Housing and Community Development, Housing Inspections Services Division
	Provides Funding for Mitigation:	No
	Hazard:	All hazards
Baltimore City, Maryland, Rules and Regulations for Land Subdivision - Effective as of December 1, 2018.	**Description:**	These Rules and Regulations for Land Subdivision are adopted to promote the health, safety, and general welfare of the community; to ensure that the subdivision of property is in accordance with the Master Plan for Baltimore City; to foster orderly urban development by ensuring that new development and redevelopment is compatible with its surroundings to promote the principles and standards enacted in Baltimore City Sustainability Plan by encouraging the most efficient and sustainable use of land; to protect the physical environment and public natural resources for all residents; to protect property values through harmony of land use; and to ensure adequate provision for open space, public access, off-street parking, and public utilities. The Planning Commission derives its authority to review and approve subdivision from Baltimore City Charter, Article VII, §§75 through 79.
	Responsible Agency:	City of Baltimore Planning Commission
	Provides Funding for Mitigation:	No
	Hazard:	All hazards

Capability	Details	
City of Baltimore Zoning Code – As Enacted & Corrected, Effective June 5, 2017, by Ordinances 16-581 & 17-015; and As Last Amended by Ord. 22-181.	**Description:**	This Zoning Code regulates buildings and land use for the purpose of promoting public health, safety, and morals (general welfare) throughout Baltimore City. Zoning accomplishes this purpose by encouraging appropriate use of lands, stabilizing, and preserving the value of property, preventing congestion and hazards in the street, securing safety from fire, flood, water contamination, air pollution and other dangers, providing adequate light, air, and open space, preventing the overcrowding of land, and avoiding undue concentrations of population. Zoning districts are delineated to reflect similar existing land uses, availability of public water and sewer or lack thereof, access, location, need for additional uses, and physical constraints such as soils, drainage, and flooding. The zoning districts may be changed to encourage appropriate growth and development and are based on consistent land use plans or policies. The Code contains a Floodplain District. The Floodplain District is to regulate flood prone land along certain rivers, creeks, streams, and other natural water courses as identified by the FEMA so as to make Baltimore City landowners eligible for flood insurance under the National Flood Insurance Program. To avoid personal loss and expenditure of public funds for the control of such flooding, it is the purpose of these regulations to prevent obstruction of the water channel and to protect structures and property from flood damage.
	Responsible Agency:	Department of Housing and Community Development, Code Enforcement Division
	Provides Funding for Mitigation:	No
	Hazard:	All hazards
Article 7: Natural Resources, City of Baltimore Code – As Last Amended by Ord. 22-125	**Description:**	Article 7: Natural Resource of Baltimore City Code sets forward provisions, rules, and regulations to protect the natural resources within Baltimore City. Topics covered in this Article include floodplain management, stormwater management, soil erosion and sediment control, forest and tree conservation, city parks and trees, and miscellaneous. The Article identifies the Planning Department as the responsible agency to ensure compliance with the National Flood Insurance Program, and that the Planning Director is responsible for appointing staff to carry out the duties of the Floodplain Manager. The Article identifies Baltimore City Department of Public Works as being responsible for administering and enforcing stormwater management and soil, erosion, and sediment control activities. The Article identifies the Baltimore Department of Planning as being the responsible agency for administering and enforcing activities related to forest and tree conservation. The Article identifies the Baltimore Department of Recreation and Parks as being the responsible agency for administering and enforcing activities related to city parks and trees.
	Responsible Agency:	Department of Planning, Department of Public Works, Department of Recreation and Parks
	Provides Funding for Mitigation:	No
	Hazard:	All natural hazards

Capability	Details	
City of Baltimore Forest Conservation Manual – Effective December 28, 2020	**Description:**	This manual supplements the provisions of the State Conservation Manual, including all tables, figures, and appendices, except as otherwise modified by Article 9A of this manual, and to the extent that said provisions are not inconsistent with the provisions of Article 9A or irrelevant to Baltimore City's Urban Forest Conservation Program. The most recent amendments to the State Manual and/or its appendices shall be considered the current regulations for Baltimore City with some modifications identified in this manual. This manual implements the provisions of Article 7 of Baltimore City Code and Natural Resources Article, § 5-103 and 5-1612, Annotated Code of Maryland by providing for an Urban Forest Conservation program within Baltimore City, and by setting forth standards of performance as described in Natural Resources Article, §5-1603-§5-1609, Annotated Code of Maryland.
	Responsible Agency:	Department of Recreation and Parks
	Provides Funding for Mitigation:	No
	Hazard:	Flooding, Drought, Extreme Temperature
City of Baltimore Landscape Manual – Effective June 5, 2017	**Description:**	This manual strives to support the goals of Baltimore City Comprehensive Master Plan, Baltimore City Zoning Code and the Baltimore Sustainability Plan through the regulation and provision of landscape elements in development and redevelopment projects in Baltimore City. The Landscape Manual will support these documents by working to achieve the following goals, as established in Section 4-503 of Baltimore City Zoning Code: • Improve and increase Baltimore City's environmental quality and green infrastructure network. • Preserve and enhance Baltimore City's character and sense of place. • Foster the economic vitality of Baltimore City's neighborhoods and commercial districts. • Provide a clear process for the design, review, and approval of landscape plans within Baltimore City's development review process. • Promote the long-term health and maintenance of Baltimore City's landscape and tree canopy The Landscape Manual requirements establish how the landscape elements required through the environmental regulations should be used to contribute to the urban design of the site, including how it relates to the street and neighboring properties
	Responsible Agency:	Department of Planning
	Provides Funding for Mitigation:	No
	Hazard:	All hazards

<table>
<tr><th>Capability</th><th colspan="2">Details</th></tr>
<tr><td rowspan="4">City of Baltimore Site Plan Review Manual – Effective June 5, 2017</td><td>Description:</td><td>The purpose of Site Plan Review, as outlined in §4-201 of Article 32, is:
to provide guidance to the applicant early in the design process,
to provide for interagency review, and
to ensure that the proposed development complies with the Zoning Code, the Subdivision Rules and Regulations, this manual, the Building, Fire and Related Codes, and other applicable guidelines and requirements.
The intent is to ensure safe, functional, efficient, and orderly development with high standards of design. In doing so, the process will:
protect the public health, safety, and welfare
minimize adverse effects upon pedestrian and vehicular traffic
ensure the design is safe, environmentally sound, aesthetically responsive, and protects properties, streets, and rights-of-way in the immediate vicinity, and the general public
ensure compliance with the Comprehensive Master Plan and Article 32
provide a consistent and uniform method of review.
This Site Plan Review Manual is therefore created to outline the process for applicants, members of participating agencies and interested parties (§4-202). This Manual and any revisions or if may take effect only after:
Planning Commission approval at a public session,
Filing with the Department of Legislative Reference, and
Posting on Baltimore City website.</td></tr>
<tr><td>Responsible Agency:</td><td>Department of Planning</td></tr>
<tr><td>Provides Funding for Mitigation:</td><td>No</td></tr>
<tr><td>Hazard:</td><td>All hazards</td></tr>
</table>

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<tr><th>Capability</th><th>Details</th><th></th></tr>
<tr><td rowspan="4">City of Baltimore Design Manual – Effective March 28, 2019</td><td>Description:</td><td>The Design Manual was developed in conjunction with and established in City Code Article 32 – “Zoning” (Zoning Code). This manual outlines the design standards and applicable components for physical construction within the identified zoning districts.

As per Title 4, Section 402 of the Zoning Code; the Planning Commission must develop and may revise from time to time a Design Manual that sets forth required design standards in accordance with the goals and objectives set forth in this subtitle.

As directed under Title 3, Section 204; the Director of Planning, or his or her designee, have the responsibility to oversee and enforce this Design Manual and any/all future updates and additions to it. Development projects that are subject to review by the Commission for Historical and Architectural Preservation (CHAP) are not subject to this Manual.

The goals governing the development of the Design Manual are:
To enhance the quality of Baltimore City’s built environment, architectural character, and sense of place,
To foster economic vitality of Baltimore City’s neighborhoods and commercial districts,
To enhance the overall urban design of Baltimore’s neighborhoods, and
To enhance the quality of life of City residents with development that is sensitive to its context and adjacencies in the public realm.
The objectives governing development of the Design Manual are:
To provide clear guidance for the design of residential, commercial, and mixed-use development throughout Baltimore City,
To facilitate the process for design review and approval of structures within Baltimore City’s development review process,
To ensure that the public realm is as thoroughly considered and articulated as principal structures,
To articulate spatial relationships, provide image, develop sense of place, and improve aesthetics of the built environment, and
To provide flexibility and encourage creative solutions to meet the intent and purpose of the Design Manual.</td></tr>
<tr><td>Responsible Agency:</td><td>Department of Planning, Planning Commission</td></tr>
<tr><td>Provides Funding for Mitigation:</td><td>No</td></tr>
<tr><td>Hazard:</td><td>All hazards</td></tr>
</table>

Capability	Details	
Nuisance Flood Plan – April 2021	**Description:**	Maryland lawmakers, local and state governments, and citizens recognize that tidally driven flood events are happening with more frequency. While "nuisance flooding" may not pose a serious threat or result in major damage, it interrupts daily routines and can negatively impact businesses. The definition of nuisance flooding, for the purpose of this plan and in accordance with §3-1001 of the Natural Resource Article of the Maryland Annotated Code, is "high tide flooding that causes a public inconvenience." The legislation requires that the Nuisance Flood Plan include three critical components: 1) Inventory of known flood hazard areas where tidal nuisance flooding occurs; 2) Identification of flood thresholds/ water levels/ conditions that lead to tidal nuisance flooding; and 3) A mechanism to document tidal nuisance flood events from 2020 to 2025. Baltimore City's Nuisance Flood Plan meets and exceeds the State's requirements. City agencies that respond to nuisance flood events were interviewed and a summary of the response process was prepared. The agencies include the Department of Public Works, Department of Transportation, and Baltimore City Fire Department.
	Responsible Agency:	Department of Planning
	Provides Funding for Mitigation:	No
	Hazard:	Flooding, Coastal Storms

Capability	Details	
Baltimore Sustainability Plan – January 2019	**Description:**	The 2019 Sustainability Plan represents a step forward for Baltimore City. The plan uses an equity lens, a transformative tool to improve planning, decision-making, and resource allocation leading to more racially equitable policies and programs. Using the Sustainability Tools for Assessing and Rating (STAR) Community Rating System framework as a basis, the plan incorporates feedback gathered from residents. The Sustainability Plan includes new topics, more intentionally addressing all three legs of sustainability: people, planet, and prosperity. The 2019 Sustainability Plan is a vision for the future of Baltimore. It serves as an umbrella document, to gather efforts together under a single, cohesive vision and identify gaps. It continues and expands the work of other plans including: • The Baltimore Green Network (2018) envisions transforming vacant properties into green community assets, connecting these spaces to schools, homes, retail districts, and other activity centers. • The Baltimore Food Waste and Recovery Strategy (2018). • The Baltimore Climate Action Plan (CAP) (2012) has a goal of reducing emissions by 15 percent by 2020. • The Disaster Preparedness and Planning Project (DP3) (2018) addresses existing hazards including flooding, coastal hazards (such as hurricanes and sea level rise), extreme wind, and extreme heat, while also preparing for the anticipated threats of climate change. • Homegrown Baltimore (2013) is Baltimore City's urban agriculture plan and aims to increase production, distribution, sales, and consumption of locally grown food within our city. Achieving the goals set forth in the Sustainability Plan will require the creativity, commitment, and participation of all of us. No single entity alone—not the government, nor any one person or community—can transform Baltimore into a more sustainable and equitable city. There is a role for every resident, community organization, business, faith-based organization, and institution in making this vision for Baltimore a reality.
	Responsible Agency:	Department of Planning
	Provides Funding for Mitigation:	No
	Hazard:	All natural hazards

Capability	Details	
Green Network Plan – September 2018	**Description:**	To increase equity, livability, and resiliency, City leaders and community partners are taking a new approach to open space. Instead of traditional parks and parkways—which are often cut off from neighborhoods and centers of commerce - cities are investing in “green networks,” holistic systems that connect parks and natural resources with safe, accessible routes for both people and wildlife. Green networks enhance a city’s existing assets, while extending the benefits of green space to all residents and maximizing those benefits to generate overlapping economic, environmental, and health gains. • The Baltimore Green Network promotes urban resiliency through land use equity and connects Baltimore residents to a system of healthy, vibrant, and resilient places. • Rooted in the triple bottom-line approach of Baltimore’s sustainability initiatives (people, prosperity, and environmental sustainability), this plan seeks to transform vacant properties into green community assets. It also connects these spaces to schools, homes, retail districts, and other activity centers. • Community benefits of the Baltimore Green Network include improved public safety, increased economic growth, a better neighborhood quality of life, and a cleaner and healthier environment. • Developed in collaboration with diverse stakeholders - community members, environmental advocates, government agencies, design and real estate professionals, and urban greening experts—this plan details strategies for Baltimore City and community partners to direct resources to the most underinvested neighborhoods, targeted to yield the greatest impact.
	Responsible Agency:	Department of Planning
	Provides Funding for Mitigation:	No
	Hazard:	Extreme Temperature, Flooding
Baltimore Climate Action Plan – September 2018, currently being updated in 2023.	**Description:**	The Climate Action Plan for Baltimore City provides residents, businesses, and City government with a framework for achieving Baltimore City’s greenhouse gas emissions reduction goals. The framework includes sections on Energy Savings & Supply, Land Use & Transportation and Growing a Green City. Buildings in Baltimore contribute 79% of our greenhouse gas emissions. The Energy Savings & Supply chapter addresses this through a total of 17 strategies geared to mitigate emissions from our City’s residential, commercial, and industrial building sectors. It is important to note that the Climate Action Plan also accounts for strategies contained within the Sustainability Plan to help achieve our reduction goals. In order to reach our 15% reduction by 2020, Baltimore City will need to not only implement strategies laid forth in the Climate Action Plan, but also continue to implement strategies from the Sustainability Plan.
	Responsible Agency:	Department of Planning

Capability	Details	
	Provides Funding for Mitigation:	No
	Hazard:	All natural hazards
Maritime Master Plan – February 2012	**Description:**	The overall Goal is to provide a framework for the safe and environmentally responsible management of competing interests in Baltimore's Harbor in order to control growth of the recreational boating industry while protecting the integrity and growth of commercial shipping and industry in the Port of Baltimore. Several key principles stem from this overall goal, and include the following: • Safeguarding areas of present and future commercial port development. • Optimizing economic benefits to Baltimore City of both recreational boating and commercial shipping. • Developing appropriate criteria for the location and design of marinas and other recreational boating activities and tourist activities. • Preserving water access and water views. • Protecting the environment from pollutants and ensuring State and federal regulations are adhered to in a manner consistent with the unique characteristics of the Harbor. • Protecting the proper operation and accessibility of storm drains and other utilities. • Providing adequate access for police and fire services. • Ensuring adequate parking and other land-side needs. • Defining management responsibilities for the Harbor and management tools for events. • Evaluating the appropriateness of seaplanes and heliports on the water. • Developing and adopting appropriate regulations to enforce the rules of navigational safety and management of the Harbor area. • Proposing appropriate new uses for the underutilized Middle Branch of the Patapsco River
	Responsible Agency:	Department of Planning
	Provides Funding for Mitigation:	No
	Hazard:	Flooding, Coastal Storms, Severe Storms

Capability	Details	
Comprehensive Economic Development Strategy – January 2022	**Description:**	This economic development plan identifies critically important goals to strengthen Baltimore City's economy and create new opportunities for residents and businesses. It outlines strategies and tactics for reaching those goals and serves as a call to action and roadmap for a range of partners over the next five years. If chosen not to adopt the strategies in this report and continue the current path, the outcomes are bleak. Baltimore City will continue to experience extreme racial disparities. Small businesses will struggle. Residents will continue to leave Baltimore City, and neighborhoods will decline. Baltimore City will miss the opportunity to lead in key sectors, forgoing significant economic benefits for its residents and tax base. We can and must do better. Baltimore City has strong economic assets, a prime East coast location, and an authentic charm. But we know that Baltimore City can be so much more with intentionality and determination.
	Responsible Agency:	Baltimore Development Corporation
	Provides Funding for Mitigation:	No
	Hazard:	All hazards
Critical Area Management Program Manual – February 2002	**Description:**	The Chesapeake Bay Critical Area Act (Section 8-1801 et. Seq., Natural Resources Article, Annotated Code of Maryland) establishes the Maryland Chesapeake Bay Critical Area Commission and requires that Baltimore City prepare and adopt a Critical Area Management Program to protect and improve the shoreline habitat and tidal waters of the Chesapeake Bay and its tributaries. All land uses within 1,000 feet of the shore (the Critical Area) must be regulated to: • Minimize the adverse impact on water quality caused by water running off the land and, • Conserve fish, plants and wildlife habitat while accommodating growth. Baltimore City Critical Area Management Program may be referred to as the "CAMP." The Maryland Critical Area Regulations (COMAR 27.01.01-27.03.01) establish Criteria, which Baltimore City's CAMP must meet. Among other things, they require that new development and redevelopment reduce pollutants running off the land by 10%, and that plant and animal habitat be protected and improved. The habitat protection elements require that a 100-foot Buffer be established along the shoreline to protect existing, naturally vegetated areas or areas planted and managed to protect shoreline and nearby water habitats.
	Responsible Agency:	Department of Public Works
	Provides Funding for Mitigation:	No
	Hazard:	All hazards

Capability	Details	
Maritime Industrial Zoning Overlay District Report – December 2010	**Description:**	The Maritime Industrial Zoning Overlay District (MIZOD) was enacted in 2004 to protect Baltimore's maritime industries by demarcating deep-water areas in industrial districts and reserving them for industrial use. The need for such protections arose during a real estate boom that greatly increased pressure to convert waterfront industrial properties to mixed-use with residential, largely by Planned Unit Developments (PUDs). The MIZOD, therefore, preserves maritime properties with deep water, rail, and highway access in order to protect maritime-dependent uses and intermodal freight movement. The boundaries of the MIZOD include existing waterfront and adjacent industrial parcels currently zoned M-3 (Heavy Industrial) in Canton, Fairfield, Curtis Bay, Hawkins Point, and Locust Point for maritime industrial use.
	Responsible Agency:	Department of Planning, Baltimore Development Corporation
	Provides Funding for Mitigation:	No
	Hazard:	Flooding, Coastal Storms, Severe Storms
Comprehensive Master Plan – April 1999, currently being updated in 2023.	**Description:**	LIVE • EARN • PLAY • LEARN: Baltimore City Comprehensive Master Plan (CMP planning process began in 1997. The objective was to create the first new comprehensive plan for Baltimore in over 30 years. While the process was led by the Planning Commission and the Department of Planning, the Fannie Mae Foundation and the Annie E. Casey Foundation partnered with Baltimore City, supporting outreach efforts which helped to ensure intergenerational input to this important plan. More than 2,000 citizens participated in a dozen meetings and workshops to provide input into the plan and a draft of the PlanBaltimore document was released in April 1999. Hundreds of additional citizens provided comments on PlanBaltimore through letters, e-mail and at two public review sessions. While the draft was greatly enhanced, it primarily provided policy recommendations instead of concise goals and strategies to move Baltimore City forward including • Create a brief, user-friendly zoning codes, which offer opportunities to neighborhoods and reflect the variety of existing building types • Review use categories to meet modern spatial requirements, new and emerging land uses, residential needs, and economic changes • Adopt new stormwater regulations that reflect current available technology and resources
	Responsible Agency:	Department of Planning
	Provides Funding for Mitigation:	No
	Hazard:	All hazards

Capability	Details	
A New Era of Neighborhood Investment: A Framework for Community Development – May 2020	**Description:**	Baltimore City, through the Department of Housing and Community Development (DHCD), is working to revitalize communities throughout Baltimore City. The vision for Baltimore City is an economically and culturally thriving city in which all people live in decent, healthy, and affordable housing. Achieving this vision without displacing longtime residents requires a commitment to equitable community development that brings new resources and opportunities to long-disadvantaged neighborhoods and their residents. DHCD presents this Framework as a starting point in a collaborative effort to guide Baltimore City into a new era of neighborhood investment. The Framework articulates a comprehensive vision for community development that leverages prior successes, builds partnerships, and breaks new ground through innovative and bold new resources and approaches to collaborative neighborhood improvement. In understanding equity, the Framework works to • Ensure community voices are central to shaping neighborhood redevelopment, • Minimize the displacement that can occur with rising values, • Support existing homeowners and residents to help them stay in their homes, • Maximize Baltimoreans' access to jobs and entrepreneurial opportunities created by reinvestment, and • Prioritize affordable housing in neighborhood revitalization efforts from the outset, not as an afterthought.
	Responsible Agency:	Department of Housing and Community Development
	Provides Funding for Mitigation:	No
	Hazard:	All hazards

<table>
<tr><th>Capability</th><th colspan="2">Details</th></tr>
<tr><td rowspan="4">City of Baltimore Neighborhood Plans – January 2004 and continuing</td><td>Description:</td><td>Baltimore City Department of Planning has worked alongside multiple neighborhoods within Baltimore City to write various plans for the neighborhood(s). Over sixty (60) plans have been written since 2004. These plans include Comprehensive Real Estate and Economic Development Assessments, Transformation Plans, Master Plans, and Corridor Assessments.

As of January 11, 2018, the Planning Commission adopted a new policy regarding community-managed plans. Community-managed plans will have to meet certain guidelines in order to be accepted by the Planning Commission. In preparing a community-led plan pursuing Planning Commission recognition, the community sponsor must
• Meet with Department of Planning staff to discuss the nature of the plan, proposed boundaries, preliminary stakeholders identified, etc.,
• Create an advisory committee to guide the planning process that includes Department of Planning staff,
• Host at least three (3) open, public meetings during the process with broad notification at least 10 days in advance,
• Provide documentation of all meeting notifications, and
• Meet with stakeholders who will be affected by the plan's recommendations (property owners, institutions, public agencies, other neighborhoods, etc.).
The plan document must:
• Be consistent with Baltimore City's Comprehensive Master Plan and other City policies,
• Include standardized topics such as process, existing conditions, background data, goals, strategies, recommended action steps,
• Include a detailed implementation chart, in a format acceptable to the Planning Department, and
• Be in a well-designed, easy to read format.</td></tr>
<tr><td>Responsible Agency:</td><td>Department of Planning</td></tr>
<tr><td>Provides Funding for Mitigation:</td><td>No</td></tr>
<tr><td>Hazard:</td><td>All hazards</td></tr>
</table>

Capability	Details	
City of Baltimore Urban Renewal Plans – May 1982 and continuing	**Description:**	An Urban Renewal Plan (URP) is a form of overlay zoning that is more restrictive than Baltimore City's zoning code. Urban Renewal Plans regulate specific geographies ranging from small business districts to entire communities. Most Urban Renewal Plans include land use restrictions and design guidelines. Some Urban Renewal Plans also include acquisition and disposition authority. Urban Renewal Plans are area plans adopted by the Mayor and City Council to establish and implement redevelopment goals. There are four major categories of plans: downtown, commercial corridors, industrial areas, and neighborhood plans. Over forty (40) plans have been written since 1982.
	Responsible Agency:	Department of Planning
	Provides Funding for Mitigation:	No
	Hazard:	All-natural hazards
Public Parks Master Plans	**Description:**	Baltimore City Department of Recreation and Parks has commissioned and adopted master plans for several parks in Baltimore City. For several years neighborhood associations and other stakeholder groups have been working hard to stabilize the surrounding neighborhoods by recruiting positive economic activity to the area and promoting desirable destinations and activities within the Park. The master planning process has included public meetings and other efforts to facilitate participation from these stakeholder groups and individual park neighbors and to encourage input from community members that have not been recent park users. The Master Plans study how the physical plan of each Park can reflect and facilitate its mission and fulfill related community needs. It studies the Park's immediate and long-term physical, programming, and historic preservation needs. The final product is a road map that guides immediate renovations and additions to grounds, buildings, and infrastructure, as well as anticipated long-term park needs. Sixteen (16) of Baltimore City's parks have had master plans written for them since 1995.
	Responsible Agency:	Department of Recreation and Parks
	Provides Funding for Mitigation:	No
	Hazard:	All-natural hazards

Table 13-2. Planning and Regulatory Capabilities – Federal and State

Capability	Details	
Disaster Mitigation Act (DMA)	**Description:**	The DMA is the current federal legislation addressing hazard mitigation planning. It emphasizes planning for disasters before they occur. It specifically addresses planning at the local level, requiring plans to be in place before Hazard Mitigation Assistance grant funds are available to communities. This plan is designed to meet the requirements of DMA, improving eligibility for future hazard mitigation funds.
	Responsible Agency:	FEMA
	Provides Funding for Mitigation:	HMPs designed to meet the requirements of DMA will remain eligible for future FEMA Hazard Mitigation Assistance funds
	Hazard:	All-natural hazards
National Flood Insurance Program (NFIP)	**Description:**	The NFIP is a federal program enabling property owners in participating communities to purchase insurance as a protection against flood losses in exchange for state and community floodplain management regulations that reduce future flood damage. The Flood Hazard Profile in Section 4 (Flooding) provides information on recent legislation related to reforms to the NFIP. Baltimore City actively participates in the NFIP. As of May 2022, there were 1,047 NFIP policies in Baltimore City. There have been 1,038 claims made, totaling over $17 million for damage to structures and contents.
	Responsible Agency:	FEMA
	Provides Funding for Mitigation:	Full compliance and good standing under the NFIP are application prerequisites for all FEMA grant programs for which participating jurisdictions are eligible under this plan.
	Hazard:	Flooding
NFIP Community Rating System (CRS)	**Description:**	As an additional component of the NFIP, CRS is a voluntary incentive program that recognizes and encourages community floodplain management activities that exceed the minimum NFIP requirements. As a result, flood insurance premium rates are discounted to reflect the reduced flood risk resulting from the community actions meeting the three goals of the CRS: (1) reduce flood losses, (2) facilitate accurate insurance rating, and (3) promote the awareness of flood insurance. Baltimore City is enrolled in the CRS program.
	Responsible Agency:	FEMA
	Provides Funding for Mitigation:	CRS premium discounts on flood insurance range from 5 percent for Class 9 communities up to 45 percent for Class 1 communities.
	Hazard:	Flooding

Capability	Details	
Maryland Department of Transportation	**Description:**	The Maryland Department of Transportation (MDOT) is an organization comprised of five business units and one Authority. They are: The Secretary's Office, MDOT State Highway Administration, MDOT Maryland Transit Administration, MDOT Motor Vehicle Administration, MDOT Maryland Port Administration, MDOT Maryland Aviation Administration and the Maryland Transportation Authority. This unique approach provides the state's leadership with the ability to develop a coordinated and balanced approach to transportation. MDOT leads operations and maintenance of state highways, bridges, tollways, transit systems, motor vehicle licensing, Baltimore/Washington International Thurgood Marshall Airport, and the Helen Delich Bentley Port of Baltimore.
	Responsible Agency:	State
	Provides Funding for Mitigation:	No
	Hazard:	All hazards
Maryland Environmental Service	**Description:**	The Maryland Environmental Service (MES) was established by the General Assembly in 1970 to assist with the preservation, improvement, and management of the quality of air, land, water, and natural resources, and to promote the health and welfare of the citizens of the State. Today, MES employs over 700 teammates and operates more than 1,000 environmental projects across Maryland and the Mid-Atlantic Region. As a not-for-profit business unit of Maryland, MES provides multi-disciplinary environmental compliance services to enhance and protect the environment through innovative solutions to the region's most complex environmental challenges.
	Responsible Agency:	State
	Provides Funding for Mitigation:	Yes
	Hazard:	All-natural hazards
Maryland Department of Emergency Management	**Description:**	The Maryland Department of Emergency Management (MDEM) is a national leader in emergency management that provides Maryland residents, organizations, and emergency management partners with expert information, programmatic activities, and leadership in the delivery of financial, technical, and physical resources "to shape a resilient Maryland where communities thrive."
	Responsible Agency:	State
	Provides Funding for Mitigation:	Yes
	Hazard:	All hazards

Capability	Details	
Maryland Department of the Environment	**Description:**	In 1987, the Maryland Department of the Environment (MDE) was created to protect and preserve the state's air, water and land resources and safeguard the environmental health of Maryland's citizens. MDE's duties also encompass enforcement of environmental laws and regulations, long-term planning, and research. MDE provides technical assistance to Maryland industry and communities for pollution and growth issues and environmental emergencies.
	Responsible Agency:	State
	Provides Funding for Mitigation:	Yes
	Hazard:	All-natural hazards
Maryland Department of Public Safety and Correctional Services	**Description:**	The Department of Public Safety and Correctional Services is one of the largest departments in Maryland with nearly 12,000 employees and a budget of more than $1 billion. To fulfill the mission of promoting safety, security has been increased at the Department's institutions while leading the way in innovative restorative justice projects that will help offenders reintegrate into society upon release. Public Safety operates 19 institutions, including several pretrial facilities, as well as 42 Parole and Probation offices throughout the state.
	Responsible Agency:	State
	Provides Funding for Mitigation:	No
	Hazard:	All hazards
Maryland Department of Planning	**Description:**	The Maryland Department of Planning (Planning) promotes a vision for economic development, flexibility, and local authority throughout Maryland. The agency helps Maryland's counties and municipalities in land use and resource planning and provides review and technical assistance on a variety of planning topics. In addition, Planning offers data, analysis and research assistance and policy development and implementation support to local governments as well as communities, businesses, and other organizations. As Planning monitors and forecasts changes in development and land use throughout the state, its staff creates tools that help plan Maryland's future. Information on demographic, socio-economic, political, cultural, geographic, and land-use trends is collected, analyzed, and distributed in multiple formats. Planning supports interactive, web-based map display of census data, land-use, parcel data and aerial imagery to assist local government growth and land-use planning decisions.
	Responsible Agency:	State
	Provides Funding for Mitigation:	Yes
	Hazard:	All hazards
Maryland Department of Natural Resources	**Description:**	The Department of Natural Resources leads Maryland in securing a sustainable future for the State's environment, society, and economy by preserving, protecting, restoring, and enhancing the State's natural resources.
	Responsible Agency:	State

Capability	Details	
	Provides Funding for Mitigation:	Yes
	Hazard:	All-natural hazards
Real Estate Disclosure – Maryland Code – Section 10-702 of the Real Property Article	**Description:**	The Residential Property Disclosure Form is a statement of certain conditions and information concerning the property known by the owner. An owner may or may not have lived at the property and unless the potential purchaser is informed in writing, the owner has no more information about the property than could be obtained by a careful inspection of the property by a potential purchaser. Unless the potential purchaser is otherwise informed, the owner has not conducted any inspection of generally inaccessible areas of the property. This form is required by Section 10-702 of the Real Property Article, *Annotated Code of Maryland*.
	Responsible Agency:	Maryland Department of Labor
	Provides Funding for Mitigation:	No
	Hazard:	Flood, Hazardous Materials
Maryland Department of Health	**Description:**	Maryland's health care delivery system consists of public and private hospitals, nursing homes, outpatient clinics, home health care services, hospices, providers, and health educators, among others. The Department of Health (MDH) seeks to improve the health status of every Maryland resident and to ensure access to quality health care. The department responsible for helping each person live a life free from the threat of communicable diseases, tainted foods, and dangerous products. MDH regulates health care providers, facilities, and organizations, and manage direct services to patients, where appropriate.
	Responsible Agency:	State
	Provides Funding for Mitigation:	Yes
	Hazard:	All hazards

Capability	Details	
Maryland Department of General Services	**Description:**	It is the mission of the Department of General Services (DGS) to be the accessible, accountable support agency delivering expertise, essential services and facilities operations and management to the State to enhance the quality of work/life environments for stakeholders and the citizens of Maryland. The Department is responsible for a variety of tasks which includes: • providing a full spectrum of design and construction, facilities operations, security, procurement, real estate, and surplus property services, • establishing policy and directing the statewide operation and maintenance of 55 buildings with 6.2 million square feet of space under the Department of General Services' authority, • purchasing a variety of goods and services statewide for State and local government agencies, as well as non-profit entities, • supervising and coordinating the design and construction of state public improvements, • establishing policy, and directing and coordinating the acquisition, disposal, valuation and leasing of real property for all state agencies except for the Department of Transportation, and • ensuring that the purchase and consumption of energy in State operations minimizes costs and enhances sustainability.
	Responsible Agency:	State
	Provides Funding for Mitigation:	Yes
	Hazard:	All hazards
Chesapeake Bay Trust	**Description:**	The Chesapeake Bay Trust is a nonprofit grant-making organization dedicated to improving the watersheds of the Chesapeake Bay, Maryland Coastal Bays, and Youghiogheny River. Created in 1985 by the Maryland General Assembly, the goal of the Trust is to increase stewardship through grant programs, special initiatives, and partnerships that support K-12 environmental education, on-the ground watershed restoration, community engagement, and the underlying science of these three realms. Through grants, the Trust engages hundreds of thousands of students and volunteers in projects that have a measurable impact on the natural resources of the region. Grantees include schools, local governments, community groups, faith-based groups, watershed organizations, and other not-for-profit entities.
	Responsible Agency:	Chesapeake Bay Trust
	Provides Funding for Mitigation:	Yes
	Hazard:	Flooding, Coastal Storms, Severe Storms

Capability	Details	
U.S. Army Corps of Engineers – Dam Safety Program	**Description:**	The U.S. Army Corps of Engineers (USACE) is responsible for safety inspections of some federal and non-federal dams in the United States that meet the size and storage limitations specified in the National Dam Safety Act. USACE has inventoried dams and has surveyed each state and federal agency's capabilities, practices, and regulations regarding design, construction, operation, and maintenance of the dams. USACE has also developed guidelines for inspection and evaluation of dam safety (USACE 1997). The Baltimore District of the USACE provides water resource planning and engineering design and construction support focused on navigation, flood risk management and environmental restoration. This work includes construction and operation of dams that help reduce flood risks, provide recreation, environmental stewardship, and water supply; dredging of major waterways; and construction of local flood risk management projects. The Baltimore District operates and maintains 290 miles of federal navigation channels, 148 miles of federally constructed levees, and 15 federal flood risk management dams and reservoirs. As a result, the Baltimore District has prevented $16 billion in flood damage, is restoring approximately 600 acres of oyster habitat and is also restoring 1,140 acres of remote islands.
	Responsible Agency:	USACE
	Provides Funding for Mitigation:	Yes
	Hazard:	Flooding

13.3 Administrative and Technical Capabilities

13.3.1 Sustainability and Resiliency Subcabinet

Mayor Scott established the Sustainability and Resiliency Subcabinet to improve long-term sustainability, preparedness, and environmental practices of the City. BOS launched the Subcabinet in September 2021, and it is chaired by the City Administrator. The Subcabinet is an internal-facing group of City agency leads and decision-makers that convene quarterly to focus on transparency, collaboration, and accountability regarding the implementation of sustainability-related plans. The Subcabinet consists of six working groups, which include Buildings and Energy, Sustainable Transportation, Flooding and Infrastructure, Extreme Heat, Waste, and People and Nature. Each working group meets monthly to explore ways to advance sustainability and resiliency goals outlined in existing city plans and find creative solutions to address resource gaps.

The focus of the Subcabinet is to drive collaborative planning and policy efforts and collectively determine climate and sustainability priorities; share data, technical expertise, and institutional knowledge across the aisle; create inter-agency support for grant proposals and coordination around capital budgeting and match-funding needs; and support collaborative public education and community outreach efforts. The Subcabinet functions as a collaborative forum for to help expand and improve the capabilities of the City to address risk and propel mitigation activities.

Since the Subcabinet's inauguration, the Flooding and Infrastructure, Sustainable Transportation, Waste, and Buildings and Energy working groups have effectively provided technical oversight and data support for a number of policy and planning efforts, including contributing to the 2023 updates of the DP3 and Climate Action Plan, successfully coordinating grant proposals (such as a USDOT PROTECT grant and US EPA grant), and securing multi-million dollar grant awards to continue building momentum for resilience-oriented projects. Priorities of the Extreme Heat and People and Nature working groups include:

- Improving education and awareness of extreme heat impacts in Baltimore
- Increasing climate literacy amongst the City's workforce
- Supporting youth-led sustainability efforts
- Integrating nature-based solutions across the City

Moving forward, the Sustainability and Resiliency Subcabinet will continue to expand and improve Baltimore's capabilities around hazard mitigation planning and the integration of hazard mitigation into other climate and sustainability initiatives.

13.3.2 Community Resiliency Hub Program

BoS coordinates Baltimore's Community Resiliency Hub Program, which is an innovative community-centered initiative that increases community capacity to prepare for, withstand, and respond to natural hazard impacts and emergency situations. The goal of this program is to better connect frontline community organizations with focused support and resources so that, in the event of a natural disaster or emergency, there is improved provision of emergency response and recovery services to under-resourced neighborhoods and their most vulnerable residents. The Program is a partnership between service-based community organizations in Baltimore's most climate-vulnerable neighborhoods and BoS, OEM, and Baltimore City Department of Health (BCHD).

Community Resiliency Hub partners are trusted, service-based non-profit community organizations (including faith-based) with strong leadership located in under-resourced neighborhoods that partner with Baltimore City to provide essential resources and community support before, during, and after hazard events. There are currently 20 Resiliency Hub partner organizations in the program. The BoS, OEM, and BCHD work with the organizations to enable them to serve as a space where vulnerable neighbors can gather in times of emergency; access reliable power for their essential devices; receive supplies, food, and drinking water; and store medications sensitive to temperature, among other things. Resiliency Hubs can also serve as community-based staging areas for emergency and recovery personnel as well as conduits for critical supply distribution to the community.

Community Resiliency Hub partners receive grant-funded and in-kind capacity-building support from Baltimore City in many forms including high-quality emergency preparedness supplies, energy efficiency upgrades to their building, back-up power capabilities (rooftop solar + battery storage if feasible), emergency preparedness and response training, connections to grant funding opportunities, and focused support and communications from BoS, OEM, and BCHD. Resiliency Hub convenings and trainings are essential pieces of the program that enable Resiliency Hub Leaders to develop relationships with and learn from one another. Trainings ensure that Hub Leaders and community members are aware of climate and health risks, learn about important City resources and preparedness strategies, and are encouraged to take action in their communities to become more resilient to potential threats. Convenings and trainings are also critical for facilitating continued conversations to determine gaps in the program, address community concerns, and identify opportunities for program growth.

13.3.3 Outreach and Public Education

Enhancing the City's ability to coordinate around mitigation-related outreach and education has been a priority for the past five years and will continue to be prioritized and expanded upon. BoS maintains a Climate and Resilience Planner, Climate and Resilience Program Manager, Sustainability Director, Floodplain Manager, and Coastal Planner, each of which play a role in mitigation outreach. The positioning of BoS within the DOP creates ideal access to the Department's Comprehensive Planning Division, which is responsible for working directly with community members and leaders in distinct districts across the City and has extensive reach.

BoS' climate and resilience staff also coordinate closely with OEM's Preparedness Section, the Baltimore City Health Department's Office of Public Health Preparedness and Response, and DPW's Office of Research and Environmental Protection. Staff from each of these offices collaborate to disseminate aligned messaging around preparedness and hazard risk reduction, attend community meetings, and share information at community events.

Additionally, BoS leads Baltimore's Community Resiliency Hub program, which creates an ideal touchpoint to communicate and share important mitigation information with community leaders who are trusted messengers in vulnerable neighborhoods across the City. The Office also co-leads the Sustainability and Resiliency Subcabinet, which is providing opportunities for coordinated mitigation outreach across the City. In 2023, the Subcabinet, in partnership with the National Aquarium, facilitated climate literacy and communications training for over 50 city employees with the goal of increasing awareness of climate impacts in Baltimore and the integration of solutions-based climate messaging across city agencies. The Subcabinet aims to continue this and similar climate literacy and education campaigns moving forward.

Table 13-3 summarizes the administrative and technical capabilities in Baltimore City.

13.4 Fiscal Capabilities

Fiscal capabilities are the resources that a jurisdiction has access to or is eligible to use to fund mitigation actions. Table 13-4 below provides a list of programs, descriptions, and links for those seeking funding sources. This table is not intended to be a comprehensive list, but rather a tool to help begin identifying potential sources of funding.

Table 13-3. Administrative and Technical Capability – City of Baltimore

Capability	Details	
Baltimore Development Corporation	**Description:**	The Baltimore Development Corporation (BDC) is the economic development agency for Baltimore City. BDC's mission is to grow Baltimore City's economy in an inclusive manner by retaining, expanding, and attracting businesses and promoting investment, thereby increasing career opportunities for residents.
	Responsible Agency:	City of Baltimore
	Provides Funding for Mitigation:	No
	Hazard:	All hazards
City of Baltimore Office of Emergency Management	**Description:**	Baltimore City Office of Emergency Management (OEM) works to maintain the highest level of preparedness to protect Baltimore's citizens, workers, visitors, and environment from the impact of natural and human-caused disasters. OEM works to prepare Baltimore City for emergencies, prepare the public for emergencies, and coordinate interagency response and recovery. To achieve this mission, OEM implements a comprehensive program of disaster mitigation, preparedness, response, and recovery.
	Responsible Agency:	City of Baltimore
	Provides Funding for Mitigation:	No
	Hazard:	All hazards
City of Baltimore Health Department	**Description:**	Baltimore City Health Department is the oldest, continuously operating health department in the United States, formed in 1793 when the governor appointed Baltimore City's first health officers in response to a yellow fever outbreak in the Fells Point neighborhood. During the more than 220 years since then, the Department has been working to improve the health and well-being of Baltimore residents. The Department strives to make Baltimore a city where all residents realize their full health potential. In collaboration with other city agencies, health care providers, community organizations, and funders, the Department aims to empower all Baltimoreans with the knowledge, access, and environment that will enable healthy living. The Health Department has a wide-ranging area of responsibility, including acute communicable diseases, animal control, chronic disease prevention, emergency preparedness, HIV/STD, maternal-child health, restaurant inspections, school health, senior services, and youth violence issues. The agency includes a workforce of approximately 800 employees and has a budget of approximately $126 million.
	Responsible Agency:	City of Baltimore
	Provides Funding for Mitigation:	No
	Hazard:	All hazards

Capability	Details	
City of Baltimore Environmental Control Board	**Description:**	Baltimore City Environmental Control Board (ECB) is responsible for the adjudication of citations issued by other agencies that affect sanitation, environmental, health, safety, and other quality of life issues.
	Responsible Agency:	City of Baltimore
	Provides Funding for Mitigation:	Yes
	Hazard:	Flooding, Severe Storms
Baltimore City Fire Department	**Description:**	The Baltimore City Fire Department (BCFD) is a diverse and evolving extension of the community, committed to providing excellent service to all we serve, in a professional and humanitarian way. The BCFD pledges to protect lives, property, and the environment through a safe, effective, and timely response. THE BCFD aims to be innovative in providing service in emergency medical services, fire suppression, rescue, emergency communications, fire prevention, community outreach, education, and other services.
	Responsible Agency:	City of Baltimore
	Provides Funding for Mitigation:	No
	Hazard:	All hazards
Baltimore City Department of Housing and Community Development	**Description:**	The Baltimore City Department and Housing and Community Development (DHCD) works to improve the quality of life for all Baltimore City residents by revitalizing and redeveloping communities and promoting access to quality affordable housing opportunities in safe, livable neighborhoods. DHCD was created in 1968 to consolidate local community development efforts with housing and building code enforcement. With just over 400 employees, DHCD strengthens City neighborhoods by attracting investors, developers, and home buyers. Through the administration of CDBG, HOME, City bond funds, and other creative financing mechanisms, the Department finances, and guides strategic development projects to meet housing and neighborhood needs. To hold property owners accountable and keep neighborhoods safe, DHCD monitors construction and building activity and enforces Baltimore City's housing and building codes. The Department also provides a host of valuable community services and administers a host of programs for residents.
	Responsible Agency:	City of Baltimore
	Provides Funding for Mitigation:	No
	Hazard:	All hazards

Capability	Details	
Mayor's Office of Homeless Services	**Description:**	The mission of the Mayor's Office of Homeless Services is to make homelessness rare, brief, and nonrecurring in Baltimore City. We believe that homelessness is both solvable and preventable. With a person-centered and data-driven approach, we meet the immediate needs of our neighbors who are experiencing homelessness while pursuing the goal of safe, long-term housing solutions. Approximately 2,200 men, women, and children are homeless in Baltimore City on any given night. Lack of affordable housing, low incomes, and limited access to comprehensive services are primary causes of homelessness. Disabilities and chronic illnesses, including substance use disorders and mental illness, create additional challenges in resolving homelessness.
	Responsible Agency:	City of Baltimore
	Provides Funding for Mitigation:	Yes
	Hazard:	All hazards
Mayor's Office of Immigrant Affairs	**Description:**	The mission of the Mayor's Office of Immigrant Affairs (MIMA) is to promote community wellbeing, economic development, and the integration of immigrant communities by identifying needs and opportunities that immigrants bring to Baltimore City, while developing public-private partnerships to strengthen the development of these communities. MIMA focuses on two broad priority areas: economic growth and community well-being. These areas have the greatest potential to leverage existing resources and identify additional gaps and opportunities, in order to recognize and benefit from the valuable assets that New Americans bring to Baltimore. Specific to hazard mitigation, MIMA works to communicate and translate information during emergencies, provides support to City agencies on matters related to foreign-born communities, and can provide trains City staff on the use of resources to overcome language barriers.
	Responsible Agency:	City of Baltimore
	Provides Funding for Mitigation:	No
	Hazard:	All hazards
Housing Authority of Baltimore City	**Description:**	The Housing Authority of Baltimore City (HABC) was established in 1937 to provide federally funded public housing programs and related services for Baltimore's low-income residents. HABC is the fifth largest public housing authority in the country, with more than 600 employees. Currently, HABC owns and manages 8,236 public housing units in 15 developments. HABC serves over 19,500 households through public housing, the Housing Choice Voucher Program, HUD's Rental Assistance Demonstration Program (RAD), and other rental assistance programs. Most recently, the agency received HUD approval to convert 4,128 units among 26 developments through RAD.
	Responsible Agency:	City of Baltimore

Capability	Details	
	Provides Funding for Mitigation:	Yes
	Hazard:	All hazards
City of Baltimore Department of Planning	**Description:**	The Department of Planning is Baltimore City agency entrusted with guiding the physical development of Baltimore City. The Department staffs three Mayoral-appointed City commissions: • Planning Commission • Commission for Historical & Architectural Preservation (CHAP) • Sustainability Commission The Department of Planning has five divisions within the Department, in addition to the Office of the Director, each with its special focus in support of the mission and the Commissions the Department serves. Cross-division collaboration is essential to planning work and is embedded in the Department's culture: • Office of the Director • Office of Sustainability • Food Policy & Planning • Community Planning and Revitalization (CPR) • Land Use and Urban Design • Policy and Data Analysis • Historical and Architectural Preservation The Department is currently renewing the focus on equity, as well as public engagement.
	Responsible Agency:	City of Baltimore
	Provides Funding for Mitigation:	No
	Hazard:	All hazards
City of Baltimore Department of Public Works	**Description:**	The Department of Public Works (DPW) prides itself on providing quality services and strives to be responsive to needs. DPW's mission is to support the health, environment, and economy of Baltimore City and the region by providing customers with safe drinking water and keeping neighborhoods and waterways clean.
	Responsible Agency:	City of Baltimore
	Provides Funding for Mitigation:	No
	Hazard:	All hazards
City of Baltimore Department of Recreation and Parks	**Description:**	Baltimore City Recreation and Parks is Baltimore City's leading provider of affordable, year-round leisure and recreational activities for residents of all ages and abilities. Beautiful parks, trails and waterways provide the perfect urban oasis.
	Responsible Agency:	City of Baltimore

Capability	Details	
	Provides Funding for Mitigation:	No
	Hazard:	All hazards
City of Baltimore Department of Transportation	**Description:**	Baltimore City Department of Transportation's mission is to maintain and improve the transportation infrastructure to produce a safe, reliable, accessible, and efficient system for everyone that provides for multiple and sustainable modes of transportation for residents, businesses, and visitors — thereby promoting livable and vibrant communities across Baltimore City.
	Responsible Agency:	City of Baltimore
	Provides Funding for Mitigation:	No
	Hazard:	All hazards
City of Baltimore Planning Commission	**Description:**	The Planning Commission in its current form dates back to a revision of Baltimore City Charter in 1947. The Commission is an eight-member board composed of three citizens appointed by the Mayor, the Director of the Department of Public Works or his designee, a member of Baltimore City Council, the Mayor or his representative, the Chairperson of the Board, and the Vicechair of the Board. The key responsibilities of the Commission include: • Preparing and updating plans showing the physical development of Baltimore City, • Developing a capital budget and six-year capital development program for consideration of the Board of Estimates, • Developing and maintaining a Comprehensive Master Plan for Baltimore City, • Reviewing all proposals for the subdivision of land within Baltimore City for conformance to specified standards, and • Reviewing all proposed amendments to Baltimore City's Zoning Ordinance and making recommendations to Baltimore City Council. The Planning Commission relies on the staff of the Department of Planning to accomplish these mandates, as well as to carry out new and expanded responsibilities commissioners have assumed over the years. The Commission meets regularly throughout the year, and its meetings are open to the public.
	Responsible Agency:	City of Baltimore
	Provides Funding for Mitigation:	No
	Hazard:	All hazards

Capability	Details	
City of Baltimore Board of Municipal & Zoning Appeals	**Description:**	Baltimore City Board of Municipal & Zoning Appeals (BMZA) is a quasi-judicial Board that hears appeals from City agencies including the following: • Land use and zoning appeals • Alleyway/footway assessments • Public right-of-way closures • False Alarm Reduction Program appeals • Miscellaneous administrative agency appeals In its capacity as a land-use regulatory agency and quasi-judicial board, BMZA hears and determines all zoning appeals under the authority granted by City Charter and the Land Use Article of the MD Annotated Code, as well as Maryland common law. BMZA decisions are based upon local and state law with the overall purpose of promoting the health, security, and general welfare of the community. The Board has these general goals with respect to land use and zoning appeals: • Prevents the overcrowding of land • Avoid undue concentration of population • Provide adequate light and air • Secure safety from fire, panic, and other dangers • Reduce congestion in the streets • Help for adequate transportation, water, sewers, schools, parks, and other public services
	Responsible Agency:	City of Baltimore
	Provides Funding for Mitigation:	No
	Hazard:	All hazards
City of Baltimore Department of Telecommunications	**Description:**	The Department of Telecommunications (Telecom), formerly the Municipal Telephone Exchange (MTE), provides telephone services to all City agencies. Services include managing Voice Over Internet Protocol, or VoIP phone service, supplying mobile phones, providing technical support for various City call centers, and providing for the billing of these services with external vendors. Telecom installs and maintains all telecommunications equipment in the various Baltimore City call centers such as 311, Department of Public Works (DPW), and Revenue Collection.
	Responsible Agency:	City of Baltimore
	Provides Funding for Mitigation:	No
	Hazard:	All hazards

Capability	Details	
BMORE Alert	**Description:**	Baltimore City updates residents on emergency and disaster status through issuing emergency alters through the BMORE ALERT program which is Baltimore City's emergency notification system. The Alerts will let residents know about severe weather, flooding, hazardous chemical releases, infectious disease outbreaks, widespread power outages and evacuations. In addition, Baltimore City website, Twitter and Facebook also alert residents of necessary evacuations and open shelters.
	Responsible Agency:	City of Baltimore
	Provides Funding for Mitigation:	No
	Hazard:	All hazards

Table 13-4. Fiscal Capabilities

Capability	Details	
Federal		
Hazard Mitigation Grant Program	**Description:**	The HMGP is a post-disaster mitigation program. It is made available to states by FEMA after each Federal disaster declaration. The HMGP can provide up to 75% funding for hazard mitigation measures. The HMGP can be used to fund cost-effective projects that will protect public or private property in an area covered by a federal disaster declaration or that will reduce the likely damage from future disasters. Examples of projects include acquisition and demolition of structures in hazard prone areas, flood-proofing or elevation to reduce future damage, minor structural improvements, and development of state or local standards. Projects must fit into an overall mitigation strategy for the area identified as part of a local planning effort. All applicants must have a FEMA-approved Hazard Mitigation Plan (this plan). Applicants who are eligible for the HMGP are state and local governments, certain nonprofit organizations or institutions that perform essential government services, and Indian tribes and authorized tribal organizations. Individuals or homeowners cannot apply directly for the HMGP; a local government must apply on their behalf. Applications are submitted to Maryland EMA and placed in rank order for available funding and submitted to FEMA for final approval. Eligible projects not selected for funding are placed in an inactive status and may be considered as additional HMGP funding becomes available. For additional information regarding HMGP, please refer to: https://www.fema.gov/hazard-mitigation-grant-program
	Responsible Agency:	FEMA
	Provides Funding for Mitigation:	Yes
	Hazard:	All natural hazards

Capability	Details	
Flood Mitigation Assistance Program	**Description:**	The FMA program combines the previous Repetitive Flood Claims and Severe Repetitive Loss Grants into one grant program. The FMA provides funding to assist states and communities in implementing measures to reduce or eliminate the long-term risk of flood damage to buildings, manufactured homes, and other structures insurable under the NFIP. The FMA is funded annually; no federal disaster declaration is required. Only NFIP insured homes and businesses are eligible for mitigation in this program. Funding for FMA is very limited and, as with the HMGP, individuals cannot apply directly for the program. Applications must come from local governments or other eligible organizations. The federal cost share for an FMA project is at least 75 percent. For the nom-federal share, at most 25 percent of the total eligible costs must be provided by a non-federal source; of this 25 percent, no more than half can be provided as in-kind contributions from third parties. At minimum, a FEMA-approved local flood mitigation plan is required before a project can be approved. The FMA funds are distributed from FEMA to the state. Maryland EMA serves as the grantee and program administrator for the FMA program. The FMA program is detailed on the FEMA website: https://www.fema.gov/flood-mitigation-assistance-grant-program.
	Responsible Agency:	FEMA
	Provides Funding for Mitigation:	Yes
	Hazard:	Flooding, Severe Storms
Building Resilient Infrastructure and Communities Program	**Description:**	Building Resilient Infrastructure and Communities (BRIC) will support states, local communities, tribes, and territories as they undertake hazard mitigation projects, reducing the risks they face from disasters and natural hazards. BRIC is a new FEMA pre-disaster hazard mitigation program that replaces the existing Pre-Disaster Mitigation (PDM) program. The BRIC program guiding principles are supporting communities through capability- and capacity-building; encouraging and enabling innovation; promoting partnerships; enabling large projects; maintaining flexibility; and providing consistency. For additional information regarding the BRIC program, please refer to: https://www.fema.gov/grants/mitigation/building-resilient-infrastructure-communities
	Responsible Agency:	FEMA
	Provides Funding for Mitigation:	Yes
	Hazard:	All natural hazards

Capability	Details	
Pre-Disaster Mitigation (PDM) Grant Program	**Description:**	The Pre-Disaster Mitigation (PDM) grant program makes federal funds available to state, local, tribal, and territorial governments to plan for and implement sustainable cost-effective measures designed to reduce the risk to individuals and property from future natural hazards, while also reducing reliance on federal funding from future disasters. The program is authorized by Section 203 of the Stafford Act. The Consolidated Appropriations Act of 2023 authorized funding for 100 projects for states, tribes, territories, and local communities for FEMA's Hazard Mitigation Assistance Pre-Disaster Mitigation grant program. These funds allow governments to plan for and implement sustainable cost-effective measures designed to reduce the risk to individuals and property from future natural hazards, while also reducing reliance on federal funding from future disasters.
	Responsible Agency:	FEMA
	Provides Funding for Mitigation:	Yes
	Hazard:	All natural hazards

Capability	Details	
Extraordinary Circumstances	**Description:**	A local government or tribal government applying as a subapplicant must have a mitigation plan approved to receive Hazard Mitigation Assistance (HMA) project subawards. However, the FEMA regional administrator may grant an exception to the plan requirements in extraordinary circumstances when the appropriate justification is provided. For HMGP, HMGP Post Fire, BRIC and FMA, extraordinary circumstances exist when FEMA or the applicant determine that the proposed project is consistent with the priorities and strategies identified in the state or tribal (standard or enhanced) mitigation plan and that the jurisdiction meets at least one of the criteria below • The jurisdiction meets the small, impoverished community criteria. • The jurisdiction has been determined to have had insufficient capacity because of lack of available assistance, staffing or other necessary expertise to satisfy the mitigation planning requirement prior to the current disaster or application deadline • The jurisdiction experienced significant disruption from a declared disaster or another event that impacts its ability to complete the mitigation planning process prior to award or final approval of a project award • The jurisdiction does not have a mitigation plan for reasons beyond the control of the state, federally recognized tribal government or local community, such as Disaster Relief Fund restrictions that delay FEMA from granting a subaward prior to the expiration of the local or tribal mitigation plan The applicant must provide written justification that identifies the specific criteria from the above list and explains why the jurisdiction will be able to have a plan both approved by FEMA and adopted by the jurisdiction within 12 months. The justification must identify the specific actions or circumstances that have eliminated or will eliminate the deficiency that prevented the jurisdiction from previously having an approved plan. The justification must clearly demonstrate how the above circumstances impacted the community beyond just stating the above circumstances. If a plan is not provided within this time frame, the project subaward will be terminated, and any costs incurred after notice of subaward termination will not be reimbursed by FEMA.
	Responsible Agency:	FEMA
	Provides Funding for Mitigation:	Yes
	Hazard:	All natural hazards

Capability	Details	
Individual Assistance	**Description:**	Individual Assistance (IA) provides help for homeowners, renters, businesses, and some non-profit entities after disasters occur. This program is largely funded by the U.S. Small Business Administration. For homeowners and renters, those who suffered uninsured or underinsured losses could be eligible for a Home Disaster Loan to repair or replace damaged real estate or personal property. Renters are eligible for loans to cover personal property losses. Individuals are allowed to borrow up to $200,000 to repair or replace real estate, $40,000 to cover losses to personal property, and an additional 20 percent for mitigation. For businesses, loans could be made to repair or replace disaster damage to property owned by the business, including real estate, machinery and equipment, inventory, and supplies. Businesses of any size are eligible. Non-profit organizations, such as charities, churches, and private universities are eligible. An Economic Injury Disaster Loan provides necessary working capital until normal operations resume after a physical disaster but are restricted by law to small businesses only. IA is detailed on the FEMA website: https://www.fema.gov/individual-disaster-assistance.
	Responsible Agency:	FEMA
	Provides Funding for Mitigation:	Yes
	Hazard:	All hazards
Public Assistance	**Description:**	Public Assistance (PA) provides cost reimbursement aid to local governments (state, county, local, municipal authorities, and school districts) and certain non-profit agencies that were involved in disaster response and recovery programs or that suffered loss or damage to facilities or property used to deliver government-like services. This program is largely funded by FEMA with both local and state matching contributions required. PA is detailed on the FEMA website: https://www.fema.gov/public-assistance-local-state-tribal-and-non-profit.
	Responsible Agency:	FEMA
	Provides Funding for Mitigation:	Yes
	Hazard:	All hazards

Capability	Details	
Department of Homeland Security Grant Program	**Description:**	The Homeland Security Grant Program (HSGP) plays an important role in the implementation of the National Preparedness System by supporting the building, sustainment, and delivery of core capabilities essential to achieving the National Preparedness Goal of a secure and resilient nation. In FY 2022, the total amount of funds available under HSGP was $1.12 billion. HSGP is comprised of three interconnected grant programs including the State Homeland Security Program, Urban Areas Security Initiative (UASI), and the Operation Stonegarden. Together, these grant programs fund a range of preparedness activities, including planning, organization, equipment purchase, training, exercises, and management and administration. Additional information regarding HSGP is available on the website: https://www.fema.gov/homeland-security-grant-program.
	Responsible Agency:	FEMA
	Provides Funding for Mitigation:	Yes
	Hazard:	All hazards
High Hazard Potential Dams Grant Program	**Description:**	The Rehabilitation of High Hazard Potential Dams Grant Program provides technical, planning, design, and construction assistance in the form of grants to non-Federal governmental organizations or nonprofit organizations for rehabilitation of eligible high hazard potential dams. Information regarding this program is available on the website: https://www.grants.gov/web/grants/view-opportunity.html?oppId=316238.
	Responsible Agency:	FEMA
	Provides Funding for Mitigation:	Yes
	Hazard:	Flooding

Capability	Details	
Small Business Administration Loan	**Description:**	The Small Business Administration (SBA) provides low-interest disaster loans to homeowners, renters, business of all sizes, and most private nonprofit organizations. SBA disaster loans can be used to repair or replace the following items damaged or destroyed in a declared disaster: real estate, personal property, machinery and equipment, and inventory and business assets. Homeowners could apply for up to $200,000 to replace or repair their primary residence. Renters and homeowners could borrow up to $40,000 to replace or repair personal property-such as clothing, furniture, cars, and appliances that were damaged or destroyed in a disaster. Physical disaster loans of up to $2 million are available to qualified businesses or most private nonprofit organizations. Additional information regarding SBA loans is available on the SBA website: https://www.sba.gov/managing-business/running-business/emergency-preparedness/disaster-assistance.
	Responsible Agency:	SBA
	Provides Funding for Mitigation:	Yes
	Hazard:	All hazards
Community Development Block Grant Program	**Description:**	Community Development Block Grant Program (CDBG) are federal funds intended to provide low and moderate-income households with viable communities, including decent housing, a suitable living environment, and expanded economic opportunities. Eligible activities include community facilities and improvements, roads and infrastructure, housing rehabilitation and preservation, development activities, public services, economic development, and planning and administration. Public improvements could include flood and drainage improvements. In limited instances and during the times of "urgent need" (e.g., post disaster) as defined by the CDBG National Objectives, CDBG funding could be used to acquire a property located in a floodplain that was severely damaged by a recent flood, demolish a structure severely damaged by an earthquake, or repair a public facility severely damaged by a hazard event. Additional information regarding CDBG is available on the website: https://www.hudexchange.info/programs/cdbg-entitlement/.
	Responsible Agency:	HUD
	Provides Funding for Mitigation:	Yes
	Hazard:	All hazards

Capability	Details	
Federal Highway Administration-Emergency Relief	**Description:**	The Federal Highway Administration (FHWA) Emergency Relief is a grant program through the U.S. Department of Transportation (DOT) that can be used for repair or reconstruction of federal-aid highways and roads on federal lands that have suffered serious damage as a result of a disaster. Maryland Department of Transportation serves as the liaison between local municipalities and FHWA. Additional information regarding the FHWA Emergency Relief Program is available on the website: https://www.fhwa.dot.gov/programadmin/erelief.cfm.
	Responsible Agency:	U.S. DOT
	Provides Funding for Mitigation:	Yes
	Hazard:	All hazards
Federal Transit Administration - Emergency Relief	**Description:**	The Federal Transit Authority (FTA) Emergency Relief is a grant program that funds capital projects to protect, repair, reconstruct, or replace equipment and facilities of public transportation systems. Administered by the Federal Transit Authority at the U.S. DOT and directly allocated to Metropolitan Transit Authority (MTA) and Port Authority, this transportation-specific fund was created as an alternative to FEMA PA. Additional information regarding the FTA Emergency Relief Program is available on the website: https://www.transit.dot.gov/funding/grant-programs/emergency-relief-program/emergency-relief-program.
	Responsible Agency:	U.S. DOT
	Provides Funding for Mitigation:	Yes
	Hazard:	All Hazards
Disaster Housing Program	**Description:**	Emergency assistance for housing, including minor repair of home to establish livable conditions, mortgage, and rental assistance available through the U.S. Department of Housing and Urban Development (HUD). Information on this program is available on the website: https://www.hud.gov/program_offices/public_indian_housing/publications/dhap.
	Responsible Agency:	HUD
	Provides Funding for Mitigation:	Yes
	Hazard:	All hazards

Capability	Details	
HOME Investment Partnerships Program	**Description:**	The HOME Investment Partnerships Program provides grants to local and state government and consortia for permanent and transitional housing, (including financial support for property acquisition and rehabilitation for low-income persons). Information on this program is available on the website: https://www.hud.gov/program_offices/comm_planning/affordablehousing/programs/home/.
	Responsible Agency:	HUD
	Provides Funding for Mitigation:	Yes
	Hazard:	All hazards
HUD Disaster Recovery Assistance	**Description:**	HUD Disaster Recovery Assistance provides grants to fund gaps in available recovery assistance after disasters (including mitigation). Information on this program is available on the website: https://www.hud.gov/info/disasterresources.
	Responsible Agency:	HUD
	Provides Funding for Mitigation:	Yes
	Hazard:	All hazards
Section 108 Loan Guarantee	**Description:**	Section 108 Loan Guarantee enables states and local governments participating in the CDBG program to obtain federally guaranteed loans for disaster-distressed areas. Information on this program is available on the website: https://www.hudexchange.info/programs/section-108/.
	Responsible Agency:	HUD
	Provides Funding for Mitigation:	Yes
	Hazard:	All hazards
Smart Growth Implementation Assistance program	**Description:**	The Smart Growth Implementation Assistance program through the U.S. Environmental Protection Agency (EPA) focuses on complex or cutting-edge issues, such as stormwater management, code revision, transit-oriented development, affordable housing, infill development, corridor planning, green building, and climate change. Applicants can submit proposals under 4 categories: community resilience to disasters, job creation, the role of manufactured homes in sustainable neighborhood design, or medical and social service facilities siting. Information on this program is available on the website: https://www.epa.gov/smartgrowth.
	Responsible Agency:	EPA
	Provides Funding for Mitigation:	Yes
	Hazard:	All hazards

Capability	Details	
Partners for Fish and Wildlife	**Description:**	Financial and technical assistance to private landowners interested in pursuing restoration projects affecting wetlands and riparian habitats. Information on this program is available on the website: https://www.fws.gov/partners/.
	Responsible Agency:	U.S. Fish and Wildlife Service
	Provides Funding for Mitigation:	Yes
	Hazard:	All natural hazards
Transportation Investment Generating Economic Recovery	**Description:**	The Transportation Investment Generating Economic Recovery (TIGER) grant program invests in critical road, rail, transit, and port projects across the nation. Information on this program is available on the website: https://www.transportation.gov/tags/tiger-grants.
	Responsible Agency:	U.S. DOT
	Provides Funding for Mitigation:	Yes
	Hazard:	All hazards
Community Facilities Direct Loan & Grant Program	**Description:**	The United States Department of Agriculture (USDA) Community Facilities Direct Loan & Grant Program provides affordable funding to develop essential community facilities in rural areas. An essential community facility is defined as a facility that provides an essential service to the local community for the orderly development of the community in a primarily rural area, and does not include private, commercial, or business undertakings. Information on this program is available on the website: https://www.rd.usda.gov/programs-services/community-facilities-direct-loan-grant-program
	Responsible Agency:	USDA
	Provides Funding for Mitigation:	Yes
	Hazard:	All hazards
Emergency Loan Program	**Description:**	USDA's Farm Service Agency Emergency Loan Program provides emergency loans to help producers recover from production and physical losses due to drought, flooding, other natural disasters, or quarantine. Information on this program is available on the website: https://www.fsa.usda.gov/programs-and-services/farm-loan-programs/emergency-farm-loans/index.
	Responsible Agency:	USDA
	Provides Funding for Mitigation:	Yes
	Hazard:	All natural hazards

Capability	Details	
Emergency Watershed Protection program	**Description:**	The Emergency Watershed Protection (EWP) program provides assistance to relieve imminent hazards to life and property caused by floods, fires, drought, windstorms, and other natural occurrences through the Natural Resources Conservation Service. Information on this program is available on the website: https://www.nrcs.usda.gov/wps/portal/nrcs/main/national/programs/landscape/ewpp/.
	Responsible Agency:	USDA
	Provides Funding for Mitigation:	Yes
	Hazard:	All natural hazards
Financial Assistance	**Description:**	USDA's Natural Resources Conservation Service (NRCS) provides financial assistance to help plan and implement conservation practices that address natural resource concerns or opportunities to help save energy, improve soil, water, plant, air, animal and related resources on agricultural lands and non-industrial private forest land. Information on this program is available on the website: https://www.nrcs.usda.gov/wps/portal/nrcs/main/national/programs/financial/.
	Responsible Agency:	USDA NRCS
	Provides Funding for Mitigation:	Yes
	Hazard:	All hazards
Emergency Management Performance Grants Program	**Description:**	The United States Department of Homeland Security (DHS) Emergency Management Performance Grants (EMPG) Program assists local, tribal, territorial, and state governments in enhancing and sustaining all-hazards emergency management capabilities. Information on this program is available on the website: https://www.fema.gov/emergency-management-performance-grant-program.
	Responsible Agency:	U.S. DHS
	Provides Funding for Mitigation:	Yes
	Hazard:	All hazards
Reimbursement for Firefighting on Federal Property	**Description:**	The U.S. DHS Reimbursement for Firefighting on Federal Property program provides reimbursement only for direct costs and losses over and above normal operating costs. Information on this program is available on the website: https://www.usfa.fema.gov/grants/firefighting_federal_property.html.
	Responsible Agency:	U.S. DHS
	Provides Funding for Mitigation:	Yes
	Hazard:	Wildfire

Capability	Details	
Land & Water Conservation Fund	**Description:**	The National Park Service Land & Water Conservation Fund provides matching grants to states and local governments for the acquisition and development of public outdoor recreation areas and facilities (as well as funding for shared federal land acquisition and conservation strategies). Information on this program is available on the website: https://www.nps.gov/subjects/lwcf/index.htm.
	Responsible Agency:	National Park Service
	Provides Funding for Mitigation:	Yes
	Hazard:	All natural hazards
State		
Community Parks and Playgrounds	**Description:**	The Community Parks and Playground Program provides funding to allow the State to focus on restoring existing and creating new park and green space systems in Maryland's cities and towns. The Community Parks and Playgrounds Program will provide flexible grants to local governments to respond to the unmet need for assistance to rehabilitate, expand or improve existing parks, create new parks, develop environmentally oriented parks and recreation projects, or purchase and install playground equipment in older neighborhoods and intensely developed areas throughout the state.
	Responsible Agency:	Maryland Department of Natural Resources
	Provides Funding for Mitigation:	Yes
	Hazard:	Flooding, Extreme Temperature
Federal Land and Water Conservation Fund	**Description:**	Authorized by the United States Congress and signed into law by President Lyndon Johnson, the Land and Water Conservation Fund Act of 1965 established a federally funded program to provide 50/50 matching grants to state and local governments for the purpose of acquiring and/or developing public outdoor recreational areas and facilities. The program is administered nationally by the United States Department of the Interior, National Park Service with the supporting revenues generated from offshore oil and gas leases. The Land and Water Conservation Fund is intended to create and maintain a nationwide legacy of quality public outdoor recreational resources as well as to stimulate non-federal investments in the purchase, development, maintenance, and protection of these highly valued outdoor recreational areas. Per section 6(f)(3) of the Land and Water Conservation Fund Act, "No property acquired or developed with assistance under this section shall, without the approval of the Secretary of the Department of the Interior, be converted to other than public outdoor recreation uses."
	Responsible Agency:	Maryland Department of Natural Resources
	Provides Funding for Mitigation:	Yes
	Hazard:	Flooding, Extreme Temperature

Capability	Details	
Program Open Space	**Description:**	Maryland Department of Natural Resources Program Open Space provides financial and technical assistance to local subdivisions for the planning, acquisition, and/or development of recreation land or open space areas.
	Responsible Agency:	Maryland Department of Natural Resources
	Provides Funding for Mitigation:	Yes
	Hazard:	Flooding, Extreme Temperature
Maryland Urban and Community Forestry Committee Grants Program	**Description:**	The Maryland Urban and Community Forestry Committee grants program helps community groups fund tree planting and education projects statewide to enhance Maryland's urban forest. Community tree projects may be organized via schools, service organizations, homeowner organizations or other volunteer-based groups. The tree planting/educational projects must be located on public lands in parks, metropolitan areas, cities, or towns.
	Responsible Agency:	Maryland Department of Natural Resources
	Provides Funding for Mitigation:	Yes
	Hazard:	Flooding, Extreme Temperature
Other		
Ecosystem Investment Partners	**Description:**	Ecosystem Investment Partners invests in major restoration. It spends private conservation money on local mitigation projects.
	Responsible Agency:	Ecosystem Investment Partners
	Provides Funding for Mitigation:	Yes
	Hazard:	Flooding, Coastal Storms, Severe Storms, Drought, Extreme Temperature, Earthquake, Soil Movement
Partners for Places	**Description:**	Partners for Places helps cities and counties in the United States and Canada improve. It builds partnerships between local government sustainability offices and place-based foundations.
	Responsible Agency:	Funders' Network
	Provides Funding for Mitigation:	Yes
	Hazard:	Flooding, Coastal Storms, Severe Storms, Drought, Extreme Temperature, Earthquake, Soil Movement
Urban Trees Grant Program	**Description:**	The Urban Trees Grant Program, called for by the Maryland General Assembly as a component of a 5,000,000-tree goal by 2031, welcomes requests for tree planting projects in urban, underserved communities. The goal of the Urban Tree Grant Program is to green communities; enhance quality of life, human health, and community livability by improving air quality and reducing urban heat island effect; and mitigate some of the effects of climate change.
	Responsible Agency:	Chesapeake Bay Trust

Capability	Details	
	Provides Funding for Mitigation:	Yes
	Hazard:	Extreme Temperature, Flooding
Outreach and Restoration Grant Program	**Description:**	This grant program encourages outreach, community engagement activities, and on-the-ground restoration projects that increase knowledge, change behavior, and accelerate stewardship of natural resources that involve residents in restoring local green spaces, waterways, and natural resources.
	Responsible Agency:	Chesapeake Bay Trust
	Provides Funding for Mitigation:	Yes
	Hazard:	Flooding, Coastal Storms, Severe Storms, Drought, Extreme Temperature, Earthquake, Soil Movement
Green Streets, Green Jobs, Green Towns (G3)	**Description:**	The Green Streets, Green Jobs, Green Towns (G3) grant program supports design and implementation of green streets, community greening, and urban tree canopy projects that enhance livability in cities and communities, in addition to white papers that address these topics. The goal of this grant program is to help communities develop and implement plans that reduce stormwater runoff, increase the number and number of green spaces in urban areas, improve the health of local waters and the Chesapeake Bay, and enhance quality of life and community livability.
	Responsible Agency:	Chesapeake Bay Trust
	Provides Funding for Mitigation:	Yes
	Hazard:	Extreme Temperature, Flooding
Five Star and Urban Waters Restoration Grant Program	**Description:**	The Five Star and Urban Waters Restoration Program focuses on care of coastal, wetland and riparian ecosystems across the country. It seeks to meet the conservation needs of important species and habitats. The program provides measurable and meaningful conservation and educational outcomes. It also requires diverse partnerships and outreach.
	Responsible Agency:	National Fish & Wildlife Foundation
	Provides Funding for Mitigation:	Yes
	Hazard:	Flooding, Coastal Storms, Severe Storms, Drought, Extreme Temperature, Earthquake, Soil Movement
Resilient Landscapes Funds	**Description:**	The Open Space Institute (OSI) launched the Resilient Landscapes Initiative (RLI) in 2013 to identify and protect the places where wildlife can thrive. The RLI works with other land trusts. The Doris Duke Charitable Foundation, Jane's Trust, the North Atlantic Landscape Cooperative, and the New York state Conservation Partnership Program/Land Trust Alliance support the RLI.
	Responsible Agency:	OSI
	Provides Funding for Mitigation:	Yes

Capability	Details	
	Hazard:	Flooding, Coastal Storms, Severe Storms, Drought, Extreme Temperature, Earthquake, Soil Movement
Mini Urban Trees Grant	**Description:**	Many communities benefit from having green spaces and trees to promote outdoor recreation, access to shaded areas, improved air quality, improved mental and physical health, and livability. Ultimately, the Mini Urban Trees Grant initiative will empower communities that have felt disenfranchised to take ownership with the tools needed to improve access to natural resources that connect their neighborhoods to a healthy, greener environment for current and future generations.
	Responsible Agency:	Chesapeake Bay Trust
	Provides Funding for Mitigation:	Yes
	Hazard:	Extreme Temperature, Flooding
Watershed Assistance Grant Program	**Description:**	This program provides support for watershed restoration project designs and permitting and for watershed planning and programmatic development. The ultimate goal of the projects funded through this opportunity will be to improve water quality in the Maryland portion of the Chesapeake Bay watershed, the Maryland portion of the Youghiogheny watershed, and the Maryland Coastal Bays. By funding the earliest phases of watershed restoration projects and planning, the funding partners aim to provide local governments and non-profit organizations with the ability to position themselves to quickly advance implementation work. The funding partners hope the products of grants funded under this opportunity will enable grantees to: • Leverage resulting designs, plans, or projects to craft future proposals for implementation funding to the Maryland Chesapeake and Atlantic Coastal Bays Trust Fund, grant programs at the Chesapeake Bay Trust, or other sources of support. • Develop deliverables that will support local planning efforts such as Financial Assurance Plans, Total Maximum Daily Load Implementation Plans, county-wide Green Infrastructure Plans, watershed action plans, and the Maryland Phase III Watershed Implementation Plan strategies and associated State Two-year Milestones.
	Responsible Agency:	Chesapeake Bay Trust
	Provides Funding for Mitigation:	Yes
	Hazard:	Flooding

Capability	Details	
BMORE Beautiful	**Description:**	BMORE Beautiful is a grassroots peer-to-peer beautification program. The goal of the program is to not only change behaviors and attitudes towards the beautification of Baltimore City but to encourage residents, businesses, and organizations to become directly involved in activities and projects that will Keep Baltimore Beautiful…. block by block and neighborhood to neighborhood. BMORE Beautiful offers seasonal grant opportunities to support community beautification efforts. Grant opportunities offered by BMORE Beautiful include: • Care-A-Lot Grant: Supports community organizations able to mow and maintain up to 25 vacant lots in Baltimore City during the "Grow Season." (April-October) • Say YES (Youth Environmental Stewards): Supports community organizations looking to engage youth in the cleaning and beautification of their neighborhood. (Spring & Fall) • Love Your Block: Supports small block-level projects. (Summer)
	Responsible Agency:	Environmental Control Board
	Provides Funding for Mitigation:	Yes
	Hazard:	Flooding, Extreme Temperature

Section 14. Mitigation Strategy

Key Changes from 2018 DP3:

- Review and update of vision and goals
- Consolidation of similar/duplicative actions
- Inclusion of new actions identified by plan participants

The Mitigation Strategy is Baltimore City's roadmap to reduce the risk of hazards identified in the DP3. The strategy is based on hazard impacts, asset vulnerability, and Baltimore City's capabilities. Actions are specific activities, such as policies, projects, and studies, that stakeholders identify to reduce risk. Actions should be forward-looking and incorporate changing conditions for the life of Baltimore City's assets. Examples of actions may include elevating electrical and HVAC equipment to reduce the likelihood of damage from floodwaters or planting trees to lower temperatures exacerbated by pavement.

14.1 Vision and Goals

FEMA Planning Policy Element C3: 44 CFR 201.6(c)(3)(i): The plan must include goals to reduce and/or avoid long-term vulnerabilities to the identified hazards.

The vision and goals set the stage for what Baltimore City wants to work towards accomplishing over the 5-year cycle of the DP3. These guiding principles are developed to address the risks and vulnerabilities identified in the risk assessment as well as the findings of the capability assessment.

The vision statement is an idealistic principle that Baltimore City aims to achieve through implementing the DP3. The vision identifies the purpose of the planning process and serves to identify the key message of the plan. It focuses the range of goals identified in the plan. Mitigation goals are broad, long-term policy statements that explain what is to be achieved by implementing the mitigation strategy. The goals represent what Baltimore City seeks to accomplish through implementing the DP3. The vision and goals can be integrated into other City planning efforts and initiatives to ensure consistency across programs and work towards building a resilient community.

During the 2023 DP3 update planning process, the CPT met twice to review the vision and goals from the 2018 DP3. The group discussed the applicability of the statements, identified opportunities to further integrate equity and systems-based approaches, and ensured the language was consistent with City priorities. The vision and all goals, with the exception of goal #5, were updated to reflect Baltimore City's current priorities and aspirations for the 2023 DP3 including integrating equity, addressing natural and human-caused hazards, and ensuring the protection of critical government and community services and facilities. The vision and goals were presented to the HMAC and reaffirmed. Table 14-1 summarizes the revisions of the 2018 DP3 vision and goals.

Table 14-1. 2023 Vision and Goals Revisions

2018 DP3	2023 Revisions
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.	**Vision:** Baltimore is a resilient city whose daily activities reflect a commitment shared by all people who work, live, and play in Baltimore City to reduce or eliminate impacts from current and future hazards, especially those exacerbated by climate change.
Goal 1: Protect the health, safety and welfare of Baltimore City residents and visitors.	**Goal 1:** Ensure the equitable protection of the health, safety and welfare of all people who work, live, and play in Baltimore City, with specific consideration for the barriers and challenges that may result in disproportionate hazard impacts to socially vulnerable populations and underserved communities.
Goal 2: Prevent damage to structures, infrastructure, and critical facilities.	**Goal 2:** Strengthen the resilience of critical government and community facilities, services, and systems, to reduce or prevent impacts from natural and human-caused hazard events.
Goal 3: Build resilience and disaster prevention and planning into all programs, policies, and infrastructure (public and private).	**Goal 3:** Enhance the integration of resilience, disaster prevention, and planning into all City programs, policies, and operations.
Goal 4: Enhance Baltimore City's adaptive capacity and build institutional structures that can cope with future conditions that are beyond past experience.	**Goal 4:** Enhance Baltimore City's adaptive capacity and build institutional structures that can proactively cope with dynamic future conditions.
Goal 5: Promote hazard mitigation and climate adaptation awareness and education throughout Baltimore City.	**Goal 5:** No changes.
Goal 6: Provide support to increase efforts toward a better Community Rating System (CRS) community rating.	**Goal 6:** Provide support to increase efforts toward a better Community Rating System (CRS) classification.

14.2 Progress on Previous Plan

The 2018 DP3 identified 49 strategies and 214 corresponding actions. The strategies served as traditional mitigation actions and were measures Baltimore City could take to reduce risk, while the corresponding actions were specific implementation steps that Baltimore City could take to implement each strategy.

The prior strategies and actions were updated through coordination with identified lead agencies, the CPT, and the HMAC. The lead agencies were provided with their prior actions to provide a status update and indicate whether the action was complete, in progress, no progress, an ongoing capability, or if it should be discontinued and provide review comments on each. Agencies were asked to quantify the extent of progress and provide reasons for the level of progress or why actions were being discontinued. Due to staff turnover, limited engagement during implementation, and other factors, many prior actions were not able to be updated by the lead agency. However, the CPT reviewed the strategies and actions to determine updates for the 2023 process.

The CPT met three times to review the 2018 strategies. The CPT used the following guiding questions to review the prior actions:

- Are there necessary corrections to the strategy or action, such as changes in lead agency names?
- Is the lead agency still the same? If not, can you identify which agency should serve as the lead?
- Is the strategy still relevant to Baltimore City's work?
- Are there any known changes to the priority of this strategy? Why or why not?
- Are there changes to the anticipated timeframe for completion?
- Has the status of the action changed?
- Are there performance metrics that were developed and were implemented in the past 5 years?

Image from Baltimore Tree Trust planting.

Mitigation actions identified as Complete, and those actions identified as Discontinued, were removed from the updated strategies. Mitigation actions identified as an Ongoing Capability, No Progress, or In Progress that remain a priority for Baltimore City, have been carried forward into the updated mitigation strategy.

Strategies and actions that were determined to be incomplete were reviewed to determine if they should be carried over to the 2023 DP3 update or removed due to changes in priorities, capabilities, or feasibility. Of the 214 actions from the 2018 DP3, 6 have been completed, 14 were discontinued or combined with other actions, and the other 194 are being carried over to the 2023 DP3.

14.3 Mitigation Action Identification

FEMA Planning Policy Element C4: 44 CFR 201.6(c)(3)(ii): The plan must identify and analyze a comprehensive range of specific mitigation actions and projects being considered to reduce the effects of hazards, with emphasis on new and existing buildings and infrastructure.

Prior DP3s organized mitigation actions into four urban sections to ensure a comprehensive approach to mitigation and resilience. Those urban sectors included infrastructure, buildings, natural systems, and public services. Prioritizing mitigation actions across all urban sectors aids in building community-wide resilience and prioritizes a systems-based approach that addresses the interconnectedness of the sectors. 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.

For the 2023 DP3 update, the CPT reaffirmed the categorization of mitigation actions into the four sectors. A description of each sector is provided below.

14.3.1 Infrastructure

Maintaining the quality and necessary capacity of the built public infrastructure that services daily needs will ensure public safety and economic security. These actions aim to protect energy, wastewater, drinking water, and transportation infrastructure. This urban sector aligns with FEMA's structure and infrastructure project category for recommended mitigation actions.

14.3.2 Buildings

Baltimore has a diverse and extensive collection of buildings in Baltimore City, many of which have historical significance. These structures are vulnerable to damage from hazards. These actions aim to improve building design and code to protect against hazards and improve resource conservation. This urban sector aligns with FEMA's structure and infrastructure project category for recommended mitigation actions.

14.3.3 Natural Systems

Natural systems have the potential to be utilized as a mitigation strategy against climate change. These actions prioritize the utilization of green corridors, preservation of shoreline areas, as well as water supply management tactics. This urban sector aligns with FEMA's natural systems protection category for recommended mitigation actions.

14.3.4 Public Services

Disaster preparedness and distribution of resources, information, and response plans are key to ensuring public safety and mitigating tragic consequences associated with hazards. These actions prioritize coordinated planning and communication efforts, as well as education and outreach. This urban sector aligns with FEMA's education and awareness programs and local plans and regulations categories for recommended mitigation actions.

An in-person workshop was held with the CPT, HMAC, and additional stakeholders to review 2018 actions and identify new actions for inclusion in the 2023 DP3 update. The goal of the workshop was to identify:

- Capabilities that contribute to the reduction of risk such as plans, ordinances, administrations, and projects
- Problem areas that represent vulnerabilities/gaps/challenges within Baltimore City
- Potential actions or projects that could be undertaken to increase Baltimore City's resilience and decrease Baltimore City's risk to future hazard events.

Participants provided feedback on the status of the 2018 strategies, opportunities to make actions easier to implement, and provide recommendations for new strategies and actions.

The key principles participants recommended for guiding the development of the mitigation strategy including the following:

- Providing funding to private properties for debris removal
- Establishing comprehensive emergency preparedness and response strategies that prioritize aiding the whole community, specifically improving support for individuals experiencing homelessness.
- Clear messaging and risk communication, including utilizing multiple languages and using multiple platforms for communication such as social media, newspaper, television, text messaging, automated calls, printed materials, etc.
- Prioritization for support to assist communities during disasters, rather than focusing on government agencies
- Support for ongoing tree care and maintenance to support the lifespan of existing and new tree plantings to maintain and expand tree canopy.
- Stronger coordination with trusted community leaders and organizations, such as Resiliency Hub leaders, faith-based organizations, etc.
- Integration of green infrastructure and nature-based solutions.
- Strengthening support for long-term recovery to support the whole community, including assisting with coordinating housing, social services, etc.
- Reviewing building codes to identify opportunities to integrate hazard-resistant concepts.
- Assessing infrastructure to identify opportunities to upgrade to standards that include considerations for climate change impacts.

Information gathered during the workshop, the risk assessment, and capability assessment was used to inform the updated mitigation strategy development. Many of the above principles were captured in the previous mitigation strategies for the DP3 and reaffirmed during the 2023 DP3 update. New mitigation actions developed during the 2023 DP3 update process include the following:

- Assess the utility of establishing or merging with an existing Resilience Authority and other institutional structure to develop, finance, and support resilience projects. (Action #: B-2-13)
- Conduct a study to develop a long-term plan for strategic retreat to reduce future loses to hazards. (Action #: PS-8-8)
- Promote portable EV charging to ensure availability of charging in the instance of impacts to fixed EV charging facilities during emergencies. (IN-7-8)
- Assess the feasibility of backflow preventers for residential buildings and incorporate educational outreach where backflow preventers are determined to be a feasible option. (Action #: B-7-6)
- Identify opportunities for installation of flood sensors accompanied by tide gates, cameras, and signage. (Action #: NS-8-6)

14.4 Mitigation Action Plan

FEMA Planning Policy Element C4: 44 CFR 201.6(c)(3)(ii): The plan must identify and analyze a comprehensive range of specific mitigation actions and projects being considered to reduce the effects of hazards, with emphasis on new and existing buildings and infrastructure.

Implementable mitigation actions require more than just a statement of activity as actions are led by different departments and agencies, require various levels of effort, and have varied resource needs. The update mitigation action plan is shown in Table 14-2. The following information is included in the plan:

- Action #: Provides the numerical identification for each action. The first character is an abbreviation which corresponds to the mitigation category. The abbreviations and categories are defined as follows:
    - IN: Infrastructure
    - B: Buildings
    - NS: Natural Systems
    - PS: Public Services

  The second character is a numerical value that corresponds to the overarching strategy of that mitigation category. The third character is a numerical value that corresponds to the specific mitigation action number.

- Action Description: Provides a narrative explanation of the mitigation action.
- Hazard(s) Addressed: Identifies the specific hazards that may be addressed by implementation of the mitigation action.
- Goals Met: Identifies the specific goals that are addressed by implementation of the mitigation action.
- Lead Agency: Identifies the agency responsible for overseeing implementation of the mitigation action.
- Support Agency: Identifies the agency or multiple agencies that can assist with contributing to the implementation of the mitigation action.
- Sources of Funding: Identifies potential sources of funding.
- Timeline: Identifies the length of time required to implement the action.
    - Shore: Less than 5 years
    - Medium: Between 5 and 10 years
    - Long: Greater than 10 years
- Costs: Identifies high-level planning cost estimates to implement the mitigation action.
- Priority: Identifies the importance of the mitigation action for consideration.
- Action Status: Description of the current state of implementation of the mitigation action.
- Project Action Status Comments: Narrative description of the current status of the mitigation action.

Agency Acronyms

- BCDOT: Baltimore City Department of Transportation
- BCFD: Baltimore City Fire Department
- BCHD: Baltimore City Health Department
- BCIT: Baltimore City Information and Technology
- BCPD: Baltimore City Police Department
- BCPSS: Baltimore City Public School System
- BCRP: Baltimore City Department of Recreation and Parks
- BDC: Baltimore Development Corporation
- 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
- CSX: CSX Corporation
- DGS: Department of General Services
- DHCD: Department of Housing and Community Development
- MDH: Maryland Department of Health
- 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
- MDEM: Maryland Department of Emergency Management
- MDNR: Maryland Department of Natural Resources
- MDTA: Maryland Transportation Authority
- MIMA: Mayor's Office of Immigrant Affairs
- MOID: Mayor's Office of Infrastructure Development
- MON: Mayor's Office of Neighborhoods
- MTA: Maryland Department of Transportation (MDOT) 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: MDOT State Highway Administration
- USACE: U.S. Army Corps of Engineers

Table 14-2. Action Plan

Action #	Action Description	Hazard(s) Addressed	Goals Met	Lead Agency	Support Agencies	Sources of Funding	Timeline	Costs	Priority	Action Status	Project Action Status Comments
B-1	**Inventory hazard protections for city-owned and private critical facilities including hospitals, fire stations, police stations, hazardous material storage sites, etc. to enhance hazardous material mitigation. (Lead Agency:)**										
B-1-1	Conduct educational outreach for city-owned, residential, commercial, and industrial buildings about proper storage and disposal of hazardous materials and heating oil	Flood, Human-caused	5	OEM	BGE, BCFD, DGS, DOP, DPW, MDE, Hospitals, Material Storage Sites	Hazard Mitigation Grant Program, Existing Capital Budgets	Short	Low	High	Ongoing Capability	BCFD's Haz Mat team conducts outreach and can be requested to present about hazardous materials storage and disposal via more channels, including Baltimore City's LEPC (Local Emergency Planning Committee), which are open to the public. BCFD Haz Mat is also willing to do this upon request from individual companies interested in learning more about proper storage and disposal and offer this service regularly at quarterly LEPC meetings.
B-1-2	Require hazardous materials stored in city-owned, residential, commercial, and industrial buildings within the regulatory floodplain to be elevated a minimum of 1 foot above the flood protection elevation	Flood, Human-caused	2, 3	DOP	BGE, DGS, MDE, Hospitals, Material Storage Sites	Existing City Budgets	Short	Low	High	No Progress	Baltimore City can only require changes when a site is undergoing new construction or major renovation, the action cannot be enforced for existing structures unless a policy change is implemented. This can be discussed at future Flooding and Infrastructure working group meetings of the Sustainability and Resiliency Subcabinet.
B-1-7	Coordinate delivery of fuel and/or access to fuel for critical facility emergency generators	All Hazards	4	OEM	BGE, DGS, DOP, Hospitals, Material Storage Sites	Existing City Budgets	Long	Low	High	Ongoing Capability	Coordination happens on a case-by-case basis through Baltimore City's EOC in partnership with other city agencies.
B-2	**Enhance City building codes that regulate development within the regulatory floodplain or the designated Critical Area, to integrate anticipated changes in climate change. (Lead Agency: DOP)**										
B-2-1	Design new projects to be resilient based on sea level rise projections based on best available data and adaptable to longer term impacts	Coastal Hazards, Flooding	2, 3, 4	DOP	DHCD, BDC, DPW, MDE, Utilities	Existing City Budgets	Long	Low	Low	Ongoing Capability	The Inner Harbor redevelopment project includes considerations for sea-level rise. Additionally, DHCD is currently in discussions with other agencies to develop plants that will incorporate sea-level rise.

Action #	Action Description	Hazard(s) Addressed	Goals Met	Lead Agency	Support Agencies	Sources of Funding	Timeline	Costs	Priority	Action Status	Project Action Status Comments
B-2-3	Continue to regulate to the 0.2% annual chance flood area in existing tidal floodplain delineation	Coastal Hazards	2, 3, 4	DOP	BDC, DHCD, DPW, MDE, Utilities	Existing City Budgets	Short	Low	Low	Ongoing Capability	Baltimore City's Floodplain Management Program continues to enforce regulations that extend to the 0.2% annual chance flood area.
B-2-4	Incorporate outfall elevation regulations	Flood, Coastal Hazards	3	DPW	DOP, Baltimore County, DHCD, MDE	Existing City Budgets	Short	Low	Medium	No Progress	This action will be included in considerations in future updates to the Baltimore City Floodplain Management Program.
B-2-5	Identify alternative buildable land to deter development in the regulatory floodplain where feasible, when not feasible develop and share construction Best Practices for development within the regulatory floodplain	Flood, Coastal Hazards	3, 4	DOP	Baltimore County, BDC, DHCD, DPW, MDE, Utilities	Existing City Budgets	Short	Low	High	Ongoing Capability	CHAP developed the Fells Point Flood Mitigation Guidelines to share best practices for retrofits in historic districts; ongoing sharing of FEMA guidance for flood protection; and ongoing CRS outreach.
B-2-6	Train all code enforcement and building inspectors about floodproofing techniques and the local floodplain ordinance	Flood, Coastal Hazards	3, 5	DOP	Baltimore County, DHCD, DPW, MDE, Utilities	Existing City Budgets	Long	Low	Low	Ongoing Capability	Last training completed in 2019. Additional staffing capacity is required to continue implementation.
B-2-7	Encourage green roof installations to include vegetative and reflective technologies for all new commercial, industrial, multifamily, and city-owned development	Extreme Temperature	4, 5	DHCD	BDC, DHCD, DOP, DPW, MDE, Utilities	Existing City Budgets	Short	Low	High	No Progress	The 2019 Sustainability Plan includes considerations for green roofs as a strategy. DHCD Homeownership and Housing Preservation (HHP) programs specify cool roof and/or cool roof coating on program projects. HHP is working with the JHU Cool Roofs SCIBAR Study. Ordinance 21-0160 was signed by the Mayor and went into effect on September 20, 2023; this bill requires newly constructed buildings and additions to existing buildings to have a reflective roof.
B-2-8 (Formerly B-1-3)	Require new critical facilities to be designed with redundant operating systems	All Hazards	2, 3, 4	DOP	BGE, BCPSS, BCIT, Law Dept., DGS, DOP, Hospitals, Material Storage Sites	Existing City Budgets	Long	Low	Medium	No Progress	Coordination between various city agencies to better identify opportunities for redundancy in new critical facilities and what legislation would need to be developed. Coordination will be facilitated through Baltimore City's Sustainability and Resiliency Subcabinet.

Action #	Action Description	Hazard(s) Addressed	Goals Met	Lead Agency	Support Agencies	Sources of Funding	Timeline	Costs	Priority	Action Status	Project Action Status Comments
B-2-9 (Formerly B-1-4)	Require pre-wiring for generators at all facilities designated critical to agency operations and hazard response	All Hazards	3, 4	DOP	BCRP (Forestry), BGE, Building Owners, DGS, DOT, DPW, Exelon, PSC, Utility customers, Vicinity, Wheelabrator	Baltimore City CIP, Federal Sources, BGE's existing funds, Smart Grid Investment Grant, Existing Capital Budgets	Short	Low	Medium	No Progress	BCFD incorporates prewiring for generators at BCFD stations and other agencies as a best practice. Coordination on how to integrate this best practice across Baltimore City can be initiated through Baltimore City's Sustainability and Resiliency Subcabinet.
B-2-10 (Formerly B-3-1)	Review zoning code and strengthen language (where necessary) in order to better protect residents and the environment and increase resiliency in buildings	All Hazards	3, 4	DOP	BDC, DHCD, DPW, Community Groups, DHCD, DGS, DPW, NAHB, NGOs, MDE, Private developers, Private landowners	Local Funding	Short	Low	Medium	In Progress	DPW utilizes an electronic permitting system, which includes permitting for the CAMP area and regulatory floodplain. DOP is able to identify concerns in the early design stage designs of projects, which helps with enhancing waterfront permitting processes. Natural Resources Code Division 1 was revised in 2021 and continues to require projects to meet the elevation of the 0.2% flood plus 2 feet of freeboard.
B-2-11 (Formerly B-3-3)	Utilize open space category in zoning code to protect sensitive areas (stormwater sites, steep slopes, floodways, etc.)	Flood	3	DOP	, City Government, Community Groups, DHCD, DGS, DPW, NAHB, NGOs, MDE, Private developers, Private landowners	Existing City Budgets	Short	Low	Low	In Progress	City agencies are beginning to identify opportunities to create additional open space designations in the zoning code.
B-2-12 (Formerly B-3-7)	Review and consider adoption of the International Green Construction code	Flood, Extreme temperature	3	DHCD	BDC, DOP, Community Groups, DHCD, DGS, DPW, NAHB, NGOs, MDE, Private developers, Private landowners	Existing City Budgets	Short	Low	Medium	In Progress	The IGCC 2018 was adopted on May 18, 2020. Currently referencing the IGCC with existing program guidelines to see where modifications can be made.
B-2-13	Assess the utility of establishing or merging with an existing Resilience Authority and other institutional structure to develop, finance, and support resilience projects.	All Hazards		DOP	Mayor's Office	Existing City Budgets	Long	Low	High	No Progress	New Action for 2023. Baltimore City agencies are beginning collaboration and coordination to discuss the feasibility of establishing a Resiliency Authority; a study will likely be conducted in 2023.

Action #	Action Description	Hazard(s) Addressed	Goals Met	Lead Agency	Support Agencies	Sources of Funding	Timeline	Costs	Priority	Action Status	Project Action Status Comments
B-4	**Update and maintain the list of flood prone and repetitive loss buildings to consider for mitigation activities to reduce potential losses. (Lead Agency: DOP)**										
B-4-1	Continue to acquire property (including repetitive loss properties) in the regulatory floodplain, where feasible and appropriate	Flood, Coastal Hazards	1, 2	DOP	DHCD, MDEM, MDE, Office of Real Estate	MDEM, FEMA, and other agencies	Long	Medium	High	Ongoing Capability	Baltimore City has identified RL and SRL properties to consider for HMA funding. Additionally, funding will be identified to offset non-federal match, which will include City general funds.
B-4-2	Prioritize Hazard Mitigation Assistance and other funding opportunities for mitigation of repetitive loss properties and severe repetitive loss properties	Flood, Coastal Hazards	1, 2		DHCD, DOP, MDEM, MDE, Office of Real Estate	Federal Funds, State Funds, Local Funds	Long	Low	Medium	Ongoing Capability	Baltimore City has identified repetitive loss and severe repetitive loss properties and HMA funds have been considered, though HMA funds often do not cover full costs associated with acquisition related activities for repetitive loss properties. Additional funding will need to be sought, including city general funds. Coordination related to opportunities for mitigation at repetitive loss sites have been ongoing and HMA funds are being considered.
B-4-3	Develop a creative financing program for flood resiliency in industrial buildings	Flood, Coastal Hazards	3	DOP	DHCD, MDEM, MDE, Office of Real Estate	Federal Funds, State Funds, Local Funds	Long	Low	High	In Progress	The USACE Coastal Storm Risk Management Study for the Baltimore Region provides 65% federal funding for industrial and commercial facilities in hazard prone areas.
B-4-4	Pursue grants to acquire flood prone properties when and where feasible	Flood	1, 2	OEM	All city agencies	FEMA grants, State Grants, Philanthropic efforts	Long	Low	Medium	In Progress	Baltimore City has identified repetitive loss and severe repetitive loss properties and HMA funds have been considered, though HMA funds often do not cover full costs associated with acquisition related activities for repetitive loss properties. Additional funding will need to be sought, including city general funds. Coordination related to opportunities for mitigation at repetitive loss sites have been ongoing and HMA funds are being considered.

Action #	Action Description	Hazard(s) Addressed	Goals Met	Lead Agency	Support Agencies	Sources of Funding	Timeline	Costs	Priority	Action Status	Project Action Status Comments
B-5	**Improve wind resiliency of new and existing structures. (Lead Agency: DHCD)**										
B-5-1	Review local building codes to determine if revisions are needed to improve the structure's ability to withstand greater wind velocities, storm impacts, and impacts from debris and projectiles	Severe Storms	3	DHCD	Commercial Building Owners, DHCD, DGS, DOP, MDE, Private Developers	Federal Funding Sources	Short	Low	Medium	On going Capability	Every three years codes are reviewed, and updates are adopted by the ICC and the State. The 2021 codes are currently being reviewed and adoption is anticipated in 2024.
B-6	**Evaluate various seismic design enhancements using prototypical Baltimore City building types. (Lead Agency: DGS)**										
B-6-1	Determine engineering effectiveness and cost benefit of various earthquake mitigation measures using computer modeling	Earthquake, Soil Movement	2, 4	DGS	DHCD, USGS	Existing City Budgets	Short	Low	Low	No Progress	Must be discussed with various stakeholders and agencies.
B-7	**Retrofit existing buildings in the regulatory floodplain to increase resiliency. (Lead Agency: DOP)**										
B-7-2	Prioritize retrofitting and increasing resiliency of Public Housing units in the regulatory floodplain and other high-risk areas	Flood, Coastal Hazards, Earthquake, Soil Movement	1, 2, 4	HABC	DHCD, BDC, DPW, Federal and State Partners, MON, OEM	Existing City Budgets	Long	Medium	Low	No Progress	The City's public housing facilities are not located in regulatory floodplains; however, mapping should be completed to determine proximity to flood change and identify current and emerging flooding that impacts public housing.
B-7-3	Educate building owners within the regulatory floodplain to ensure that all electrical, mechanical, and key building systems are above the base flood elevation and meet existing codes	Flood, Coastal Hazards	1, 5	DOP	BDC, DHCD, DPW, Federal and State Partners, MCC, MON, NGOs, OEM	Existing City Budgets, FEMA grants	Long	Low	High	Ongoing Capability	Ongoing CRS outreach and education.
B-7-4	Pursue grants to elevate flood prone properties when and where feasible	Flood	1, 2	OEM	All city agencies	FEMA grants, State Grants, Philanthropic efforts	Long	Low	Medium	Ongoing Capability	CHAP has developed Fells Point Flood Mitigation Guidelines to support opportunities for elevating flood prone properties in accordance with historic district design requirements.
B-7-5	Pursue grants for dry flood proofing of Commercial and Historic structures in the most flood prone areas when and where feasible	Flood	2	OEM	All city agencies	FEMA grants, State Grants, Philanthropic efforts	Long	Low	Medium	Ongoing Capability	CHAP has developed Fells Point Flood Mitigation Guidelines to support opportunities for elevating flood prone properties in accordance with historic district design requirements. Coordination for opportunities for commercial floodproofing and will be ongoing.

Action #	Action Description	Hazard(s) Addressed	Goals Met	Lead Agency	Support Agencies	Sources of Funding	Timeline	Costs	Priority	Action Status	Project Action Status Comments
B-7-6	Assess the feasibility of backflow preventers for residential buildings and incorporate educational outreach where backflow preventers are determined to be a feasible option.	Flood		DPW	DOP, OEM	FEMA grants, Existing City Budget	Short	Medium	High	In Progress	N/A
B-8	**Improve resource conservation practices in all city-owned buildings. (Lead Agency: DGS)**										
B-8-1	Install energy-efficient and low-water-use equipment during renovations in all City-owned buildings	All Hazards	4	DGS	MOE, DHCD, DGS, DOP	MEA grants, energy performance contracting, existing City budgets	Long	Medium	High	In Progress	Since FY20, DGS has obtained more than $2.5 million for energy projects for City buildings. DGS also works to incorporate energy efficiency principles into capital projects where feasible.
B-8-2	Support energy efficiency efforts at Baltimore City Public Schools as part of its Sustainability Plan.	All Hazards	3, 4	DOP	BCPSS, DGS	BCPSS CIP, IRA grants, private grants	Long	High	High	In Progress	BCPSS' 2019 Sustainability Plan includes a key goal of reducing the impacts of schools on the environment and saving money by conserving energy and natural resources.
B-8-3	Offering multiple compliance paths for green building standards for new and substantially renovated construction of city-owned buildings	All Hazards	3, 4, 5	DHCD	BCPSS, DHCD, DGS, DOP	Existing City Budgets	Short	Low	Medium	Ongoing Capability	The Baltimore Green Building Standards were replaced with the 2018 International Green Construction Code.
B-9	**Conduct educational outreach to increase resource conservation practices in private buildings. (Lead Agency: DOP)**										
B-9-1	Conduct educational outreach and provide information about savings related to reduced water use	Drought, Extreme Temperature	5	DPW	BGE, DOP, DOP, Exelon, MON, NGOs, OEM, MIMA	Housing Recovery Funding, MEA Conservation Loan Program	Short	Low	High	Ongoing Capability	DPW provides information to residents about conserving water. Rate structure was switched to AMR/AMI in 2014 so a rate payer can review their consumption in almost real-time through a portal.
B-9-2	Educate and provide resources and information about utility rebate programs	Drought, Extreme Temperature	5	BGE	DOP, DPW, Exelon, MON, NGOs, OEM, MIMA	Existing City Budgets	Short	Low	High	Ongoing Capability	DPW provides information to residents about utility rebates.

Action #	Action Description	Hazard(s) Addressed	Goals Met	Lead Agency	Support Agencies	Sources of Funding	Timeline	Costs	Priority	Action Status	Project Action Status Comments
B-9-3	Provide energy efficiency education to include information on conserving electrical power, efficiency retrofits, and building management systems. Emphasize reductions during summer peak demand hours (S)	Drought, Extreme Temperature	5	DOP	BGE, DPW, Exelon, MON, NGOs, OEM, MIMA	State, Local and Foundation Funding	Short	Low	High	Ongoing Capability	Energy efficiency education is included in the monthly Sustainability Newsletter and discussed at the Commission on Sustainability meetings. The Buildings and Energy Workgroup of the Sustainability and Resiliency Subcabinet is a new advisory body to aid in promoting energy efficiency projects.
B-10	**Use Hazus computer modeling and other available tools to determine losses generated by coastal storms. (Lead Agency: DOP)**										
B-10-1	Utilize engineering studies and cost-benefit analyses to identify additional mitigation needs and actions	All Hazards	4	DPW	DOP, FEMA, MDEM, OEM, NOAA	FEMA Grant Programs	Short	Low	High	Ongoing Capability	DPW conducts hydrology and hydrologic studies to identify opportunities to mitigate flooding issues.
B-10-2	Evaluate various building design enhancements to reduce losses generated by earthquakes, floods, and storm surge	Earthquake, Soil Movement	3, 4	DOP	DHCD, FEMA, MDEM, NOAA	Existing City Budgets	Short	Low	Low	Ongoing Capability	These actions are taken each time a regulatory code is reviewed and updated.
IN-1	**Protect and enhance the resiliency and redundancy of electricity system. (Lead Agency:)**										
IN-1-1	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 Baltimore City	All Hazards	2, 3	PSC	MEA, BGE, Building Owners, DGS, DOT, DPW, Exelon, PSC, Utility customers, Vicinity, Wheelabrator	Baltimore City CIP, Federal Sources, BGE's existing funds, Smart Grid Investment Grant	Short	Low	High	Ongoing Capability	State and local utilities continue to partner around emergency services and power outage reduction.
IN-1-2	Evaluate Baltimore City's utility distribution system, and identify "underground utility districts" using BGE's May 2013 short-term reliability improvement plan	All Hazards	2, 3	DPW	BCRP (Forestry), BGE, Building Owners, DGS, DOT, DPW, Exelon, PSC, Utility customers, Vicinity, Wheelabrator	Baltimore City CIP, Federal Sources, BGE's existing funds, Smart Grid Investment Grant	Short	Low	High	No Progress	This action required coordination with DOT (right-of-way), MOID, and DGS. The Office of Sustainable Energy was moved from DPW to DGS in FY 2018
IN-1-3	Support BGE's collaboration with the Maryland Public Service Commission to implement various smart grid solutions that will provide Baltimore City with real-time access to data during events	All Hazards	2, 3	DPW	BCRP (Forestry), BGE, Building Owners, DGS, DOT, DPW, Exelon, PSC, Utility customers, Vicinity, Wheelabrator	Baltimore City CIP, Federal Sources, BGE's existing funds, Smart Grid Investment Grant	Short	Low	Medium	No Progress	This action required coordination with DOT (right-of-way), MOID, and DGS. The Office of Sustainable Energy was moved from DPW to DGS in FY 2018

Action #	Action Description	Hazard(s) Addressed	Goals Met	Lead Agency	Support Agencies	Sources of Funding	Timeline	Costs	Priority	Action Status	Project Action Status Comments
IN-1-4	Identify, harden, and water seal critical infrastructure relative to pump stations, treatment plants, electrical, heating, and ventilation facilities within the regulatory floodplain	Coastal Hazards, Flood, Severe Storms	2, 3	DPW	BGE, DGS, DPW, Exelon, PSC, MEO, Vicinity, Wheelabrator	Baltimore City CIP, Federal Sources, BGE's existing funds, Smart Grid Investment Grant	Short	High	Low	Ongoing Capability	This action is part of DPW's continual asset management efforts within its operation and capital program.
IN-1-5	Work with stakeholders to encourage facility owners to develop decentralized power generation and fuel flexibility capabilities	All Hazards	2, 3	OEM / BCRP (Forestry), BGE, Building Owners, DGS, DOT, DPW, Exelon, PSC, Utility customers, Veolia, Wheelabrator, CISA (Cyber Infrastructure Security Agency)	BCRP (Forestry), BGE, Building Owners, DGS, DOT, DPW, Exelon, PSC, Utility customers, Vicinity, Wheelabrator	Baltimore City CIP, Federal Sources, BGE's existing funds, Smart Grid Investment Grant	Short	Medium	Medium	In progress	Many critical facilities already have backup power or alternative fuel source systems in place. Electrification of fleet and buildings is also currently a city priority and will be moved forward significantly over the coming years. Baltimore OEM facilitated FEMA's Disaster Management for Utilities training for city agencies in 2023. CISA is also working on increasing redundancies throughout Baltimore City. Any gaps in this can be identified and addressed in conversations through the Sustainability and Resiliency Subcabinet.
IN-1-6	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	All Hazards	2, 3, 5	DGS	BCRP (Forestry), BGE, Building Owners, DGS, DOT, DPW, Exelon, PSC, Utility customers, Vicinity, Wheelabrator	Baltimore City CIP, Federal Sources, BGE's existing funds, Smart Grid Investment Grant	Short	Low	Low	Ongoing Capability	Baltimore City maintains a contract with a vendor to perform comprehensive maintenance on generators at facilities. In-house staff regularly performs fuel checks on in-ground tanks, additional training can be provided for new staff down in the coming years with more of an emphasis on hazard events.
IN-1-7	Install external generator hookups for critical City facilities that depend on mobile generators for backup power	All Hazards	2, 3, 4	DGS	BCRP (Forestry), BGE, Building Owners, DGS, DOT, DPW, Exelon, PSC, Utility customers, Vicinity, Wheelabrator	Baltimore City CIP, Federal Sources, BGE's existing funds, Smart Grid Investment Grant	Short	High	Medium	In progress	Exelon has been working on hardening their infrastructure in Baltimore City for the last 2 years and will continue to do so. Discussions around other ways to harden utility infrastructure have been ongoing between BGE, OEM, and DPW.

Action #	Action Description	Hazard(s) Addressed	Goals Met	Lead Agency	Support Agencies	Sources of Funding	Timeline	Costs	Priority	Action Status	Project Action Status Comments
IN-1-8	Partner with utilities to evaluate protecting power and utility lines from all hazards	All Hazards	2, 3	OEM / BCRP (Forestry), BGE, Building Owners, DGS, DOT, DPW, PSC, Veolia, Wheelabrator	BCRP (Forestry), BGE, Building Owners, DGS, DOT, DPW, Exelon, PSC, Vicinity, Wheelabrator	Baltimore City CIP, Federal Sources, BGE's existing funds, Smart Grid Investment Grant	Long	High	High	In Progress	Baltimore City is coordination with utility owners and operators; BCRP is developing guidelines to inform City agencies and private utility owners and operators how to better management the tree canopy during construction of utilities.
IN-1-9	Determine low-lying substation vulnerability and outline options for adaptation and mitigation	Coastal Hazards, Flood, Severe Storms	2, 3	DPW	BGE, BCRP (Forestry), BGE, Building Owners, DGS, DOT, DPW, Exelon, PSC, Vicinity, Wheelabrator	Baltimore City CIP, Federal Sources, BGE's existing funds, Smart Grid Investment Grant	Short	Low	Medium	In Progress	The referenced substations are BGE assets. DPW's roles have been limited to regulatory plan review and stormwater management, erosion and sediment control, and wet utility inspection for eight substation projects since 2018.
IN-2	**Increase energy conservation efforts (Lead Agency: BoS)**										
IN-2-2	Encourage critical facilities and institutions to connect to existing cogeneration systems, or develop new cogeneration systems	All Hazards	3, 4	MEO	BGE, Building owners, DOP, DPW, DGS Energy Division, PSC	Federal Emergency Grant Funds, Local Funds	Short	Low	Medium	In Progress	DGS considered cogeneration in a recent study of downtown buildings, but due to the Mayor's goal to reduce greenhouse gases, investing in natural gas-based cogeneration facilities is not an interest of DGS. DPW is evaluating alternatives and replacements of its aging digester-gas cogeneration technology at wastewater plants
IN-2-3	Continue Baltimore City's electricity demand-response program during peak usage or pre-blackout periods	All Hazards	1, 2	BGE	BGE, Building owners, City Delegates, DOP, DPW, DGS Energy Division, PSC	BGE, Federal Funds	Short	Low	Low	Ongoing Capability	BGE operates residential Demand Response Programs under Rider 15 – Demand Response Service and Rider 26 – Peak Time Rebate of BGE's Electric Service Rates and Tariffs. These programs are designed to reduce electric load in BGE's service territory and customers can opt into the program.

Action #	Action Description	Hazard(s) Addressed	Goals Met	Lead Agency	Support Agencies	Sources of Funding	Timeline	Costs	Priority	Action Status	Project Action Status Comments
IN-2-4	Evaluate and ensure backup power generation is available to healthcare facilities (nursing homes, critical care facilities, hospitals, etc.)	All Hazards	2, 3	MDH	DGS, BCHD, DOP, DOT, DPW,	Hospital Budgets, Federal Emergency Funds	Short	High	Medium	In Progress	DGS, in partnership with the Health Department, supported a renovation to Eastern Health Clinic that included a backup generator. Conversations are ongoing for how to continue integrating back up power into systems upgrades to city health facilities over the long term. Evaluation of gaps in backup power infrastructure at healthcare facilities can take place via a review of the healthcare facilities' Building Emergency Plans, as all facilities are required to have such plans.
IN-3	**Ensure backup power generation for critical facilities and identified key infrastructure during power outages (Lead Agency:)**										
IN-3-1	Investigate off-grid, on-site renewable energy systems, generators, and technologies for critical facilities to ensure redundancy of energy systems	All Hazards	2	DGS	BGE, DGS, MDH, DOP, DOT, DPW,	Baltimore City CIP, Federal Programs	Short	Low	Low	In Progress	DGS received $100,000 from the MEA Resilient Maryland Grant to complete a study of the downtown area and results are currently under review.
IN-3-1	Seek funding to purchase and install generators for all city buildings designated as critical to agency functions	All Hazards	2, 4	DGS	DGS, DOP, DOT, DPW, OEM	Federal Grants, State Grants	Short	High	Medium	In Progress	Most city critical facilities have backup generators, but funding will be sought for evaluating existing equipment for potential upgrade or replacement needs. When building upgrades are being considered, DGS typically includes a backup generator if needed.
IN-4	**Protect and manage compressed liquefied natural gas sites and (city) fueling stations before and during hazard events (Lead Agency:)**										
IN-4-1	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	All Hazards	2, 3	BGE	BGE, DGS, DOP, DOT, DPW, Vicinity	BGE	Short	Low	Medium	Ongoing Capability	The BGE Spring Gardens facility is a 72-acre site that is certified by the Wildlife Habitat Council, The National Wildlife Foundation, and Audubon. The site features a 9-acre, 100-ft. wide riparian forest buffer that borders the Middle Branch of the Patapsco River.
IN-4-2	Adopt building code that requires anchoring of 50-gallon storage tanks or larger	All Hazards	2, 3	DHCD	MDE, BGE, DGS, DOP, DOT, DPW, Vicinity	Existing City Budgets	Short	Low	Medium	In Progress	DHCD is currently in the process of reviewing and adopting the 2021 ICC. As part of this project Baltimore City will review the requirements related to anchoring 50 gallon and larger storage containers.

Action #	Action Description	Hazard(s) Addressed	Goals Met	Lead Agency	Support Agencies	Sources of Funding	Timeline	Costs	Priority	Action Status	Project Action Status Comments
IN-4-3	Support the Maryland Public Service Commission's effort to accelerate replacement of aging natural gas infrastructure, which will harden the system against flooding	All Hazards	2, 3, 4	BGE	BGE, DGS, DOP, DOT, DPW, Vicinity	BGE	Short	Low	Medium	Ongoing Capability	State and local utilities continue to partner around opportunities for emergency preparedness and replacement of natural gas infrastructure.
IN-5	**Evaluate and improve resiliency of liquid fuels infrastructure (Lead Agency:)**										
IN-5-1	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	All Hazards	2, 3	OEM	BCFD, BCPD, DES, DOT, DPW, MOE	Fuel Up Maryland, Federal Sources	Short	High	Medium	No Progress	OEM is currently working with utility companies on critical power restoration for essential fuel stations. Designing a generator program with support from other agencies needs to be completed through the Sustainability and Resiliency subcabinet.
IN-5-2	Increase and ensure fuel availability during distribution disruptions. Priority given to critical facilities and emergency responders	All Hazards	1, 2, 3	DGS	BCFD, BCPD, DES, DOT, DPW, MOE	Fuel Up Maryland, Federal Sources	Short	High	Medium	In Progress	Based on the current burn rate of fuel, Baltimore City has up to 2 weeks of fuel for city operations and a fleet of mobile trucks that carry both gasoline and diesel fuel. DGS would adapt fuel purchasing needs during emergencies and can provide deliveries to fuel tanks that support the needs of other agencies.
IN-6	**Evaluate and improve resiliency of communication systems that are in place for sudden extreme weather events (Lead Agency: OEM)**										
IN-6-1	Utilize new technologies such as fiber optics, external hook-ups, and mobile generators to improve resiliency	All Hazards	2, 3, 4	Mayor's Office of Broadband and Digital Equity	BGE, OEM, DOT, DGS Energy Division, FCC, BCIT, Private Entities, PSC	Federal Grant Programs, State Grant Programs, Baltimore City CIP	Short	High	Medium	Ongoing Capability	The city's Mayor's Office of Broadband and Digital Equity is a newly created office that is supporting the roll out of improved digital access and communications technologies including broadband, fiber, etc. OEM continues to support the roll out of external mobile battery hookups where permanent generators are not installed.

Action #	Action Description	Hazard(s) Addressed	Goals Met	Lead Agency	Support Agencies	Sources of Funding	Timeline	Costs	Priority	Action Status	Project Action Status Comments
IN-6-2	Evaluate, improve, and build redundancy into all public and inter-agency warning and communication systems	All Hazards	2, 3, 4	OEM	BCPD, BCFD, MOE, BGE, DOT, DGS Energy Division, FCC, BCIT, PSC	Federal Grant Programs, State Grant Programs, Baltimore City CIP	Short	High	Medium	No Progress	Baltimore City purchased a new warning system, Everbridge, in 2023 and continues to partner with the National Weather Service to refine their alert and warning system through wireless emergency alert improvements. OEM will roll out a public campaign to increase awareness of the new system across Baltimore City and will continue doing trainings for city agencies to become familiar with the system as well.
IN-6-3	Identify best practices for the installation and management of floodproofing for all communication infrastructure at risk of water damage	Coastal Hazards, Flood, Severe Storms	2, 3, 4	BCIT	BGE, DOT, DGS Energy Division, FCC, OEM, Private Entities, PSC	Federal Grant Programs, State Grant Programs, Baltimore City CIP	Short	Low	Medium	No Progress	OEM and DPW will partner with BCIT on ways to integrate floodproofing practices into communication infrastructure and will discuss opportunities to relocate at-risk infrastructure to non-flood prone areas.
IN-6-4	Implement additional nurse triage phone lines and community health centers to reduce medical surge on hospitals	All Hazards	3, 4	MDH	BGE, BCHD, Maryland Institute for Emergency Management Services System, United Way 211, MAPS, DOT, DGS Energy Division, FCC, BCIT, Private Entities, PSC, MIMA	Private Funding	Short	Medium	Low	Complete	Baltimore City utilizes 911, 211 (United Way), 311, and 988 (Baltimore Behavioral Health System), as well as Maryland Access Point (for seniors). The EMS, under BCFD, facilitated a campaign to bring awareness to crisis response services that can serve as alternatives to 911.
IN-6-6	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	All Hazards	3, 4	BCIT	BGE, DOT, DGS Energy Division, FCC, Private Entities, PSC	Baltimore City CIP	Short	Medium	Medium	Ongoing Capability	OEM continues to partner with BCIT on ways to build redundancy into network operations, particularly around the EOC.

Action #	Action Description	Hazard(s) Addressed	Goals Met	Lead Agency	Support Agencies	Sources of Funding	Timeline	Costs	Priority	Action Status	Project Action Status Comments
IN-7	**Integrate climate change into transportation design, building and maintenance (Lead Agency: DOT)**										
IN-7-1	Determine the coastal storm vulnerability and complete an exposure assessment of City transportation assets	Coastal Hazards	1, 2, 3	DOT	CSX, DOT, DPW, MTA, Private Contractors	Federal Grant Programs	Short	Medium	Medium	Ongoing Capability	Assessment was completed as a part of the 2023 DP3 update process. Through the NOAA program, Baltimore City will leverage $15 million in funding to enhance resiliency in four funding categories - waterfront development, material reuse and weather extremes, mainly extreme heat, and general coastal resilience.
IN-7-2	Improve stormwater management, operations and maintenance for stream flooding that erodes bridge supports	Flood, Severe Storms	2, 4	DOT	CSX, DOT, DPW, MDTA, MDOT, SHA, MTA, Private Contractors	Incorporate into existing Capital Projects	Long	Medium	Medium	No Progress	Baltimore City DOT's bridge engineering section will take the lead on this element and will discuss funding mechanisms.
IN-7-3	Incorporate compliance with earthquake standards to withstand a magnitude 8 earthquake for all new, improved, and rebuilt bridges	Earthquake, Soil Movement	2, 3, 4	DOT	CSX, DOT, MDTA, MDOT, SHA, DPW, MTA, Private Contractors	Federal Funds, City Capital Funds	Long	High	Medium	No Progress	Baltimore City DOT's bridge engineering section will take the lead on this element and will discuss funding mechanisms.
IN-7-4	Design bridge expansion joints for longer periods of high heat, and develop a more robust inspection and maintenance process	Extreme Temperature	2, 3, 4	DOT	CSX, DOT, MDTA, MDOT, SHA, DPW, MTA, Private Contractors	Incorporate into existing Capital Projects	Short	High	Medium	No Progress	Baltimore City DOT's bridge engineering section will take the lead on this element and will discuss funding mechanisms.
IN-7-5	Research utilizing existing and new rating systems for all new infrastructure and road projects	All Hazards	3, 4	DOT	CSX, DOT, DPW, MTA, Private Contractors	Existing City Budgets	Short	Low	Medium	No Progress	Issue will be addressed in the plan development and funding will be discussed.
IN-7-6	Identify, investigate, and incorporate Best Management Practices related to transportation design, construction, and maintenance	All Hazards	3, 4	DOT	CSX, DOT, DPW, MTA, Private Contractors	Existing City Budgets	Short	Low	Low	In progress	DOT has begun developing an SOP with DPW on ways to incorporate stormwater best management practices into traffic calming plans, streetscapes, and bicycle facilities. This partnership arose out of the Sustainable Transportation working group of the Sustainability and Resiliency Subcabinet.

Action #	Action Description	Hazard(s) Addressed	Goals Met	Lead Agency	Support Agencies	Sources of Funding	Timeline	Costs	Priority	Action Status	Project Action Status Comments
IN-7-7	Require that backup solar-powered streetlights and signals be integrated along evacuation routes and high-traffic areas	All Hazards	4	DOT	CSX, DOT, DPW, MTA, Private Contractors	Emergency Grant Programs	Short	Medium	Low	In progress	BCDOT and OEM developed an updated Mass Evacuation Plan, finalized in 2022. Though it did not require solar-powered streetlights and signals, this is something that can be integrated in future Evacuation Planning efforts. Other back-up power sources, such as solar + battery systems and back-up generators, were identified in the plan.
IN-7-8	Promote portable EV charging to ensure availability of charging in the instance of impacts to fixed EV charging facilities during emergencies.	All Hazards		DPW	DOP, MEA	Existing City Budget, Federal and State Funding	Medium	High	Medium	No Progress	N/A
IN-8	**Identify additional alternative routes and modes for effective transport and evacuation efforts during emergency situations (Lead Agency: OEM)**										
IN-8-2	Evaluate existing systems and coordinate a comprehensive evacuation plan with regional partners	All Hazards	1, 3	OEM	BCFD, BCHD, BMC, DOP, DOT, OEM, UASI	Federal Funds, State Funds, Local Funds	Short	Low	Medium	In progress	DOT worked with the Center for Health and Homeland Security to develop a Mass Evacuation Resource Document, which is being used to improve current evacuation plans in Baltimore City. Regionally, Baltimore City works with the BMC to align evacuation plans with surrounding jurisdictions and the UASI. Baltimore City is participating in a regional evacuation tabletop exercise in October 2023. An evacuation workshop including members of the regional Whole-Community Subcommittee will follow in 2024. Evacuation related trainings will continue to occur as needed. BMC received an FY2020 grant from the Regional Catastrophic Preparedness Grant Program to increase the whole-community component of evacuation planning.
IN-8-3	Develop and prioritize clearance of specified transportation routes for delivery of emergency response supplies	All Hazards	1, 3	OEM	BCFD, BCHD DOP, DOT, OEM	Federal Funds, State Funds, Local Funds	Short	Low	High	Ongoing Capability	OEM collaborates with DOT and DPW and BPD to prioritize transportation routes as needed working through Baltimore City's EOC.

Action #	Action Description	Hazard(s) Addressed	Goals Met	Lead Agency	Support Agencies	Sources of Funding	Timeline	Costs	Priority	Action Status	Project Action Status Comments
IN-8-4	Educate the public on the dangers of driving through flooded roads	Flood, Coastal Hazards, Severe Storms	5	OEM	BCFD, BCHD, DOP, DOT, OEM, MIMA	Federal Funds, State Funds, Local Funds	Short	Low	Medium	Ongoing Capability	OEM has a Preparedness Section that prioritizes educating the public through in-person and online campaigns and outreach events. Flood hazard materials, including the dangers of driving through floodwaters, are part of the messaging. OEM is working with DOT on increasing roadway signage installations in flood prone areas and Baltimore City's mass alert system will be utilized to remind residents about possible flood alerts in their communities. DOP's NFIP and Floodplain Program, as part of CRS credit maintenance, also promotes public messaging on social media each year about the dangers of driving through floodwaters, such as Turnaround, Don't Drown.
IN-8-5	Make available a network of dedicated pedestrian and bicycle transportation routes leading into and throughout Baltimore City	All Hazards	1	DOT	BCFD, BCHD, DOP, DOT,	Federal Funds, State Funds, Local Funds	Long	High	High	Ongoing Capability	In 2017, BCDOT finalized its Separated Bike Lane Network Plan, which proposes high quality separated bike lanes on key corridors throughout Baltimore City. BCDOT continues to implement this plan with new lanes of separated bike facilities each year. BCDOT also is developing a Safe Streets For All Plan, which will identify locations for Complete Streets improvements that target high crash areas of Baltimore City. Further, Baltimore City passed a Complete Streets Ordinance in 2018 which requires all roadway projects to comply with Complete Streets best practices and a modal hierarchy that prioritizes pedestrians and bicyclists above drivers.

Action #	Action Description	Hazard(s) Addressed	Goals Met	Lead Agency	Support Agencies	Sources of Funding	Timeline	Costs	Priority	Action Status	Project Action Status Comments
IN-9	**Alter transportation systems in flood-prone areas in order to effectively manage stormwater (Lead Agency: DOT)**										
IN-9-1	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	Flood, Coastal Hazards, Severe Storms	2, 3, 4	DOT	Amtrak, BCRP, CSX, Developers, DOT, DPW, FHWA, MDTA, MON, NGOs	Baltimore City's existing capital plan	Long	Low	Low	No Progress	Issue will be discussed at Sustainable Transportation Subcabinet meetings.
IN-9-2	Raise streets in identified flood prone areas as they are redeveloped	Flood, Coastal Hazards, Severe Storms	2, 4	DOT	Amtrak, BCRP, CSX, Developers, DOT, DPW, FHWA, MDTA, MON, NGOs	FEMA Funding programs, Baltimore City Capital Budget	Long	High	Low	No Progress	Issue will be discussed at Sustainable Transportation Subcabinet meetings.
IN-9-3	Encourage development of Green Streets in flood prone areas and throughout Baltimore City	Flood, Coastal Hazards, Severe Storms	2, 3, 4	DOT	DOT, DPW, MON, Public, NGO's, Property Owners	Existing City Budgets	Short	Low	Low	Ongoing Capability	Partially addressed through the growing partnership between DOT and DPW regarding impervious surface removal. Additionally, the Complete Streets Manual identifies the need for greening as part of a Complete Streets project in Baltimore City.
IN-9-6	Assess need for new culvert capacity and identify where upgrades are needed	Flood, Coastal Hazards, Severe Storms	2, 3, 4	DOT	DOT, Amtrak, BCRP, CSX, Developers, DOT, DPW, FHWA, MDTA, MON, NGOs	Emergency Grant Programs	Long	Medium	Medium	In Progress	A preliminary assessment was completed for culverts at Wyndhurst on Stony Run. DOT also assessed culverts at the project-level for individual bridge reconstruction/repair capital projects based on current design standards (1972 City / 1981 SHA). There has not been a comprehensive City-wide assessment. DPW's City-wide H&H model can support this, but a detailed assessment would still be required. SHA has drafted updated design guidance regarding design storms, climate change, and debris accumulation.

Action #	Action Description	Hazard(s) Addressed	Goals Met	Lead Agency	Support Agencies	Sources of Funding	Timeline	Costs	Priority	Action Status	Project Action Status Comments
IN-9-7	Conduct an in-depth analysis of the impacts of drainage areas that discharge to the harbor	Flood, Coastal Hazards, Severe Storms	2, 3, 4	DPW	Amtrak, BCRP, CSX, Developers, DOT, DPW, FHWA, MDTA, MON, NGOs	Emergency Grant Programs	Long	Medium	High	In Progress	In FY 2022, DPW initiated an integrated H&H model for the City's public storm sewer system, completing a model for three pilot sub-watersheds, including the Middle Branch portion of the Baltimore Harbor Watershed. The proposed model will allow the City to identify and understand the causes of current flooding (pluvial, riverine, and tidal), identify remedial measures, and evaluate potential future scenarios based on development trends and climate change.
IN-9-8	Expand and reinforce existing stormwater education programs	Flood, Coastal Hazards, Severe Storms	2, 3, 4, 5	DPW	MTA, Amtrak, BCRP, CSX, Developers, DOT, DPW, FHWA, MDTA, MON, NGOs	Existing City Budgets	Long	Low	High	Ongoing Capability	This is also a requirement of the City's MS4 permit (general public education); efforts are documented in the City's MS4 Annual Report under Public Outreach. In addition to print and web-based data, DPW initiated GROW Cener pop-up events in the community.
IN-9-9	Design and implement floodgates and barriers for transportation tunnels and subterranean roadways.	Flood, Coastal Hazards, Severe Storms	2, 3, 4	DOT	Amtrak, BCRP, CSX, Developers, DOT, DPW, FHWA, MON, NGOs, MTA, MDTA, SHA	Funding options dependent on ownership of tunnel	Long	High	Low	No Progress	For transportation tunnels and underpasses in DOT's ROW, DOT will address these concerns through the planning process on the PROTECT and NOAA grants, should those applications be successful. DOT's bridge engineering section will take the lead.
IN-9-10	Encourage Federal and State Government to design and install floodgates and barriers at vulnerable transportation tunnels	Flood, Coastal Hazards, Severe Storms	2, 3, 4	FHWA	Amtrak, BCRP, CSX, Developers, DOT, DPW, FHWA, MON, NGOs, MTA	Existing City Budgets	Long	Low	High	No Progress	Coordination is need with the owners of infrastructure and surrounding communities to ensure these efforts are prioritized for implementation.
IN-9-11	Upgrade existing floodgate hardware and mechanisms to control rise rate of water into all city tunnels	Flood, Coastal Hazards, Severe Storms	2, 3, 4	FHWA	Amtrak, BCRP, CSX, Developers, DOT, DPW, FHWA, MON, NGOs, MTA, MDTA, MDOT, SHA	Existing City Budgets	Long	High	Low	No Progress	DOT will coordinate with MDTA around this issue and incorporate it into the planning efforts for PROTECT and NOAA if appropriate.

Action #	Action Description	Hazard(s) Addressed	Goals Met	Lead Agency	Support Agencies	Sources of Funding	Timeline	Costs	Priority	Action Status	Project Action Status Comments
IN-10	**Ensure structural stability of all transportation tunnels to reduce impact from seismic activity (Lead Agency: CSX, Amtrak, MTA)**										
IN-10-1	Repair cracks and leaks in all tunnels to reduce impact of seismic activity	Earthquake, Soil Movement	2, 4	MTA	Amtrak, CSX, DOT, DPW, FHWA, MDTA,	Funding options dependent on ownership of tunnel	Short	High	Low	No Progress	DOT will coordinate with MDTA around this issue and incorporate it into the planning efforts for PROTECT and NOAA if appropriate.
IN-10-2	Follow Federal, State, and local criteria for the stabilization of historic transportation tunnels (e.g., Howard Street)	Earthquake, Soil Movement	2, 3, 4	MTA	Amtrak, CSX, DOT, DPW, FHWA, MTA	Funding options dependent on ownership of tunnel	Long	High	Low	No Progress	DOT will coordinate with MDTA around this issue and incorporate it into the planning efforts for PROTECT and NOAA if appropriate.
IN-10-3	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	Earthquake, Soil Movement	2, 3, 4	MTA	Amtrak, CSX, DOT, DPW, FHWA, MDTA,	Funding options dependent on ownership of tunnel	Long	High	High	No Progress	DOT will coordinate with MDTA around this issue and incorporate it into the planning efforts for PROTECT and NOAA if appropriate.
IN-11	**Encourage changes to road maintenance and construction materials based on anticipated changes in climate (Lead Agency: DOT)**										
IN-11-1	Implement a repaving strategy that reduces heat-related damage to asphalt and incorporates maintenance and operations that extend the life of the road surface	Extreme temperature	2, 4	DOT	DOT, SHA	Baltimore City's existing capital plan	Long	High	Medium	No Progress	The Complete Streets Ordinance extends to all resurfacing projects. All resurfacing projects are legally required to incorporate pedestrian and bicycle accommodations, which extends the life of the roadway due to reduced load. Additional coordination is needed.
IN-11-3	Develop deicing strategies and materials that are effective in extreme cold temperatures and prolonged events to stabilize roadway and bridge surfaces	Severe Storms	2, 3, 4	DOT	DOT, SHA	Baltimore City's existing capital plan	Long	High	Low	No Progress	DOT's Transportation Engineering and Construction section will take the lead.
IN-12	**Enhance the resiliency of Baltimore City's waterfront to better adapt to impacts from hazard events and climate change (Lead Agency: DOT)**										
IN-12-1	Raise bulkhead height along shoreline areas most at risk	Coastal Hazards	2, 3, 4	DOT	BDC, Development Community, DGS, DHCD, DOP, DOT, MDE, MDNR, Waterfront Partnership	Federal Funding Sources	Long	High	Low	In progress	In partnership with the Waterfront Partnership and others, Baltimore City is evaluating opportunities for raising the bulkhead along the inner harbor as part of the Inner Harbor redevelopment project. Baltimore City's Nuisance Flood Plan also addresses opportunities for the elevation of waterfront infrastructure

Action #	Action Description	Hazard(s) Addressed	Goals Met	Lead Agency	Support Agencies	Sources of Funding	Timeline	Costs	Priority	Action Status	Project Action Status Comments
IN-12-3	Encourage the development of integrated flood protection systems that use structural (engineering) and non-structural (wetlands) measures	Coastal Hazards	2, 3, 4	DPW	BDC, Development Community, DGS, DHCD, DOP, DOT, MDE, MDNR, OEM	FEMA Funds, Wetland and Wildlife funds, City Capital Budget	Long	Low	Medium	Ongoing Capability	DPW enforces the 2007 Maryland Stormwater Management Act which requires quantitative control for 1-year and 10-year, 24-hour storm for any development that increases impervious area. Control for 100-year, 24-hour storm is also required for development in inter-jurisdictional watersheds. The Maryland Stormwater Design Manual includes both structural and non-structural measures. DPW also assesses all development for impacts to surface runoff / drainage within the public roadway. MDE plans to update design requirements by 2025 under the Advancing Stormwater Resiliency in Maryland (A-Storm) initiative, which will incorporate climate change and equity in the design standards and acceptable practices. DPW's H & H model for the storm sewer, plus collaboration with the Baltimore Social-Environmental Collaboration (BSEC), the Baltimore Ecosystem Study (BES), the Chesapeake Bay Trust Pooled Monitoring program and other research initiatives, will allow the City to assess the applicability, effectiveness, and trade-offs of these practices.
IN-12-4	Review and enhance coastal area design guidelines to better mitigate the impacts of flooding	Coastal Hazards	2, 3, 4	DOP	DPW, Development Community, DGS, DHCD, DOT, MDE, MDNR, OEM	State Funds Critical Area Law Funds and Fees-in-Lieu from CAMP	Long	Low	Medium	In Progress	The 2020 Critical Area Management Program (CAMP) manual incorporates shoreline conservation area designations. Development within 1000 feet of waterways must comply with CAMP regulations.
IN-13	**Increase the resilience of all wastewater systems and protect them from current and projected extreme weather events (Lead Agency: DPW)**										
IN-13-10	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	Coastal Hazards	2, 3	DPW	DPW, Planning	Utility CIP	Long	Medium	Low	InProgress	Pending State decisions under A-Storm, but capital projects receiving state funding will be designed using CRAB boundary.

Action #	Action Description	Hazard(s) Addressed	Goals Met	Lead Agency	Support Agencies	Sources of Funding	Timeline	Costs	Priority	Action Status	Project Action Status Comments
IN-13-3	Develop and adopt increased level of protection for construction, redevelopment, and design of all water and wastewater facilities that incorporate future climate projections	All Hazards	2, 3	DPW	DPW, DGS Energy Division	Federal Funds, State Funds, Local Funds	Long	Low	Medium	No Progress	Pending State policies under A-Storm initiative and climate action (basis of emissions scenarios) regarding stormwater management. Many water and wastewater capital improvement projects receive state funding and would therefore be required to comply with Maryland Coast Smart regulations, which includes the Climate Ready Action Boundary (CRAB).
IN-13-5	Establish protocols and ensure effective operations and security for wastewater treatment plants when facilities are overwhelmed during large storm events	All Hazards	2, 3	DPW	DPW, DGS Energy Division	Federal Funds, State Funds, Local Funds	Long	Low	Low	Ongoing Capability	Standard Operating Procedures and emergency operations plans have been developed for intense storms and are updated annually for Back River WWTP. The Patapsco WWTP is in design and scheduled to be completed by FY 2025.
IN-13-8	Conduct a risk assessment of Baltimore City's current water and sewer systems to identify age, condition of infrastructure, capacity, weaknesses, and areas for priority upgrades	Flood, Severe Storms	2, 3	DPW	DPW	Existing City Budgets, FEMA grants	Long	Medium	Medium	Ongoing Capability	DPW's Office of Asset Management was created in 2014 and continues to perform this activity for all three water utilities, plus the water and wastewater facilities.
IN-13-9	Conduct and utilize a detailed risk assessment to determine vulnerability of the sewage treatment plant to prevent overflows from extreme storm events	Flood, Coastal Hazards, Severe Storms	2, 3	DPW	DPW	Federal Funds, State Funds, Local Funds	Long	Medium	Medium	In Progress	Preliminary mapping of the inundation was provided in the SHA Vulnerability tool. Funding will be proposed for a more comprehensive study for FY 25 CIP budget.
IN-14	**Integrate resiliency, redundancy, structural stability, and back-up energy into Baltimore City's drinking and water system to ensure safe and reliable water storage and distribution (Lead Agency: DPW)**										
IN-14-1	Repair leaks and improve connection from all City reservoirs and the Susquehanna River	Flood, Severe Storms	2, 3, 4	DPW	BCHD, BCRP, DHCD, DOP, DOT, DPW, MCC, MDE, Regional Watershed Groups, Reservoir Watershed Management Committee, SHA, Water Utility	City's existing capital plan, Federal Funding Sources	Long	High	High	Ongoing Capability	Risk model and assessments are on-going and managed by the Office of Asset Management. Any large tunnel repairs are completed by the Office of Engineering and Construction as part of the Capital Improvement Program.

Action #	Action Description	Hazard(s) Addressed	Goals Met	Lead Agency	Support Agencies	Sources of Funding	Timeline	Costs	Priority	Action Status	Project Action Status Comments
IN-14-2	Provide water conservation education, and continue to protect our watersheds to assist in maintaining water quality	Flood, Severe Storms	5	DPW	BCHD, BCRP, DHCD, DOP, DOT, DPW, MCC, MDE, Regional Watershed Groups, Reservoir Watershed Management Committee, SHA, Water Utility	Grant Programs, Educational Budget of Stormwater Utility	Short	Low	Medium	Ongoing Capability	DPW issues messaging through publications and social media each year. This topic is also a requirement of Baltimore City's, Baltimore County's, and Carroll County's MS4 permit since 2014.
IN-14-3	Ensure dam emergency plans account for impacts of climate change	All Hazards	3	DPW	BCHD, BCRP, DHCD, DOP, DOT, DPW, MCC, MDE, Regional Watershed Groups, Reservoir Watershed Management Committee, SHA, Water Utility	Existing City Budgets	Short	Low	Low	No Progress	Pending policy decisions from the State under the A-Storm Initiative and other climate action programs.
IN-14-4	Identify and document post-damage responsibilities in memorandums of understanding as addendums to the Reservoir Watershed Management Agreement	Flood, Severe Storms	3	DPW	DOP	Existing City Budgets	Short	Low	Low	No Progress	Reservoir Watershed Management Agreement may be impacted by the Baltimore Regional Water Task Force, scheduled to be completed by January 2024.
IN-14-5	Review dam capacity, load and failure points and review them against 1,000-year and 10,000-year precipitation events	Flood, Severe Storms	2	DPW	BCHD, BCRP, DHCD, DOP, DOT, DPW, MCC, MDE, Regional Watershed Groups, Reservoir Watershed Management Committee, SHA, Water Utility	Federal Emergency Grants	Short	Low	Low	In Progress	A consultant has been contracted to complete a watershed comprehensive study in FY 24 and 25.

Action #	Action Description	Hazard(s) Addressed	Goals Met	Lead Agency	Support Agencies	Sources of Funding	Timeline	Costs	Priority	Action Status	Project Action Status Comments
IN-14-6	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)	Earthquake, Soil Movement	2, 3	DPW	BCHD, BCRP, DHCD, DOP, DOT, DPW, MCC, MDE, Regional Watershed Groups, Reservoir Watershed Management Committee, SHA, Water Utility	Federal Emergency Grants	Short	Medium	Low	No Progress	Will incorporated any standards or guidelines if established by the State.
IN-14-8	Evaluate the impacts of sediment loading on reservoir capacity	Flood, Severe Storms	3, 4	DPW	BCRP, DHCD, DOP, DOT, DPW, MCC, MDE, Regional Watershed Groups, Reservoir Watershed Management Committee, SHA, Water Utility	Utility CIP	Short	Medium	Medium	In Progress	A consultant has been contracted to complete bathymetric survey of all three raw water reservoirs, as part of a watershed comprehensive study. USGS is assisting in this activity.
IN-14-9	Manage watershed forests to provide maximum benefits for water quality and to maintain resiliency during extreme weather events	Flood, Severe Storms	3, 4	DPW	DPW, BCHD, BCRP, DHCD, DOP, DOT, DPW, MCC, MDE, Regional Watershed Groups, Reservoir Watershed Management Committee, SHA, Water Utility	Existing City Budgets	Short	Medium	High	Ongoing Capability	BCRP is collecting watershed data in the City's larger parks. Forest Management Plans will be developed for each park and a big component of the plans will be watershed and ecosystem resiliency. DPW currently administers programs to manage forests around drinking water reservoirs.
IN-14-10	Adopt new policies on salt application to prevent high salinization of drinking water supplies	Flood, Severe Storms	3	DOT	DPW, MDE, SHA, Baltimore County Govt, Regional watershed groups, NGO's	Federal Funds, State Funds, Local Funds	Short	Low	Low	No progress	Issue needs additional coordination and input from responsible departments.

Action #	Action Description	Hazard(s) Addressed	Goals Met	Lead Agency	Support Agencies	Sources of Funding	Timeline	Costs	Priority	Action Status	Project Action Status Comments
IN-14-11	Establish a structured Firming Program to maintain adequate storage and water quality in the source-water reservoirs during drought conditions	Severe Storms	3	DPW	BCHD, BCRP, DHCD, DOP, DOT, DPW, MCC, MDE, Regional Watershed Groups, Reservoir Watershed Management Committee, SHA, Water Utility	Existing City Budgets	Long	Low	Low	Ongoing Capability	A Firming Program has been maintained for over 20 years. DPW has contacted a consultant to complete drought forecasting and develop withdrawal/ blending options from the Susquehanna River for various scenarios. This project should be complete by FY 25 and may provide recommendations to update the Firming Program.
IN-14-12	Maintain appropriate agreements with Susquehanna River Basin Commission and Exelon Power Company to ensure adequate water withdrawals from the Susquehanna River during drought emergency	Severe Storms	1, 3	DPW	BCRP, DHCD, MDH, DOP, DOT, MCC, MDE, Regional Watershed Groups, Reservoir Watershed Management Committee, SHA, Water Utility	Existing City Budgets	Long	Low	Medium	Ongoing Capability	This agreement is in place with the Susquehanna River Basin Commission. Modifications may be upcoming, pending the outcome of the Baltimore Regional Water Task Force.
IN-15	**Conduct an assessment that evaluates and improves all pipes' ability to withstand extreme heat and cold (Lead Agency: DPW)**										
IN-15-1	Replace old and malfunctioning pipes with new pipes and pipe-lining technologies	Flood, Severe Storms	2, 3, 4	DPW	DOT	City's existing capital plan	Long	High	High	Ongoing Capability	Since 2015, DPW continues to replace the drinking water distribution system at a rate of 15 miles of pipe / year within the City. Pipelining technologies are also considered as an alternative to full pipe replacement. Changes to the design standards to withstand extreme heat and cold are pending State guidance for climate change projections and DPW's on-going assessment of pipe material technologies.

Action #	Action Description	Hazard(s) Addressed	Goals Met	Lead Agency	Support Agencies	Sources of Funding	Timeline	Costs	Priority	Action Status	Project Action Status Comments
IN-16-1	Implement the requirements of Baltimore's MS4 (separate stormwater and sewer system) permit	Flood, Severe Storms	3, 4	DPW	Community Groups, DOT, DPW, MDNR, NGOs, Private Developers, Stormwater Utility	The Stormwater Utility existing capital plan	Long	High	Medium	Ongoing Capability	The MS4 permit is a 5-year permit, with continuous mandates to install new practices and maintain the practices implemented from pervious permits. Although the intent of the mandates is to improve water quality, the practices can include nature-based practices (tree planting, bioretention areas, wetlands), restore degraded streams, and maximize the capacity of City's storm sewer system (inlet cleaning and street sweeping).
IN-16	**Enhance and expand stormwater infrastructure and systems (Lead Agency: DPW)**										
IN-16-2	Prioritize storm drain upgrades and replacement in areas with reoccurring flooding	Flood	2, 3, 4	DPW	DOT, Community Groups	Stormwater Utility	Short	Low	Low	In progress	In FY 2022, DPW initiated an H&H model for Baltimore City's storm sewer system. As an equity, diversity, and inclusion initiative, the City has initiated research on flood report data sources (i.e., social media and neighborhood canvassing), as an alternative to 3-1-1 reports directly associated with flooding. Additionally, an inter-agency Flood and Infrastructure working group under the Sustainability and Resiliency Subcabinet was created. DPW has initiated capital improvement projects for the storm sewer system to mitigate flooding for the following areas: Cherry Hill, Patapsco Avenue, Frederick Avenue, 35th & Hillen, Stony Run, Pulaski Highway, and Fells Point.
IN-16-3	Install backflow-prevention devices or other appropriate technology along waterfront to reduce flood risk	Flood, Coastal Hazards, Severe Storms	2, 3, 4	DPW	Community Groups, DOT	Federal Funds, State Funds, Local Funds	Long	High	Medium	In Progress	USACE completed a study in 2022; potential implementation strategies and resources will be coordinated with the Flood and Infrastructure working group of the Sustainability and Resiliency Subcabinet.

Action #	Action Description	Hazard(s) Addressed	Goals Met	Lead Agency	Support Agencies	Sources of Funding	Timeline	Costs	Priority	Action Status	Project Action Status Comments
IN-16-4	Preserve and protect natural drainage corridors	Flood	2	DPW	Community Groups, DOT, DPW, MDNR, NGOs, Private Developers, Stormwater Utility	Existing City Budgets, Federal and State Grants, Non-governmental funding	Short	High	Medium	In Progress	DPW has multiple capital improvement projects in design or construction for restoration of stream channels along Maidens Choice, Dead Run, Western Run, Biddison Run, Chinquapin Run, and Herring Run. DPW staff members received geomorphology training for routine assessments of stream channel degradation. DPW also conducts routine stream sampling to identify and eliminate illicit discharges, in addition to performing annual biological and habitat assessments of the streams. BCRP continues to perform forest assessments and implement integrated vegetative management within forested park land. Baltimore City has supported ecological research focused on stream health, forest health, and soil health within riparian areas.
IN-16-5	Review and revise storm drain design on a continuous basis, to accommodate projected changes in intense rainfall	Flood	2, 4	DPW	Community Groups, DOT, DPW, MDNR, NGOs, Private Developers, Stormwater Utility, USACE	City's existing capital plan	Long	Low	High	In Progress	In 2022, DPW and DOT initiated a review of existing local design standards (issued in 1972) with respect to SHA's draft design guidance updates for drainage design. However, any modifications to the City's design manual will be pending SHA's final document and MDE's A-STORM initiative by MDE, validated by the City's H&H model for the storm sewer system. Both SHA and MDE are depending on the MARISA Projected Intensity-Duration-Frequency Curve Data Tool for the Chesapeake Bay Watershed and Virginia.

Action #	Action Description	Hazard(s) Addressed	Goals Met	Lead Agency	Support Agencies	Sources of Funding	Timeline	Costs	Priority	Action Status	Project Action Status Comments
IN-16-6	Pursue grants for Flood Control measures to alleviate flooding in the most flood prone areas when and where feasible	Flood	2, 4	OEM/DPW	All City Agencies	FEMA grants, State Grants, Philanthropic efforts	Long	Low	Medium	Ongoing Capability	Various flood prone areas of Baltimore City have been identified and Baltimore City will continue to apply for BRIC, FMA, HMGP, and other funds to mitigate flood risk both for urban, riverine, and tidal flooding. Continued coordination around grant applications will come through the Sustainability and Resiliency Subcabinet, particularly the Flooding and Infrastructure Working Group.
IN-17	**Modify urban landscaping requirements and increase permeable surfaces to reduce stormwater runoff; ensure consistency across City regulations and initiatives. (Lead Agency: DOP)**										
IN-17-2	Encourage urban landscaping requirements and permeable surfaces into community-managed open spaces	Flood	3, 4	DOP	BCRP, BDC, Citizens, DHCD, DOT, DPW, NGOs, Private Developers	Small grants programs at Parks and People, Other Foundation Grants	Short	Low	High	Ongoing Capability	DPW, BCRP, and DOT collaborate on impervious surface removal projects and conversion to green/open space. The Landscape Manual promotes green landscape practices. The Complete Streets Manual encourages impervious surface removal as a road diet strategy and for public realm improvements along roadways
IN-17-3	Utilize water conservation elements such as green roofs, rain gardens, cisterns, and bioswales on residential, commercial, industrial, and City-owned properties to capture stormwater	Flood	3, 4	DPW	BDC, BCRP, Citizens, DHCD, DOP, DOT, DPW, NGOs, Private Developers	Existing City Budgets, Small grants programs at Parks and People, Other Foundation Grants, FEMA Grants	Long	High	Low	Ongoing Capability	These water conservation elements are part of the Environmental Site Design (ESD, Chapter 5 of MDE's Stormwater Management Design Manual); DPW prioritizes ESD practices for all development projects in the City, per Article 7, Division II of the City Code. DPW also provides incentives for implementation via the GROW Center events, outreach and restoration grants administered by the Chesapeake Bay Trust.
IN-17-4	Encourage permeable paving on low-use pathways	Flood	3, 4	DOP	BCRP, BDC, Citizens, DHCD, DOT, DPW, NGOs, Private Developers	Small grants programs at Parks and People, Other Foundation Grants	Long	Low	Low	Ongoing Capability	DPW, BCRP, and DOT collaborate on impervious surface removal projects and conversion to green / open space and the city's Landscape Manual promotes green landscape practices. However, the city's urban soils are heavily compacted, making permeable pavement an ineffective option in flood mitigation.

Action #	Action Description	Hazard(s) Addressed	Goals Met	Lead Agency	Support Agencies	Sources of Funding	Timeline	Costs	Priority	Action Status	Project Action Status Comments
IN-17-5	Pursue grants for Floodplain Storage and Diversion projects to alleviate flooding in the most flood prone areas when and where feasible	Flood	2, 4	OEM/DPW	All City Agencies	FEMA grants, State Grants, Philanthropic efforts	Long	Low	Medium	Ongoing Capability	Various flood prone areas of Baltimore City have been identified and Baltimore City will continue to apply for BRIC, FMA, HMGP, and other funds to mitigate flood risk both for urban, riverine, and tidal flooding. Continued coordination around grant applications will come through the Sustainability and Resiliency Subcabinet, particularly the Flooding and Infrastructure Working Group.
IN-18	**Evaluate and support DPW's stream maintenance program; ensure consistency across City regulations and initiatives. (Lead Agency: DPW)**										
IN-18-1	Establish an inter-agency stream maintenance program, including culvert inspection and debris removal, between BCRP, DOT, and DPW. The maintenance program may also include policies for private property owner obligations and / or the establishment of easements along natural water courses.	Flood	3, 4	DPW	BCRP, DOT, MDE, MDNR, USACE	City's existing capital plan	Long	Low	Medium	No Progress	Other than provisions under § 32 of the City Charter, there is no standing maintenance requirement. Many stream channels are on private land with no easement for City access. Other DPW's efforts to remove debris from the Jones Falls drift catcher and the commitment to maintain restored stream reaches (MS4 capital projects), there are no standing maintenance programs.
IN-18-3	Identify opportunities where stream restoration efforts will offset maintenance costs	Flood	3, 4	DPW	DOT, MDE, MDNR, OEM, USACE	Existing City Budgets	Long	Low	Medium	No Progress	N/A
IN-18-4	Identify interdependencies and benefits of stream maintenance with other transportation programs	Flood	3, 4	DOT	DPW, MDE, MDNR	Existing City Budgets	Long	Low	High	Ongoing Capability	DOT and DPW are working together to retain more water in the public right of way, reducing polluted runoff into Baltimore City's stream system.

Action #	Action Description	Hazard(s) Addressed	Goals Met	Lead Agency	Support Agencies	Sources of Funding	Timeline	Costs	Priority	Action Status	Project Action Status Comments
IN-18-5	Conduct regular maintenance of streams and stormwater quality facilities: increase inspection and cleaning of culverts and storm drains	Flood	3, 4	DPW	DOT, MDE, USACE	Stormwater and DOT ongoing maintenance programs, Federal Grants, State Grants, Local Grants, Foundation Grants	Long	Medium	Medium	Ongoing Capability	Per Article 7, Division II of the City Code, DPW is required to complete routine maintenance inspections of all stormwater management facilities (including stream restoration projects) at least once every 3 years. The results of the inspections are reported as part of the MS4 Annual Report. DPW staff have received geomorphology training and are scheduled to initiate stream channel assessments in FY 24 for all stream channels on public land, plus all restored stream channels. DPW committed to maintaining stream reaches that were part of the stream restoration projects (capital projects). In 2017, DPW initiated a pro-active inlet cleaning program, with a focus on inlets in sump areas or flood-prone areas. In FY 24, DPW will initiate a storm sewer inspection and condition assessment program; this program will focus on large pipes that may also be prone to sediment accumulation due to flat slopes.

Action #	Action Description	Hazard(s) Addressed	Goals Met	Lead Agency	Support Agencies	Sources of Funding	Timeline	Costs	Priority	Action Status	Project Action Status Comments
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); ensure consistency across City regulations and initiatives. (Lead Agency: DPW)**										
IN-19-1	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)	Flood	3, 4	DPW	BCRP, County Governments, DOP, DPW, MCC, MDNR, NGOs (e.g., regional watershed organizations), Stormwater Utility	Existing jurisdiction budgets, FEMA grants, Federal and State grants	Long	Low	Medium	In Progress	Since 2019, Baltimore City and Baltimore County staff have participated in the Actionable Science Workgroup under the Baltimore Urban Waters Federal Partnership, hosting two workshops focused on flooding. The results of the 2020 workshop are available on EPA's website and recommended that flood mitigation and stormwater management be considered in the context of a whole watershed. The 2022 workshop was a case study focused on the Maidens Choice: a proposed solution was the creation of inter-jurisdictional watershed agreement, which recognized the lack of funding and dedicated staffing for agreement administration which had been the challenge for a previous similar agreement. Other potential solutions included expanding the City's H&H stormwater model to include county storm sewer systems, creating a data sharing platform for flood data, and integrating state agencies and private entities into implementation strategies.

Action #	Action Description	Hazard(s) Addressed	Goals Met	Lead Agency	Support Agencies	Sources of Funding	Timeline	Costs	Priority	Action Status	Project Action Status Comments
IN-20	**Reevaluate and support a comprehensive debris management plan for hazard events (Lead Agency: DPW)**										
IN-20-2	Expand and integrate existing programs to reduce or intercept debris before it gets into the streams and harbor	Flood, Coastal Hazards	3, 4	DPW	DPW, DOT, NGOs	Stormwater Utility Operating Programs and CIP	Long	Low	High	Ongoing Capability	DPW initiated proactive inlet cleaning in 2017 and plans to expand operations pending increased staffing and equipment. Baltimore City continues source reduction efforts via education and enforcement programs. The Healthy Harbor Initiative has installed multiple end-of-pipe debris capture devices (trash wheels) along the Baltimore Harbor, in addition to issuing litter reduction educations through social media.
IN-20-3	Investigate, develop, and promote solid waste management actions for disposing of waste debris removal before a hazard event	Flood, Coastal Hazards, Severe Storms	3, 4	DPW	DOP, P&P, NGOs	Existing trash management education budgets.	Short	Low	High	Ongoing Capability	Baltimore City issued the Less Waste Better Baltimore Plan in 2021. Baltimore Metropolitan Council has also created a task force for debris removal during disasters.
IN-21	**Encourage the integration of climate change and natural hazards into private and State planning documents, systems, operations, and maintenance. (Lead Agency: DOP)**										
IN-21-1	Incorporate consideration of hazards and climate adaptation efforts into all plans, systems, operations, and maintenance	All Hazards	3	DOP	DPW, DOT, DGS, SHA, MTA, MDEM, OEM	Existing City Budgets	Short	Low	Low	In Progress	The Sustainability and Resiliency Subcabinet was formed to provide additional coordination for the Capital Improvement Plan, Comprehensive Plan, Climate Action Plan, Emergency Operations Plan Annexes, and additional efforts.
IN-21-2	Ensure Red Line planning incorporates adaptation strategies (if resurrected)	All Hazards	3, 4	DOP	DOT, DOP, MTA, MDOT	Existing City Budgets	Short	Low	High	No Progress	The restart of the Red Line was announced in June 2023.
IN-21-3	Ensure hazard scenarios, utilized in vulnerability assessments, are at a minimum 25% greater in intensity and impact than historical record events to date	All Hazards	2, 3, 4	OEM	DOT, Health Care Community, Hospitals, MD2HE, MDEM, MTA, OEM, SHA	Existing City Budgets	Long	Low	Low	Ongoing Capability	During the development of the Flood Annex for the EOP, tabletop exercises were performed based on the 1% annual chance flood.
IN-21-4	Develop guidelines for hospital, health care facilities and other institutional entities (e.g., Universities)	All Hazards	3, 5	BCHD	DOT, Health Care Community, Hospitals, MD2HE, MDEM, MTA, SHA	Hazard Mitigation Grant Programs	Long	Low	Low	No Progress	Coordination between the City and these institutions is needed as these institutions have independent planning mechanisms to address these environmental issues.

Action #	Action Description	Hazard(s) Addressed	Goals Met	Lead Agency	Support Agencies	Sources of Funding	Timeline	Costs	Priority	Action Status	Project Action Status Comments
IN-21-5	Partner with regional air quality institutions to integrate air quality measures and messaging into City climate change policy efforts	Extreme temperature	1, 3	DOP	Health Care Community, Hospitals, MDEM, MTA, OEM, SHA	Existing City Budgets	Long	Low	Low	Ongoing Capability	Baltimore City partners with Johns Hopkins University (JHU) Department of Earth and Planetary Sciences regarding local air quality monitoring and research. JHU recently received Department of Energy funding as part of a collaborative effort (Baltimore Social Environmental Collaborative) to support local air quality research and monitoring.
IN-22	**Develop City policy which requires new city government capital improvement projects to incorporate hazard mitigation principles. (Lead Agency: DOP)**										
IN-22-1	Discourage new public projects in hazard-prone areas such as floodplains or the coastal high hazard areas	Flood, Coastal Hazards	2, 3, 4	DOP	BCHD, BCRP, DGS, DOT, DPW, OEM	City's existing capital plan	Short	Low	High	Ongoing Capability	This is achieved through proper enforcement and administration of the CAMP.
IN-22-2	Utilize hazard resistant design requirements that exceed minimum standards for critical facilities	All Hazards	2, 3, 4	DOP	BCHD, BCRP, DGS, DOT, DPW, DGS Energy Division	City's existing capital plan	Short	Low	Low	No Progress	A policy change is required to enforce this action a requirement; however, Baltimore City continuously encourages the use of hazard resistant design
IN-22-3	Use comprehensive infrastructure assessments to identify infrastructure in need of replacement and prioritize funding for those projects	All Hazards	4	DGS	BCHD, BCRP, DOP, DOP, DOT, DPW, DGS Energy Division	Existing City Budgets	Short	Low	Low	Complete	Baltimore City's DGS has a facilities condition assessment program (using VFA) to better understand current and future facility conditions and needs at the systems-level.
IN-22-3	Retrofit emergency shelter windows to withstand winds associated with coastal storm events	Wind	2, 4	DGS	Commercial Building Owners, DHCD, DGS, DOP, MDE, OEM, Private Developers	FEMA Funding	Long	High	Low	No Progress	Necessary buildings that need emergency shelter windows need to be identified and funding needs to be obtained.
NS-1	**Utilize green corridors and parks to help protect surrounding communities from the impacts of hazard events. (Lead Agency: BCRP)**										
NS-1-1	Evaluate green corridors and parks for possible improvements for floodplain management	Flood	4	BCRP	DOP, NGOs, Community Orgs., Baltimore Greenspace	Existing City Budget	Short	Low	Low	Ongoing Capability	BCRP is in conversations with DPW about flood risk and stream resiliency in city parks that experience flooding. BCRP partners with DPW on MS4 permit implementation and incorporating stormwater management into parks planning.

Action #	Action Description	Hazard(s) Addressed	Goals Met	Lead Agency	Support Agencies	Sources of Funding	Timeline	Costs	Priority	Action Status	Project Action Status Comments
NS-1-2	Increase the resiliency of park facilities and buildings	All Hazards	4	BCRP	DGS	Existing City Budget	Short	Medium	Low	Ongoing Capability	BCRP's new recreational facilities comply with the IGCC building code. Two new recreational centers are being constructed and will have rooftop solar. Renovation of systems for existing facilities is also taking place, including more efficient HVAC and installation of LED lighting. EV chargers are being installed at various park facilities across the city.
NS-2	**Increase and enhance the resilience and health of Baltimore's urban forest, street trees, and biodiversity. (Lead Agency: BCRP)**										
NS-2-1	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	All Hazards	4, 5	BCRP	NGOs, Community Orgs., Baltimore Greenspace	Local and Foundation Funding	Short	Low	High	In Progress	A Healthy Trees, Healthy cities app was developed by TNC and the USDA Forest Service to improve monitoring of tree health. In the summer of 2023, a full plan for scaling the program in Baltimore is anticipated. BCRP is revising the approved street tree list and is also expanding it to capture other vegetation. In the new iteration, BCRP will be looking at more adaptable species that have improved tolerances to changing climate conditions
NS-2-2	Establish and routinely update a comprehensive tree inventory to anticipate insect and forest structural impacts of climate change	All Hazards	4, 5	BCRP	NGOs, Community Orgs., Baltimore Greenspace	Existing City Budget, State, Local and Foundation Funding	Short	Low	High	Ongoing Capability	Baltimore City completed data collection for the Forestry Division's first ever citywide street tree and park tree inventory in 2018, a process that spanned two years, during the leaf-on season. At the time of completion, the inventory included over 122,000 trees, and approximately 40,000 vacant planting sites. BCRP is maintaining this inventory and rewriting their scope and data specifications for updates to the inventory on a rotating schedule for continuous data collection. BCRP is also looking to forecast current and future tree removals to minimize impacts and streamline the city's urban wood reuse program.

Action #	Action Description	Hazard(s) Addressed	Goals Met	Lead Agency	Support Agencies	Sources of Funding	Timeline	Costs	Priority	Action Status	Project Action Status Comments
NS-2-3	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	All Hazards	3	BCRP	NGOs, Community Orgs., Baltimore Greenspace	P&P Operating Budget Federal, State, Local and Foundation Funding	Short	Medium	High	In Progress	Over 730 acres of forest land have been surveyed as part of the creation of Forest Management Plans for three large City parks: Druid Hill, Herring Run, and Cylburn. Natural Resource Inventories will be prepared for 150 acres of smaller parks. BCRP will include a modified tree risk assessment in the updated tree inventory and will use it to guide and inform a proactive pruning and tree removal program. Proactively identifying structurally compromised trees will be a priority of the risk assessment, including areas with the highest concentration of trees of the highest risk. In 2024, BCRP is starting a young tree maintenance program to support the structural pruning of young trees to improve future growth and resilience.
NS-2-4	Continually adjust and modify planting details and specifications to assure the health and longevity of trees	All Hazards	4, 5	BCRP	NGOs, Community Orgs., Baltimore Greenspace	Federal, State, Local and Foundation Funding	Short	Low	Low	Ongoing Capability	A BCRP priority is to clarify specifications and guidelines for how other agencies (like DOT and DPW) work around / with trees. They are also working on creating a tree planting handbook for communicating planting specifications to the public. BCRP's TreeKeepers program (a community tree planting certification program) was revamped in 2023 to support improved community-driven planting specifications and tree planting goals for Baltimore City.

Action #	Action Description	Hazard(s) Addressed	Goals Met	Lead Agency	Support Agencies	Sources of Funding	Timeline	Costs	Priority	Action Status	Project Action Status Comments
NS-2-5	Increase the urban tree canopy and target areas with urban heat island impacts	Extreme Heat, Drought	4, 5	BCRP	NGOs, Community Orgs., Baltimore Greenspace	Baltimore City Capital Budget, Mitigation Funds, Forest Conservation Program	Long	Medium	Medium	Ongoing Capability	BCRP's tree planting strategy prioritizes planting in areas of the city with the lowest tree canopy, which are also areas that are impacted by UHI, in addition to utilizing social and demographic indicators as proxy to UHI. B is working with the Baltimore Social Environmental Collaborative on better understanding hyperlocal climate conditions, including ground-level temperature differentials across the city to potentially inform their tree planting strategy.
NS-3	**Create an interconnected network of green spaces to support biodiversity and watershed-based water quality management. (Lead Agency: DOP)**										
NS-3-1	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	Extreme temperature	3, 4, 5	DOP	DHCD, DPW, Rec & Parks, BDC, State Agencies, Federal Agencies, NGO's, Community Groups	Federal Grants, State Grants, Foundation Grants	Long	Medium	High	Ongoing Capability	The Baltimore Green Network Plan is continuing to be implemented and areas are targeted that currently lack greenspace, which tend to experience the UHI the most.
NS-3-2	Convert vacant land and row houses into meaningful and connected open space	Flood	2, 4, 5	DHCD	BCRP, BDC, Community Groups, DHCD, DOP, DPW, Federal Agencies, MDNR, NGOs, State Agencies	Baltimore City Bond Funds	Long	High	Low	In Progress	DHCD is working to reduce the number of vacant buildings by either restoring them to viable homes or creating safe open spaces. Additionally, vacant lands are being utilized as urban farms, community gardens, etc.
NS-3-3	Complete a habitat analysis for Baltimore City	All Hazards	5	DOP	BCRP, BDC, Community Groups, DHCD, DOP, DPW, Federal Agencies, MDNR, NGOs, State Agencies	Federal Grants, State Grants, Foundation Grants	Long	Medium	Medium	In Progress	The Baltimore Ecosystem Study supports ongoing ecological research in Baltimore.

Action #	Action Description	Hazard(s) Addressed	Goals Met	Lead Agency	Support Agencies	Sources of Funding	Timeline	Costs	Priority	Action Status	Project Action Status Comments
NS-3-4	Create a strategic plan that identifies areas of focus for tree planting, stormwater management, and forest preservation	Flood	3	DOP	BCRP, DPW, BDC, Community Groups, DHCD, DOP, DPW, Federal Agencies, MDNR, NGOs, State Agencies	Federal Grants, State Grants, Foundation Grants	Short	Medium	Medium	In Progress	There are multiple efforts occurring, including: the Tree Baltimore planting, DPW impervious surface removal, Baltimore Greenspace forest patch preservation and stewardship, and Bluewater Baltimore targeted tree plantings.
NS-3-5	Certify Baltimore as a Community Wildlife Habitat through the National Wildlife Foundation	All Hazards	3, 5	DOP	BCRP, BDC, Community Groups, DHCD, DOP, DPW, Federal Agencies, MDNR, NGOs, State Agencies, City Schools	Federal Grants, State Grants, Foundation Grants	Short	Low	High	In Progress	Masonville Cove is an urban wildlife refuge designated by the National Wildlife Foundation. All new gardens in Baltimore will count towards this goal of creating the largest National Wildlife Federation Community Wildlife Habitat® along the Chesapeake Bay.
N-4	**Expand, protect, and restore riparian areas in Baltimore City. (Lead Agency: DOP)**										
NS-4-2	Evaluate current regulations regarding stream buffers and floodplains to integrate natural buffer requirements such as wetlands and soft shorelines, to assure they adequately protect perennial stream corridors	Flood	3	DOP	BCRP, DOP, DPW	Federal Grants, State Grants, Local Grants, Foundation Grants	Short	Low	Medium	No Progress	Revised to capture intent of NS-5-1.
NS-4-3	Evaluate potential for completion of Maidens Choice stream restoration project (Army Corps of Engineers, Baltimore District identified project)	Flood	3, 4	USACE	DOT, DPW	USACE Continuing Authorities Program	Long	High	Medium	In Progress	Stream geomorphic restoration project completed at Beechfield Elementary and Mt. St. Joe's; environmental benefits included stream/floodplain reconnection, daylighting approximately 200' of piped stream, and sanitary sewer rehabilitation. Components of the USACE feasibility report still require implementation including a wetlands restoration project at Loudon Cemetery, stormwater and wetlands restoration at Seton Keough School, and additional projects in Dead Run.

Action #	Action Description	Hazard(s) Addressed	Goals Met	Lead Agency	Support Agencies	Sources of Funding	Timeline	Costs	Priority	Action Status	Project Action Status Comments
NS-5	**Preserve and create new coastal buffer efforts and support creating more wetlands and soft shoreline along coastal areas. (Lead Agency: DOP)**										
NS-5-2	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	Flood	4, 5	DPW	BCRP, BDC, DOP, DPW, NGOs, State Agencies, Waterfront Partnership	Federal Grants, State Grants, Local Grants, Foundation Grants	Long	High	Medium	In Progress	DPW has multiple capital improvement projects in design or construction for restoration of stream channels along Maidens Choice, Dead Run, Western Run, Biddison Run, Chinquapin Run, and Herring Run. DPW also conducts routine stream sampling to identify and eliminate illicit discharges, in addition performing annual biological and habitat assessments of the streams. BCRP continues to perform forest assessments and implement integrated vegetative management within forested park land. The City has supported ecological research focused on stream health, forest health, and soil health within riparian areas as well as the Reimagine Middle Branch Initiative which includes a series of shoreline restoration projects along the Middle Branch.
NS-5-3	Identify and evaluate areas in the Critical Area buffer to prioritize ecological buffer restoration efforts	Coastal Hazards	4, 5	DOP	BCRP, BDC, DPW, NGOs, State Agencies, Waterfront Partnership	Critical Area Buffer Offset Fees, Private Funds	Short	Medium	Medium	Ongoing Capability	The 2020 Critical Area Management Program (CAMP) manual incorporated an assessment of Baltimore City's shoreline and integrated additional restrictions for bulkheads in shoreline conservation areas.
NS-6	**Require Baltimore City's drought management plan to account for changes in climate and impacts on Baltimore City's environmental resources. (Lead Agency: DPW)**										
NS-6-2	Update drought management plans to recognize changing conditions	Severe Storms	3	DPW	BCHD, Water Utility	Existing City Budgets	Short	Low	High	Ongoing Capability	The State routinely monitors precipitation, stream flow, groundwater levels and reservoir storage in combination with seasonal weather patterns to assess drought risks regionally. Additionally, the Drought Management Plan will be updated pending completion of watershed comprehensive studies and recommendations from the Baltimore Regional Water Task Force.

Action #	Action Description	Hazard(s) Addressed	Goals Met	Lead Agency	Support Agencies	Sources of Funding	Timeline	Costs	Priority	Action Status	Project Action Status Comments
NS-7	**Integrate climate change and natural hazards planning into small watershed action plans. (Lead Agency: DPW)**										
NS-7-1	Review existing watershed management plans and identify future actions to address climate impacts	Flood, Coastal Hazards, Severe Storms	3	DPW	DOP and NGOs	Existing City Budgets	Long	Low	Medium	In Progress	DPW is currently preparing watershed management plans.
NS-8	**Conduct detailed ongoing analysis of climate information, trends in storm events, and hydrology to support policy changes responding to climate change. (Lead Agency: DPW)**										
NS-8-1	Expand the use of climate information (e.g., seasonal forecasts) in water resources planning and management	Flood, Coastal Hazards, Severe Storm	3	DOP	BDC, FEMA, MDE, MDNR, MDEM, NGOs, State Agencies, Waterfront Partnership, Bluewater Baltimore	State, Local, Foundation Funding	Short	Low	Medium	In Progress	The Waterfront Partnership is currently conducting a study to assess Inner Harbor conditions that include sea-level rise and climate data to inform future projects.
NS-8-2	Research and actively monitor trends in storm events, stream flow and other conditions affecting hydrology and water	Flood, Coastal Hazards, Severe Storms	3, 4, 5	DOP	BDC, DPW, OEM, FEMA, MDE, MDNR, MDEM, USGS, NOAA, NGOs, State Agencies, Waterfront Partnership	Federal Grants, State Grants, Foundation Grants	Long	Medium	Medium	Ongoing Capability	OEM deployed flood warning sensors in areas prone to flash flooding. USGS stream and tide gauges are actively being monitored.
NS-8-3	Update flood maps to reflect changing risk associated with climate change	Flood	3	DOP	BDC, FEMA, MDE, MDNR, MDEM, NGOs, State Agencies, Waterfront Partnership	Federal Grants, State Grants, Local Grants	Short	High	Medium	No Progress	FEMA Flood Insurance Rate Maps (FIRMs) are updated by FEMA. Baltimore City would need to independently conduct modeling and adopt maps in addition to the FIRMs.
NS-8-4	Continuously improve and enhance flood vulnerability data	Flood	3	DPW	DPW, BDC, FEMA, MDE, MDNR, MDEM, NGOs, State Agencies, Waterfront Partnership	Federal Grants, State Grants, Foundation Grants	Long	High	High	Ongoing Capability	Baltimore City published a Nuisance Flood Plan in 2020 and is planning to update the plan by 2025.

Action #	Action Description	Hazard(s) Addressed	Goals Met	Lead Agency	Support Agencies	Sources of Funding	Timeline	Costs	Priority	Action Status	Project Action Status Comments
NS-8-5	Pursue grants and technical assistance to conduct hydrology and hydraulic studies on flood prone areas within Baltimore City, to include Maiden's Choice Branch, when and where feasible	Flood	3	OEM	DOT, DPW	FEMA grants, State Grants	Long	Low	Medium	In progress	Baltimore City received an FMA grant for the Baltimore City Advanced Assistance Project along Frederick Avenue corridor of SW Baltimore to analyze the Maiden's Choice watershed and associated flood risk. Led by DPW, an H&H study (Frederick Ave Culvert Watershed Action Plan) was completed in 2022. The Army Corps of Engineers, with support from the Maryland Silver Jackets, supported a new stormwater and floodplain map for the area. This all happened in coordination with the Frederick Ave Flood Mitigation Workgroup, which has been meeting quarterly since 2018 and is led by DPW.
NS-8-6	Identify opportunities for installation of flood sensors accompanied by tide gates, cameras, and signage.	Flood, Coastal Hazards		DPW	OEM, DOP	Existing City Budgets, FEMA Grants	Medium	High	Medium	No Progress	N/A
PS-1	**Strengthen emergency preparedness coordination between local government, NGOs, and private entities by incorporating emergency preparedness coordination in Baltimore City's Emergency Operations Plan (EOP) and its functional hazard-specific annexes. (Lead Agency: OEM)**										
PS-1-1	Identify and develop a common database and communication technology that all city government agencies and departments should utilize for hazard information, preparedness, and response	All Hazards	3, 5	OEM	MOE, DOT, BCHD, County Governments, DOP, MDH, BCIT, PSC, MIMA	Federal Grants, State Grants, Foundation Grants	Short	Medium	High	In progress	Baltimore City purchased a new warning system, Everbridge, in 2023 and continues to partner with the National Weather Service to refine their alert and warning system through wireless emergency alert improvements. OEM, in partnership with the Mayor's Office of Digital Services, is developing a dashboard for all agencies in Baltimore City's EOC to have real time, accurate data for emergency communication and coordination.
PS-1-2	Ensure consistency and integration with existing and future response plans within and between agencies	All Hazards	3	DOP	BCHD, OEM, DOT, Baltimore Metropolitan Council, County Governments, DOP, MDEM, MDH, Humane Society, BCIT, PSC, MIMA	Existing City Budgets	Long	Low	Medium	Ongoing Capability	Various local and regional response plans are being updated and integrated such as strategies for mass evacuation, mass care and sheltering, etc.

Action #	Action Description	Hazard(s) Addressed	Goals Met	Lead Agency	Support Agencies	Sources of Funding	Timeline	Costs	Priority	Action Status	Project Action Status Comments
PS-1-4	Coordinate outreach efforts of OEM, Mayor's Office of Neighborhood and Constituent Services, and BCHD to leverage messages related to all-hazards emergency preparedness, response, and recovery	All Hazards	3, 5	OEM	BCFD, BCHD, BCPD, Community Groups, County Governments, DOP, MDH, Humane Society, OEM, BCIT, MON, PSC, MIMA	State Grants, Local Grants, Foundation Grants	Long	Low	High	Ongoing Capability	OEM, BCHD, Johns Hopkins, and HABC coordinate regularly on preparedness outreach to build community resilience. Baltimore City coordinated a Joint Information Center during the COVID-19 Pandemic from 2020-2022 to coordinate messaging and outreach efforts across agencies.
PS-1-5	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	All Hazards	5	OEM	BCHD, County Governments, DOP, MDH, FEMA, MDE, MDNR, MDEM, BCIT, PSC, MIMA	State Grants, Local Grants, Foundation Grants	Long	Low	High	Ongoing Capability	Lessons learned from response and recovery efforts for the COVID-9 pandemic are continuously being integrated into City operations. Baltimore City's Sustainability and Resiliency Subcabinet, established in 2021, is also an important mechanism that will be leveraged for increasing coordination around whole-government emergency preparation. Timely planning and coordination sessions between OEM and the Mayor's Cabinet often follow SWEM (Statewide Emergency Managers) calls to improve coordination with all applicable agency leaders.
PS-1-6	Review and improve specific response plans contained in the EOP and related ESFs, now called Functional Annexes and Hazard-Specific Annexes, that relate to extreme weather events (such as snow, extreme heat, extreme cold, flooding, and hurricanes wind), electrical outages, and other hazard events	All Hazards	3	OEM	BCHD, County Governments, DOP, MDH, Humane Society, BCIT, PSC	State Grants, Local Grants, Foundation Grants	Long	Low	Low	In Progress	The EOP is currently being updated. ESFs have been replaced by Functional Annexes that include things like communications, food resiliency, healthcare, and public safety as well as Hazard Annexes, such as hurricanes, flooding, and heat. The EOP will be reviewed annually and will incur another major update in 2028.
PS-1-7	Ensure equipment purchases and communication systems are compatible across agencies and jurisdictions	All Hazards	3, 4, 5	OEM	BCHD, County Governments, DOP, MDH, Humane Society, OEM, BCIT, PSC	Federal Grants, State Grants, Local Grants	Long	Low	High	Ongoing Capability	Baltimore City has numerous committees focused on coordinating equipment purchases and aligning compatibility across agencies and will continue to do so.

Action #	Action Description	Hazard(s) Addressed	Goals Met	Lead Agency	Support Agencies	Sources of Funding	Timeline	Costs	Priority	Action Status	Project Action Status Comments
PS-1-9	Ensure all animal rescue and care shelters located within the regulatory floodplain are provided the support to apply for and obtain funds to relocate	Flood, Coastal Hazards	2, 3	BCHD	BCHD, County Governments, DOP, MDH, MDH, Humane Society, BCIT, PSC	State Grants, Local Grants, Foundation Grants	Short	Low	Medium	No Progress	The Baltimore Animal Rescue and Care Shelter (BARCS) is the only animal rescue facility in the city near the coast / floodplain and it is not a priority for them to relocate as they recently built a new facility.
PS-1-10	Facilitate the sharing of hospital-based best practices and resources with Baltimore City hospitals that foster community resilience to climate change	All Hazards	2, 5	BCHD	BCHD, DOP, MDH, Humane Society, BCIT, PSC	Private funding	Long	Low	Low	No Progress	A number of these institutions have their own plans for mitigating climate change, so additional coordination and communication could support this.
PS-2	**Develop a Hazard Awareness Program to increase disaster literacy and provide notification and warning of hazards. (Lead Agency: OEM)**										
PS-2-1	Create a standardized early warning system for members of the public and educate them on actions they should take when an alarm sounds	All Hazards	1, 5	OEM	BCHD, MDH, DOP, MDH2E, MDEM, OEM, MIMA	Local Funding	Short	Medium	High	In Progress	The BMORE Alert program is currently being updated. City also purchased a new warning system, Everbridge, in 2023 and continues to partner with the National Weather Service to refine their alert and warning system through wireless emergency alert improvements. OEM will do a public campaign to increase awareness across Baltimore City and will continue doing trainings for agencies to become familiar with the new system and will continue to educate around what to do in all cases of emergency.
PS-2-2	Evaluate and improve community health center strategies for communicating with patients during an emergency	All Hazards	1, 3, 5	OEM	MDH2E, MDEM, OEM, MIMA	Private funding	Long	Low	High	No Progress	This action will be discussed during LEPC meetings.
PS-2-5	Hold climate-specific seminars, in partnership with MHA, for hospital emergency and sustainability managers	All Hazards	1, 5	DOP	MDEM, OEM	Federal Grants, State Grants, Foundation Grants	Long	Low	High	No Progress	Need to identify opportunities for communications around climate change.

Action #	Action Description	Hazard(s) Addressed	Goals Met	Lead Agency	Support Agencies	Sources of Funding	Timeline	Costs	Priority	Action Status	Project Action Status Comments
PS-3	**Designate community leaders and organizations that can assist and provide support during hazard events. (Lead Agency: OEM, DOP, and DPW)**										
PS-3-1	Prior to a hazard event, identify lead contacts serving vulnerable populations and coordinate actions to maximize safety and information sharing	All Hazards	1, 5	OEM	BCFD, BCHD, BCPD, Community Groups, DOP, HABC, Hospitals, OEM, MON, MIMA	Community Development Block Grant Program (CDBG)	Long	Low	High	Ongoing Capability	OEM maintains a list of lead contacts throughout Baltimore City and often involves the Mayor's Cabinet and the Health Department which, for example, maintains Baltimore City's list of senior centers. OEM also coordinates with DOP on messaging and information sharing to the Community Resiliency Hubs, which are community facing centers that serve vulnerable populations. In a notice hazard event, the EOC will be activated in advance and the incident commander will request to activate a Joint Information Center to proactively share messaging to maximize safety and information sharing
PS-3-2	Develop a community group coordination plan and implementation guide equipped to respond to or direct residents before, during, or after hazard events	All Hazards	3	OEM	BCFD, BCHD, BCPD, Community Groups, DOP, HABC, Hospitals, OEM, MON, MIMA	Federal Grants	Short	Low	Low	Ongoing Capability	OEM maintains coordination with and participates in meetings with several community groups, such as the LEPC and the Community Resiliency Hubs for different planning efforts, such as Baltimore City's Code Red Extreme Heat Plan, which gets updated each year.
PS-3-3	Identify and evaluate plans already in place and work to improve utilization of community-based leaders to assist in preparedness and response	All Hazards	3	OEM	BCFD, BCHD, BCPD, Community Groups, DOP, HABC, Hospitals, OEM, MON, MIMA	State Grants, Local Grants, Foundation Grants	Long	Low	High	No Progress	OEM re-initiated Baltimore City's CERT program in 2023 to improve community based leadership around emergency preparedness and response. OEM also coordinates with the Community Resiliency Hub Program, which includes community-based leaders dedicated to emergency preparedness, response, and resiliency. Baltimore City's Code Blue Extreme Cold Plan and Code Red Extreme Heat Plan have been identified as key opportunities for incorporation of strategic community-based response efforts.

Action #	Action Description	Hazard(s) Addressed	Goals Met	Lead Agency	Support Agencies	Sources of Funding	Timeline	Costs	Priority	Action Status	Project Action Status Comments
PS-3-4	Continue developing and updating innovative training and guidance documents for Community Resiliency Hub partners that support the development of Resiliency Hub emergency operations plans, including elements such checklists and instructions for opening, running, and closing	All Hazards	3, 5	DOP	OEM, BCHD, MIMA, Community and Faith Based Groups	FEMA grants, State Grants	Short	Low	Medium	Ongoing Capability	Plans are being developed to provide emergency planning training to Resiliency Hubs. In 2019, a scenario-based tabletop exercise was developed and implemented with partners. In 2023 a Heatlhcare Ready training was organized for Resiliency Hubs and a Community Resiliency Hub Operations Toolkit was developed for each Community Resiliency Hub partner. The Toolkit included a hub-specific, customizable, emergency operations plan framework (prepare, activate, respond, recover), supplies inventory checklist, emergency contacts list, asset mapping activity, and an emergency management 101 glossary.
PS-3-5	Increase funding and resources for continuing to implement the Baltimore City Community Resiliency Hub Program and seek opportunities to grow the number of Community Resiliency Hubs in the partnership	All Hazards	4	DOP	OEM, BCHD, MIMA, Community and Faith Based Groups	FEMA grants, State Grants	Short	Medium	Medium	Ongoing Capability	The Community Resiliency Hub program has grown to 20 Community Resiliency Hub partners, tripling the number of hubs since 2018. Over the past several years, grant funding has been obtained for an additional four Community Resiliency Hubs to receive solar and batter systems to be installed by 2024. A FEMA HMGP application was in 2022 for an additional 17 Community Resiliency Hubs to receive solar and batter systems.
PS-3-6	Initiate community resiliency planning, outreach, and support	All Hazards	3, 5	DOP	OEM, BCHD, Community and Faith Based Groups	FEMA grants, State Grants	Long	Low	Medium	Ongoing Capability	Resiliency planning has been ongoing with Resiliency Hub partners as well as other City agencies to improve resiliency in vulnerable communities.
PS-4	**Integrate climate change and natural hazards planning into all City and community plans. (Lead Agency: OEM and DPW)**										
PS-4-1	Develop guidelines to include proactive resilience planning into plan development processes	All Hazards	3	DOP	BCHD, OEM, State and Federal Agencies	Community Development Block Grant Program (CDBG)	Short	Low	Low	In Progress	The CIP process now integrates concepts of the DP3 and the Sustainability Plan. This is demonstrated through the CIP budget prioritization process.

Action #	Action Description	Hazard(s) Addressed	Goals Met	Lead Agency	Support Agencies	Sources of Funding	Timeline	Costs	Priority	Action Status	Project Action Status Comments
PS-4-3	Partner with MDH and Mental Hygiene or other pertinent entity to develop institutional checklist and materials for health care - specific resilience plans	All Hazards	3, 5	BCHD	BCHD, DOP, OEM, MIMA, State and Federal Agencies	Private funding	Long	Low	Medium	No Progress	This action requires coordination with leadership at State departments. Baltimore City maintains the Baltimore City Local Health Improvement Coalition that can serve as a mechanism for discussion and coordination.
PS-6	**Anticipate and address potential disease outbreaks caused by extreme weather events and changing climatic conditions. (Lead Agency: BCHD)**										
PS-6-1	Support studies of heat- and flood-related vector-borne diseases in the Baltimore region based on changing temperature and moisture	Flood, Extreme temperature	3	MDH	BCHD, CDC, MDH, MDNR, MDEM, OEM, State Agencies	Federal Grants, State Grants, Foundation Grants	Short	Medium	Medium	No Progress	This action requires coordination with leadership at State departments. Baltimore City maintains the Baltimore City Local Health Improvement Coalition that can serve as a mechanism for discussion and coordination.
PS-6-2	Evaluate existing programs that detect disease outbreaks to determine their flexibility to respond to new conditions	All Hazards	3	MDH	BCHD, CDC, State Agencies	Existing City Budgets	Long	Low	Low	No Progress	This action requires coordination with leadership at State departments. Baltimore City maintains the Baltimore City Local Health Improvement Coalition that can serve as a mechanism for discussion and coordination.
PS-7	**Protect Baltimore residents from potential hazards by utilizing protective measures and providing safety communications. (Lead Agency: OEM and BCHD)**										
PS-7-1	Re-evaluate and update existing heat and cold alerts and advisories,	Extreme temperature	3	BCHD	BCFD, BCHD, BCPD, BCRP, MDH, Licenses and Permitting, MDE, OEM, MIMA, Healthcare providers	State Grants, Local Grants, Foundation Grants	Short	Low	Low	Ongoing Capability	BCHD and the Code Red Extreme Heat/Extreme Cold workgroup review plans and data after each heat/cold season to identify any changes that should be made prior to the next season.
PS-7-2	Ensure that residents and visitors have access and transportation to cooling centers during extreme heat events	Extreme temperature	1, 5	BCHD	BCHD, BCRP, Community Groups, MDH, Licenses and Permitting, MDE, OEM, Transportation partners	State Grants, Local Grants, Foundation Grants	Long	Medium	Low	Ongoing Capability	The Charm City Circulator is a free bus that has lines that run near some city cooling centers. The MTA MobilityLink Shuttle is a free service for seniors that can drop off residents in need at cooling center sites. Other shuttle services are offered depending on availability and opportunities to coordinate during Code Red planning.

Action #	Action Description	Hazard(s) Addressed	Goals Met	Lead Agency	Support Agencies	Sources of Funding	Timeline	Costs	Priority	Action Status	Project Action Status Comments
PS-7-3	Communicate with city agencies at the start of the Heat Season on how to protect city staff working outside	Extreme temperature	3, 5	BCHD	BCFD, BCHD, BCPD, BCRP, MDH, Licenses and Permitting, MDE, OEM, Risk Management, Agencies with outdoor workers	Federal Grants, State Grants, Foundation Grants	Long	Low	Low	Ongoing Capability	BCHD coordinates a multi-agency Code Red Extreme Heat planning effort before each Code Red season begins. Continued and improved messaging around worker safety can be integrated into this process.
PS-7-5	Include information about Code Red in the event permitting process	Extreme temperature	3, 5	BCHD	BCHD, BCRP, Licenses and Permitting, MDE	State Grants, Local Grants, Foundation Grants	Short	Low	Low	No Progress	This action will be discussed during future meetings of the Sustainability and Resiliency Subcabinet (working groups Buildings and Energy and Extreme Heat).
PS-7-6	Work with regional, State, and local partners to improve air quality and reduce respiratory illnesses	Extreme temperature	3, 5	MDE	BCHD, BCRP, Licenses and Permitting, MDE	Federal Grants, State Grants, Foundation Grants	Long	Low	Medium	Ongoing Capability	Baltimore City continues to partner with the State on accelerating climate action and implementing ways to reduce emissions and local pollutants in the city.
PS-7-7	Create and implement programs to manage combined health impacts of heat and air pollution	Extreme temperature	3	BCHD	BCHD, BCRP, MDH, Licenses and Permitting, MDE	Federal Grants, State Grants, Foundation Grants	Long	Medium	Low	No Progress	Baltimore City has begun to consider developing an Extreme Heat Mitigation plan, which would likely incorporate both heat and air quality.
PS-8	**Conduct climate, resiliency, and emergency planning education and outreach. (Lead Agency: OEM and DOP)**										
PS-8-1	Incorporate environmental health and climate change into curriculum at schools, universities, and health care facilities	All Hazards	3, 5	DOP	BCHD, MDNR, DOP, DPW, MDH, BCIT, MON, MIMA, Hospitals	Community Development Block Grant Program (CDBG, Federal Funding Sources	Long	Low	Medium	No Progress	Baltimore City has started to increase climate literacy opportunities within its workforce but could work to expand this in the coming years if successful.
PS-8-6	Create curriculum for hospitals to teach communities about climate change as part of hospital community benefits programs	All Hazards	3, 5		BCHD, MDNR, DOP, DPW, MDH, MH2E, BCIT, MON, MIMA, Hospitals	Federal Grants, State Grants, Foundation Grants	Long	Low	Medium	No Progress	Many area hospitals have sustainability managers that might be well positioned to roll out a program like this.
PS-8-7	Utilize existing preparedness messaging to include information on universal precautions to insect-borne and other infectious diseases	All Hazards	1, 5	BCHD	BCHD, MDNR, DOP, DPW, MDH, MH2E, OEM, BCIT, MON, MIMA, Hospitals	State Grants, Foundation Grants	Short	Low	Low	Ongoing Capability	BCHD partners with OEM, DPW, and other agencies on messaging around infectious diseases.
PS-8-8	Conduct a study to develop a long-term plan for strategic retreat to reduce future loses to hazards	Flood, Coastal Hazards		DOP	DHCD, OEM	Existing City Budgets, FEMA Grants	Long	Medium	Medium	No Progress	Studying strategic retreat has not been seen as a necessary means of mitigating flood risk at this time.

Action #	Action Description	Hazard(s) Addressed	Goals Met	Lead Agency	Support Agencies	Sources of Funding	Timeline	Costs	Priority	Action Status	Project Action Status Comments
PS-9	**Conduct outreach to enhance community resilience in regard to flood preparedness and insurance. (Lead Agency: DOP)**										
PS-9-1	Create an educational program centered on flood hazards, coastal construction practices and evacuation procedures	Flood, Coastal Hazards	1, 5	OEM	Community Groups, DHCD, MDH, FEMA, MDEM, OEM, MON, NFIP, NGOs, OEM, MIMA	Housing Recovery Funding, NFIP	Short	Low	High	No Progress	The Frederick Ave Flood Mitigation Workgroup is a great example of how educational programs can be centered around flood hazards and can be looked to as a best practice for coastal construction practices and evacuation procedures. Social media messaging can also be leveraged for education and awareness
PS-9-2	Encourage owners of properties to purchase flood insurance, and improve policyholder awareness at time of sale or renewal	Flood, Coastal Hazards	1, 5	DOP	Community Groups, DHCD, MDH, DOP, FEMA, MDEM, OEM, MON, NFIP, NGOs, OEM, MIMA	Housing Recovery Funding, NFIP	Short	Low	High	Ongoing Capability	Ongoing CRS outreach and education.
PS-9-4	Identify programs and grants that assist residents in purchasing flood insurance and making floodproofing changes	Flood, Coastal Hazards	1, 2, 3	DOP	Community Groups, DHCD, BCHD, Civic Works, MDH, FEMA, MDEM, OEM, MON, NFIP, NGOs, OEM, MIMA	Housing Recovery Funding, NFIP	Long	Low	Medium	Ongoing Capability	DHCD weatherization program includes floodproofing. The Housing Upgrades to Benefit Seniors Program prioritizes seniors.
PS-9-5	Distribute notifications annually to inform and remind owners of property in the regulatory floodplain about flood insurance and floodproofing activities they should undertake	Flood, Coastal Hazards	1, 2, 3	DOP	Community Groups, DHCD, MDH, FEMA, MDEM, OEM, MON, NFIP, NGOs, OEM, MIMA	State Grants, Foundation Grants	Short	Low	Low	In Progress	Ongoing CRS outreach and education. BoS distributes a monthly newsletter for broader outreach and awareness. BoS dos a targeted mailer annually to those insured under the NFIP.
PS-9-7	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	Flood, Coastal Hazards	1, 2, 3	DHCD	Community Groups, DHCD, DOP, FEMA, MDEM, OEM, MON, NFIP, NGOs, MIMA	Federal Grants, State Grants, Foundation Grants	Short	Low	High	No Progress	This action will be discussed during future meetings of the Sustainability and Resiliency Subcabinet (working groups Buildings and Energy and Extreme Heat). Leadership from State departments will be needed.

Action #	Action Description	Hazard(s) Addressed	Goals Met	Lead Agency	Support Agencies	Sources of Funding	Timeline	Costs	Priority	Action Status	Project Action Status Comments
PS-10	**Increase Baltimore resident's food security. (Lead Agency: DOP)**										
PS-10-1	Incorporate Baltimore's food policy initiative into planning efforts	All Hazards	3	FPP	Community Groups, DHCD, MDH, FEMA, MDEM, OEM, MON, NFIP, NGOs, OEM	CDBG, State Grants, Foundation Grants, Healthy Food Priority Area Funds	Long	Low	High	In Progress	FPP actively participates in efforts across Baltimore City, including developing a Food Distribution Annex for Baltimore City's Emergency Operations Plan developed by OEM. FPP works across City agencies to support urban farms and community gardens to secure land tenure and provide funding for water access and infrastructure needs.
PS-10-2	Increase food distribution infrastructure and local food aggregation to link regional and local food producers to local distributors	All Hazards	4	FPP	MDA, Urban Farms and Community Gardens (P&P and CGRN)	Current ARPA funding through 2026	Long	Medium	Medium	In Progress	To-date two ARPA funded projects have been completed in partnership with the Farm Alliance of Baltimore. The projects total approximately $6 million and support the Farm Alliance of Baltimore's farm incubator and produce box distribution.
PS-10-4	Develop a food security plan for Baltimore	Severe Storms	3	DOP	DOP, DOP, MDA, MIMA, Urban Farms and Community Gardens (P&P and CGRN)	Federal Grants, State Grants, Foundation Grants	Long	Medium	High	Ongoing Capability	FPP is currently implementing a five-pillar plan to address food insecurity, totaling $11.2 million funded through ARPA.
PS-10-5	Increase land under cultivation for urban agriculture	Severe Storms	3	DOP	MDA, Urban Farms and Community Gardens (P&P and CGRN)	Federal Grants, State Grants, Foundation Grants	Long	High	High	Ongoing Capability	FPP works across City agencies to support urban farms and community gardens to secure land tenure and provide funding for water access and infrastructure needs. To-date two ARPA funded projects have been completed in partnership with the Farm Alliance of Baltimore. The projects total approximately $6 million and support the Farm Alliance of Baltimore's farm incubator and produce box distribution.
PS-10-6	Increase the amount of land permanently secured for food production, from community gardens, market gardens, to urban agriculture	All Hazards	3	FPP	MDA, Farm Alliance, BCRP, Baltimore Green Space, Urban Farms and Community Gardens	FEMA grants, State Grants	Long	High	Medium	Ongoing Capability	FPP works across City agencies to support urban farms and community gardens to secure land tenure and provide funding for water access and infrastructure needs.

Action #	Action Description	Hazard(s) Addressed	Goals Met	Lead Agency	Support Agencies	Sources of Funding	Timeline	Costs	Priority	Action Status	Project Action Status Comments
PS-10-7	Implement the Plan for Food Access During Incidents and Disasters	All Hazards	3	DOP	OEM, MIMA, Emergency Food Working Group partners	FEMA grants, State Grants	Short	Low	Medium	Ongoing Capability	DOP has updated the Food Distribution Annex for the EOD; however, FPP will revise the annex to reflect lessons learned from stakeholders and the COVID-19 response.
PS-10-8	Increase food system resilience over the long-term	All Hazards	1, 3	DOP	CLF, OEM	FEMA grants, State Grants	Long	Low	Medium	In Progress	FPP has funded various initiatives to promote long-term resiliency such as: urban agriculture programs and farms, online SNAP nutrition incentives, Produce Rx, and allocated Health Food Priority Area funding.

14.5 Mitigation Strategy Evaluation and Prioritization

FEMA Planning Policy Element C5: 44 CFR 201.6(c)(3)(iii – iv): The plan must contain an action plan that describes how the actions identified will be prioritized, including cost benefit review, implemented, and administered.

The 2023 DP3 update process carried forward the same evaluation and prioritization methodology as the 2013 and 2018 DP3 for actions that remained from the 2018 DP3.

The following summarizes the prioritization methodology for new action implementation.

- Will the action result in life safety?
- Will the action result in property protection?
- Will the action be cost-effective? (future benefits exceed cost)
- Is the action technically feasible?
- Is there political support?
- Does Baltimore City have the legal authority to implement it?
- Is funding available for the action?
- Will the action have a positive impact on the natural environment?
- Is there community support?
- Does Baltimore City have the administrative capability to execute the action?
- Will the action reduce risk to more than one hazard?
- Can the action be completed in less than 5 years?
- Is there an agency/department local champion for the action?
- Will the action meet other objectives (such as capital improvements, economic development, environmental quality, or open space preservation?) Does it support the policies of other plans and programs?

Section 15. Plan Implementation and Maintenance

Key Changes from 2018 DP3:

- A schedule has been developed to identify targeted timeframes to complete monitoring and evaluation tasks each year.

15.1 Adoption

FEMA Planning Policy Element F1: 44 CFR 201.6(c)(5): For single-jurisdictional plans, the governing body of the jurisdiction must formally adopt the plan to be eligible for certain FEMA assistance. Documentation of plan adoption, such as a resolution, must be provided.

The DP3 serves as Baltimore City's hazard mitigation plan, as required under 44 CFR 201. This plan has been formally adopted by the Baltimore Commission on Sustainability and the Baltimore City Planning Commission, as required by 44 CFR 201.6(c)(5). Development of the DP3 was a collaborative partnership with stakeholders from local, regional, state, and federal government agencies as well as nonprofit and private sector organizations and the community. It represents the shared goals, objectives, and actions identified through the planning process for Baltimore City to pursue to reduce risk and build community resilience.

Adoption of the DP3 signifies the shared commitment of Baltimore City's agencies, partners, and communities to implement the mitigation strategy and utilize the DP3 and its contents to guide hazard mitigation and resilience efforts over the next five years. The adopted DP3 communicates Baltimore City's priorities and facilitates communication and collaboration among communities and stakeholders.

On November 30, 2023, the Baltimore City Planning Commission adopted the DP3 after receiving "Approvable Pending Adoption" status from FEMA on XXXX. The adoption resolution were submitted to FEMA, and FEMA provided full approval of the DP3 on XXXX, making the DP3 effective as of XXXX. Copies of the adoption resolutions and FEMA approval letter are included on the following pages, documenting the successful completion and adoption of the 2023 DP3.

INSERT ADOPTION RESOLUTIONS AND FEMA APPROVAL LETTER

15.2 Plan Maintenance

FEMA Planning Policy Element D1: 44 CFR 201.6(c)(4)(iii): The plan must include a discussion of how each community will continue public participation in the plan maintenance process, including a description of how the participant(s) will continue to seek public participation after the plan has been approved and during the plan's implementation, monitoring, and evaluation.

The Baltimore Office of Sustainability (BoS) is committed to keeping the DP3 accurate, current, and relevant over the five-year performance period. BoS is responsible for monitoring, evaluating, and updating the DP3 and monitoring the progress of mitigation actions. This is accomplished through a collaborative effort that maintains the partnerships built during the 2023 planning process. Although BoS is responsible for maintenance and monitoring, partner agencies and stakeholders are often responsible for implementing the mitigation strategy to achieve the DP3's goals and objectives.

15.3 Monitoring, Evaluating, and Updating the Plan

FEMA Planning Policy Element D2: 44 CFR 201.6(c)(4)(i): The plan must include a description of the method and schedule for keeping the plan current (monitoring, evaluating, and updating the mitigation plan within a five-year cycle). This includes identifying how, when, and by whom the plan will be tracked for implementation, assessed for effectiveness, and reviewed and revised at least once every five years.

The DP3 is a dynamic document that requires frequent reviews to ensure the goals and priorities align with community needs in instances of disasters or other events. If risk changes due to these impacts, continuous review and evaluation permits Baltimore City to revise the DP3, as appropriate, to address new or emerging risks and ensure the DP3 remains current. The following sections support and document Baltimore City's ongoing efforts to monitor, evaluate, and update the DP3 during its five-year life cycle.

The DP3 Coordinator, identified as the Climate and Resilience Planner within BoS, is responsible for maintaining and updating the plan during its performance period. The DP3 Coordinator will be the prime point of contact for questions regarding the plan and its implementation as well as to coordinate incorporation of additional information into the plan.

The Hazard Mitigation Advisory Committee (HMAC) shall support the efforts of the DP3 Coordinator with monitoring, evaluating, and updating the DP3. Each HMAC stakeholder is expected to maintain a representative on the HMAC throughout the plan performance period.

Regarding the composition of the committee, it is recognized that individual commitments change over time, and it shall be the responsibility of each stakeholder and its representatives to inform the DP3 Coordinator of any changes in representation. The DP3 Coordinator will strive to keep the committee makeup as a uniform representation of planning partners and stakeholders within Baltimore City.

Currently, the Baltimore City DP3 Coordinator is designated as:

Aubrey Germ, Climate and Resilience Planner

Baltimore City Office of Sustainability

Aubrey.Germ@baltimorecity.gov

The Sustainability and Resiliency Subcabinet, established in 2021 by Mayor Scott, is an internal mechanism for moving sustainability and climate plans, priorities, and initiatives forward. The Subcabinet is a group of city agency leads and decision-makers that convenes around climate and sustainability priorities to increase transparency, collaboration, and accountability surrounding the implementation of city sustainability-related plans and projects. The Subcabinet convenes quarterly and is chaired by the Chief Administrative Officer. There are six working groups that are organized by the following focus areas: Buildings and Energy, Transportation, Flooding and infrastructure, Extreme Heat, Waste, and People and Nature. The working groups meet monthly to move priorities forward. The Sustainability and Resiliency Subcabinet and its working groups have the potential to support the maintenance of the DP3 by elevating the maintenance, implementation, and update needs of the plan to city agency leads and the Mayor's Office, particularly around identifying mitigation projects, coordinating grant funding opportunities, identifying non-federal cost share, and aligning with or enhancing upcoming projects in the Capital Improvements Program pipeline.

Continuous community outreach and engagement is a priority of the BoS and its partners. Upon approval and adoption of the 2023 DP3, a public meeting will be held to kick off the implementation of the plan. This will provide an opportunity for community members to continue to be involved in the planning process as it transitions to implementation. The 2023 update and previous versions of the DP3 are maintained on the BoS website. Subsequently, BoS will publish status reports annually during the five-year performance period to provide updates to stakeholders and the public.

The Annual Sustainability Open House is an additional forum to actively engage with stakeholders and the public. The Open House aims to inform attendees of ongoing City initiatives focused on sustainability, including the DP3. This will provide a dedicated opportunity for the public to remain informed and current about the risk posed by hazards and to ensure public feedback is continuously integrated into the DP3. Continuous public engagement aids in ensuring the plan remains accurate, current, and relevant to community concerns and priorities.

Throughout the planning process, BoS identified numerous opportunities to obtain feedback from community members, including leveraging existing meetings, deploying surveys, forming focus groups, and engaging the public through social media. BoS will continue to utilize these methods to collect additional feedback or to share information on plan implementation.

BoS maintains active social media accounts that will continue to serve as a platform to share information with the public on the progress of the DP3. In collaboration with the Office of Emergency Management (OEM), information will also be shared on the Nextdoor platform.

BoS staff regularly participate in meetings led by community-based organizations to provide updates on BoS initiatives, including the DP3.

15.3.1 Monitoring

The DP3 Coordinator, with support from the HMAC, will be responsible for monitoring progress, evaluating effectiveness, and documenting annual progress of the plan. Monitoring activities may include meetings to discuss the progress on implementing the mitigation strategy and achieving the plan's goals; conducting site visits for active projects to observe the current status of actions; periodic reporting either required by the funding agency, such as FEMA, or as a function of BoS's efforts to monitor the plan; and regularly convening a forum, such as the HMAC.

Each year, beginning one year after the approval and adoption of the plan, Baltimore City will collect and process information from the departments, agencies, and organizations identified as lead and supporting organizations for implementing mitigation actions identified in the plan. The collection of this information documents the ongoing activities responsible agencies are taking to implement the action and includes information on challenges and delays. The DP3 Coordinator will initiate contact via email and specify the information requested. This information will include the following (at minimum):

- Mitigation strategy number
- Mitigation action number
- Timeframe
- Action purpose
- DP3 goal addressed
- Lead organization
- Supporting organization
- Action to be taken (per year for the five-year cycle)
- Current status
- Summary of completed tasks
- Challenges
- Reviewer name, title, and agency

At the time of this plan update, BoS is currently exploring tools to streamline tracking the performance and status of resilience-focused actions, including those identified in the *Climate Action Plan*. Once a tool has been selected, it will provide BoS greater visibility into the overall work being accomplished to meet Baltimore City's climate and resilience goals, identify common challenges, and ensure consistency and compatibility across initiatives.

It is anticipated that this annual reporting will support the submittal of an increased number of project grant applications due to the additional visibility on what tasks need to be completed and continuously engaging implementers in the process. Annual reporting supports continued prioritization of projects based on current needs and resources.

In addition to monitoring the progress on the implementation of mitigation actions, BoS will schedule annual meetings dedicated to the review of the DP3. At a minimum, the following will be reviewed and discussed during each annual meeting:

- Review the DP3 goals and identify any changes in priority.

- Review the Risk Assessment and identify any new data or information that should be integrated.
- Review the approved mitigation strategy, provide a status summary of implementation, and review effectiveness of completed projects based on the information collected from the implementing organizations.
- Provide an overview of active disaster response and recovery efforts, if applicable.
- Solicit projects for inclusion in upcoming grant cycles.

The annual meeting will serve as a dedicated opportunity to review the DP3 in its entirety. This meeting will take place during Quarter 1 (October 1 to December 31) of the federal fiscal year. Conducting the annual review during this time of the year provides Baltimore City and its partners with an opportunity to identify projects to submit for grant funding that is likely to be announced in Quarter 4 (July 1 to September 30), such as FEMA's Flood Mitigation Assistance (FMA) and Building Resilient Infrastructure and Communities (BRIC) grant programs, with enough lead time to compile project designs, cost estimates, benefit-cost analyses (BCA), etc.

BoS will coordinate with OEM to employ additional monitoring methods through grant management practices, such as monitoring expenditures against project budgets, monitoring implementation progress, and compiling documentation of project and financial activities, for activities supported by FEMA's Hazard Mitigation Assistance grant programs.

15.3.2 Evaluating

The evaluation of the DP3 is an assessment of whether the planning process and actions have been effective, whether the DP3 goals are being achieved, and whether changes are needed. The DP3 will be evaluated annually to determine the effectiveness of the programs and to reflect changes that could affect mitigation priorities or available funding.

The status of the DP3 will be discussed and documented at annual plan review meetings of the HMAC and additional partners as described in Section 15.3.1. The meetings will be held either in person or via teleconference, with the first meeting taking place approximately one year from the date of local adoption of this update and successively thereafter. At least four weeks before the annual plan review meeting, the Baltimore City DP3 Coordinator will advise HMAC members of the meeting date, agenda, and expectations of the members.

The DP3 Coordinator will be responsible for coordinating the annual plan review meeting and soliciting input regarding progress toward meeting plan goals and objectives. These evaluations will assess whether:

- Goals and objectives address current and expected conditions
- The nature or magnitude of the risks has changed
- Current resources are appropriate for implementing the DP3 and if different or additional resources are now available
- Actions are cost-effective
- Schedules and budgets are feasible
- Implementation problems, such as technical, political, legal, or coordination issues with other agencies, are present
- Outcomes have occurred as expected

- Changes in City resources impacted plan implementation (e.g., funding, personnel, and equipment)
- New agencies/departments/staff should be included, as defined under 44 CFR 201.6

Specifically, the HMAC will review the mitigation goals and actions using performance-based indicators, including:

- New agencies/departments engaged in the DP3
- Project completion
- Under/overspending
- Achievement of the goals
- Resource allocation
- Timeframes
- Budgets
- Lead/support organization commitment
- Resources
- Feasibility

Finally, the HMAC will evaluate how other programs and policies have conflicted or augmented planned or implemented measures and shall identify policies, programs, practices, and procedures that could be modified to accommodate hazard mitigation actions. Other programs and policies can include those that address:

- Economic development
- Environmental preservation
- Historic preservation
- Redevelopment
- Health and/or safety
- Recreation
- Land use/zoning
- Public education and outreach
- Transportation

The DP3 Coordinator shall be responsible for preparing an annual DP3 Status Report for each year of the performance period based on the information provided by the HMAC members, information presented at the annual meeting, and other information as appropriate and relevant. These annual status reports will provide data for the five-year update of this DP3 and will assist in pinpointing any implementation challenges. By monitoring the implementation of the DP3 on an annual basis, the HMAC will be able to assess which projects are completed, which are no longer feasible, and which projects should require additional funding.

The annual DP3 Status Report shall be posted on the Baltimore City Office of Sustainability's website to keep the public appraised of the plan's implementation (located at https://www.baltimoresustainability.org/plans/disaster-preparedness-plan/). Additionally, the website provides details on the DP3 update planning process.

Baltimore City participates in the Community Rating System (CRS) Program and can use this report to meet annual CRS recertification requirements. To meet this recertification timeline, the Planning Team will strive to complete the review process and prepare an annual DP3 Status Report by January 31 of each year.

The DP3 will also be evaluated and revised following any major disasters to determine if the recommended actions remain relevant and appropriate. The risk assessment will also be revisited to see if any changes are necessary based on the pattern of disaster damage or if data listed in Section 3 (Risk Assessment) of this plan has been collected to facilitate the risk assessment. This is an opportunity to increase the community's disaster resistance and build a better and stronger community.

15.3.3 Updating

To facilitate the update process, the DP3 Coordinator will develop and commence the implementation of a detailed plan update program. At a minimum, the program will establish who shall be responsible for managing and completing the plan update effort, what needs to be included in the updated plan, and a detailed timeline with milestones to ensure that the update is completed according to regulatory requirements.

A five-year milestone schedule is provided in Table 15-1. This schedule represents key activities for monitoring, evaluating, and updating the DP3 and identifies the responsible party for each action. This schedule will be used for planning purposes to guide the implementation of the DP3 through the performance period. Specific activities and timelines will be established as the DP3 is implemented.

Table 15-1. DP3 Performance Period Implementation Milestone Schedule Example

Period	Action
Year 1: DP3 is approved, new 5-year performance period begins	
4th Quarter (July–September 2024)	BoS notifies lead and supporting organizations to provide status updates on mitigation strategies and actions.
1st Quarter (October–December 2024)	BoS convenes stakeholders and HMAC to conduct annual DP3 review and provide a summary of the status of implementing the mitigation strategy.
2nd Quarter (January–March 2025)	BoS implements revisions and updates to the DP3 as appropriate and provides assistance to lead and supporting organizations to identify solutions for identified challenges.
3rd Quarter (April–June 2025)	BoS and OEM conducts outreach and awareness to notify stakeholders of potential funding opportunities to support the implementation of mitigation actions.
Year 2	
4th Quarter (July–September 2025)	BoS notifies lead and supporting organizations to provide status updates on mitigation strategies and actions.
1st Quarter (October–December 2025)	BoS convenes stakeholders and HMAC to conduct annual DP3 review and provide a summary of the status of implementing the mitigation strategy.
2nd Quarter (January–March 2026)	BoS implements revisions and updates to the DP3 as appropriate and provides assistance to lead and supporting organizations to identify solutions for identified challenges.
3rd Quarter (April–June 2026)	BoS and OEM conducts outreach and awareness to notify stakeholders of potential funding opportunities to support the implementation of mitigation actions.
Year 3	
4th Quarter (July–September 2026)	BoS notifies lead and supporting organizations to provide status updates on mitigation strategies and actions. BoS identifies funding and technical support for the 2028 DP3 update.
1st Quarter (October–December 2026)	BoS convenes stakeholders and HMAC to conduct annual DP3 review and provide a summary of the status of implementing the mitigation strategy.

Period	Action
2nd Quarter (January–March 2027)	BoS identifies any additional needs for updating the DP3 and procures support services if required.
3rd Quarter (April–June 2027)	BoS kicks off 2028 DP3 update process and meets regularly with the HMAC. Feedback from the annual meeting is utilized to guide the development of the 2028 DP3 update.
Year 4	
4th Quarter (July–September 2027)	BoS notifies lead and supporting organizations to provide status updates on mitigation strategies and actions to compile summary of progress on the 2023 DP3 to inform the 2028 DP3 update and meets regularly with the HMAC.
1st Quarter (October–December 2027)	BoS continues to draft the 2028 DP3 update and meets regularly with the HMAC.
2nd Quarter (January–March 2028)	BoS continues to draft the 2028 DP3 update and meets regularly with the HMAC.
3rd Quarter (April–June 2028)	BoS continues to draft the 2028 DP3 update and meets regularly with the HMAC.
4th Quarter (July–September 2028)	BoS hosts a public comment period for the 2028 DP3 update and meets regularly with the HMAC.
1st Quarter (October–December 2028)	BoS submits 2028 DP3 update to FEMA Region III for review and approval.
Begin new 5-year performance period	

The need for ad hoc reviews outside of the milestone schedule may arise during the plan's five-year performance period. These ad hoc reviews may be prompted by a disaster, the availability of updated data that would significantly impact the risk assessment, or completion of major risk reduction activities that substantially reduce the vulnerability of Baltimore City. During the annual meeting, the HMAC will determine what resources will be needed to complete and continuously update the plan. The DP3 Coordinator is responsible for assuring that needed resources are secured.

Following each five-year update of the mitigation plan, the updated plan will be distributed for public comment. After all comments are addressed, the DP3 will be revised and distributed to the HMAC, State of Maryland Hazard Mitigation Officer, and FEMA.

15.4 Integration Process of the DP3 into City Planning Mechanisms

FEMA Planning Policy Element D3: 44 CFR 201.6(c)(4)(ii): The plan must describe a process for each community to integrate the requirements of the mitigation plan into other planning mechanisms, such as a comprehensive or capital improvement plans. The plan must include a process the community will follow, identify the planning mechanisms for each plan participant, and describe each participant's individual process for integrating information from the mitigation strategy into their identified planning mechanisms.

Integrating hazard mitigation into a community's existing plans, policies, codes, and programs leads to development patterns that do not increase risk from known hazards or lead to redevelopment that reduces risk from known hazards. Effective mitigation is achieved when hazard awareness and risk management approaches and strategies become an integral part of public activities and decision-making. Within Baltimore City, there are many existing plans and programs that support hazard risk management, and thus it is critical that this hazard mitigation plan integrate and coordinate with and complement those existing plans and programs.

Section 13 (Capability Assessment) provides a summary and description of the existing plans, programs, and regulatory mechanisms at all levels of government (Federal, State, and City) that support hazard mitigation within Baltimore City.

It is the intention of HMAC representatives to continue to incorporate mitigation planning as an integral component of daily government operations. Therefore, this continued integration is a component of the plan's maintenance strategy.

During the DP3 annual review process, each participating stakeholder will be asked to document how they are utilizing and incorporating the 2023 DP3 update into their day-to-day operations and planning and regulatory processes. Additionally, Baltimore City will identify additional policies, programs, practices, and procedures that could be modified to accommodate hazard mitigation actions and include these findings and recommendations in the annual DP3 Progress Report. The following checklist (Table 15-2) was adapted from FEMA's *Local Mitigation Handbook (2013)*, Appendix A, Worksheet 4.2. This checklist will help Baltimore City analyze how hazard mitigation is integrated into local plans, ordinances, regulations, ordinances, and policies. Completing the checklist will help Baltimore City identify areas that integrate hazard mitigation currently and where to make improvements and reduce vulnerability to future development. In this manner, the integration of mitigation into activities will evolve into an ongoing culture within Baltimore City.

Table 15-2. Plan Integration Checklist

Planning Mechanisms	Do You Do This?		Notes: How is it being done, or how will this be utilized in the future?
	Yes	No	
Operating, Municipal, and Capital Improvement Program Budgets			
• When constructing upcoming budgets, hazard mitigation actions will be funded as budget allows. Construction projects will be evaluated to see if they meet the hazard mitigation goals.			
• During the annual adoption process, Baltimore City will review mitigation actions when allocating funding.			
• Do budgets limit expenditures on projects that would encourage development in areas vulnerable to natural hazards?			
• Do infrastructure policies limit extension of existing facilities and services that would encourage development in areas vulnerable to natural hazards?			
• Do budgets provide funding for hazard mitigation projects identified in Baltimore City DP3?			
Human Resource Manual			
• Do any job descriptions specifically include identifying and/or implementing mitigation projects/actions or other efforts to reduce natural hazard risk?			
Building and Zoning Ordinances			
• Prior to zoning changes or development permitting, Baltimore City will review the DP3 and			

Planning Mechanisms	Do You Do This? Yes	No	Notes: How is it being done, or how will this be utilized in the future?
other hazard analyses to ensure consistent and compatible land use.			
• Does the zoning ordinance discourage development or redevelopment within natural areas, including wetlands, floodways, and floodplains?			
• Does it contain natural overlay zones that set conditions?			
• Does the ordinance require developers to take additional actions to mitigate natural hazard risk?			
• Do rezoning procedures recognize natural hazard areas as limits on zoning changes that allow greater intensity or density of use?			
• Do the ordinances prohibit development within or filling of wetlands, floodways, and floodplains?			
Subdivision Regulations			
• Do the subdivision regulations restrict the subdivision of land within or adjacent to natural hazard areas?			
• Do the subdivision regulations restrict the subdivision of land within or adjacent to natural hazard areas?			
• Do the regulations provide for conservation subdivisions or cluster subdivisions to conserve environmental resources?			
• Do the regulations allow density transfers where hazard areas exist?			
Comprehensive Plan			
• Are the goals and policies of the plan related to those of Baltimore City DP3?			
• Does the future land use map clearly identify natural hazard areas?			
• Do the land use policies discourage development or redevelopment of natural hazard areas?			
• Does the plan provide adequate space for expected future growth in areas located outside natural hazard areas?			
Land Use			
• Does the future land use map clearly identify natural hazard areas?			
• Do the land use policies discourage development or redevelopment of natural hazard areas?			
• Does the plan provide adequate space for expected future growth in areas located outside natural hazard areas?			
Transportation Plan			
• Does the transportation plan limit access to hazard areas?			
• Is transportation policy used to guide growth to safe locations?			

Planning Mechanisms	Do You Do This? Yes	No	Notes: How is it being done, or how will this be utilized in the future?
• Are transportation systems designed to function under disaster conditions (e.g., evacuation)?			
Environmental Management			
• Are environmental systems that protect development from hazards identified and mapped?			
• Do environmental policies maintain and restore protective ecosystems?			
• Do environmental policies provide incentives to development located outside protective ecosystems?			
Grant Applications			
• Data and maps will be used as supporting documentation in grant applications.			
City Ordinances			
• When updating City ordinances, hazard mitigation will be a priority.			
Economic Development			
• Local economic development groups will consider information regarding identified hazard areas when assisting new businesses in finding a location.			
Public Education and Outreach			
• Does Baltimore City have any public outreach mechanisms / programs in place to inform citizens about natural hazards, risks, and ways to protect themselves during such events?			

Other planning processes and programs to be coordinated with the recommendations of the hazard mitigation plan include the following:

- Emergency operations and response plans
- Training and exercise of emergency response plans
- Debris management plans
- Recovery plans
- Capital improvement programs
- City codes
- Community design guidelines
- Water-efficient landscape design guidelines
- Stormwater management programs
- Water system vulnerability assessments
- Community wildfire protection plans
- Comprehensive flood hazard management plans
- Resiliency plans
- Community Development Block Grant-Disaster Recovery action plans
- Public information/education plans

Section 16. Moving Forward

This section of the 2023 DP3 highlights integration between the 2018 DP3 plan and the 2023 update. Similar to the 2018 DP3, this section details future visions for the plan and identifies opportunities for improvement. The following sections document how recommendations from the 2018 DP3 are integrated into the 2023 DP3 update and future opportunities to continue to build on these recommendations. This section intends to serve as an opportunity for Baltimore City, stakeholders, communities, and officials to further resilience discussions and to promote mitigation planning in the future. Hazard mitigation is an ongoing mission, and it is important for the DP3 to continue on the path of updating and evolving as the hazards and community needs, which are critical to assessing risk and vulnerability, also evolve throughout Baltimore City.

The 2018 DP3 provided specific recommendations within the following topic areas:

- Community Resilience
- Food Resilience
- Integration of Historic and Cultural Considerations

16.1 Community Resilience Recommendations

The 2018 DP3 put forth seven specific recommendations to continue efforts to build resilience for Baltimore City. Those recommendations are listed below.

16.1.1 Recommendation 1: Continue planning efforts centered on increasing community resilience, including ongoing formalization and expansion of Resiliency Hubs.

The 2018 recommendation focused on strengthening the connection between neighborhoods, community-based organizations (such as Community Resiliency Hubs), and Baltimore City's preparedness vision and planning efforts. Community Resiliency Hubs are trusted, service-based non-profit community organizations, including faith-based, with strong leadership located in under-resourced neighborhoods. The DP3 noted that, although these organizations are trusted members of the community, they are often under-resourced and not equipped to assist during emergency situations.

Since the 2018 DP3, the network of Community Resiliency Hubs has expanded to 20 partner sites. BoS leads the Resiliency Hub Program, which is a community-centered initiative to increase community capacity to prepare for, withstand, and respond to natural hazard impacts and emergency situations. The program is a partnership between BoS, OEM, and BCHD; BoS is responsible for growing and managing the program.

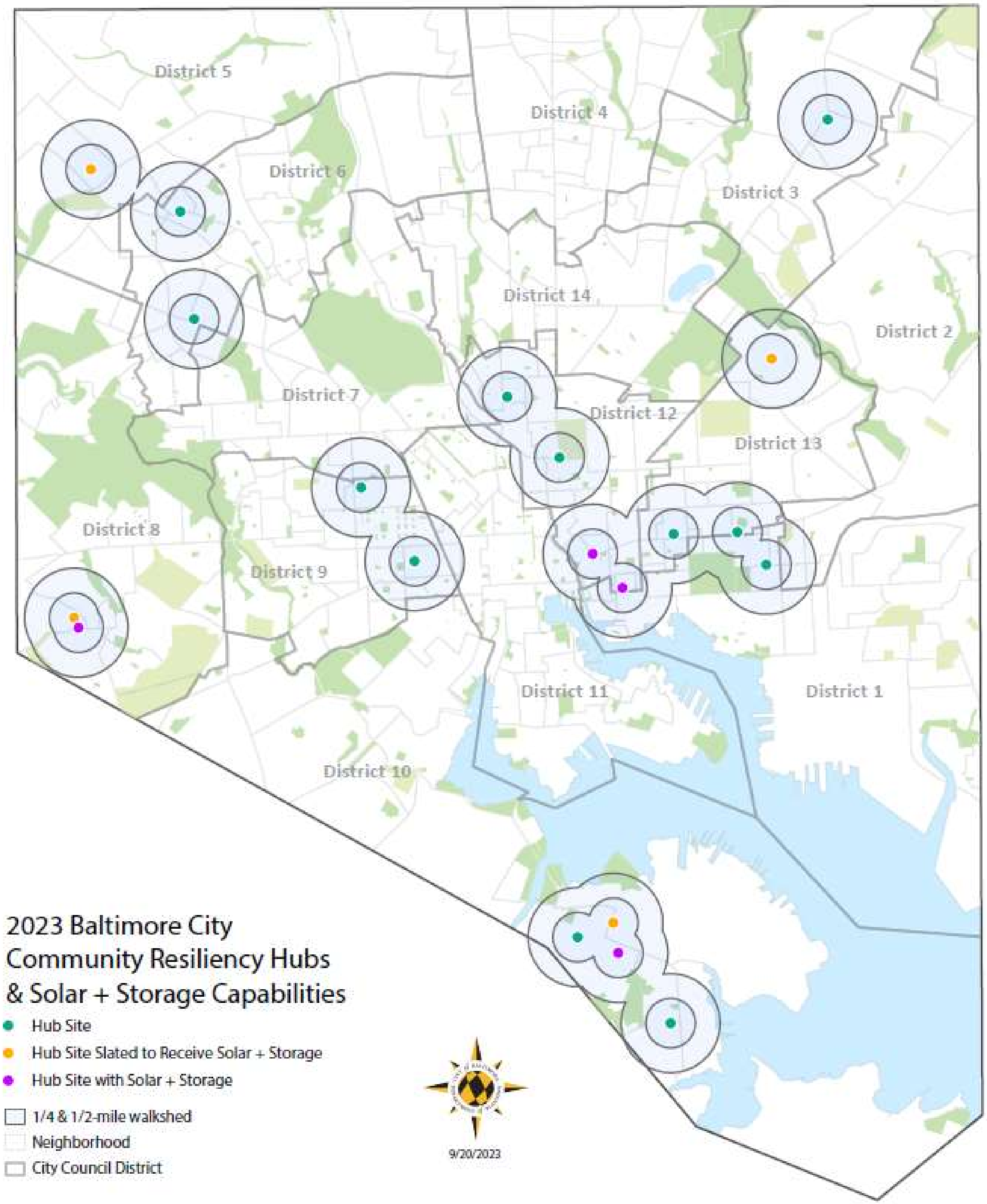
Baltimore City agencies collaborate with the Community Resiliency Hubs to connect them to resources to enable them to serve as a space where vulnerable neighbors can gather in times of emergency; access reliable power for their essential devices; receive supplies, food, and drinking water; and store medications sensitive to temperature, among other things.

Resiliency Hubs can also serve as community-based staging areas for emergency and recovery personnel as well as conduits for critical supply distribution to the community.

Hubs receive grant-funded support from Baltimore City to support a variety of activities including procuring high-quality emergency preparedness supplies, completing energy efficiency upgrades to their building, establishing back-up power capabilities, receiving emergency preparedness and response training, receiving assistance to navigate grant funding opportunities, and receiving focused support and communications from BoS, OEM, and BCHD. The Resiliency Hub Program has been awarded funding to support the purchase and installation of solar power and battery storage systems for four Community Resiliency Hubs; four hubs currently have solar and battery back-up capabilities (BoS 2022). Figure 16-1 shows existing Community Resiliency Hubs throughout Baltimore City.

During the 2023 update process, Community Resiliency Hubs were integrated into the process through outreach and engagement efforts. Mitigation actions were developed to specifically continue support for these community resiliency hubs. For the 2023 DP3 update, it is recommended that this recommendation remains as-is.

Figure 16-1. 2022 Community Resiliency Hub Partner Locations



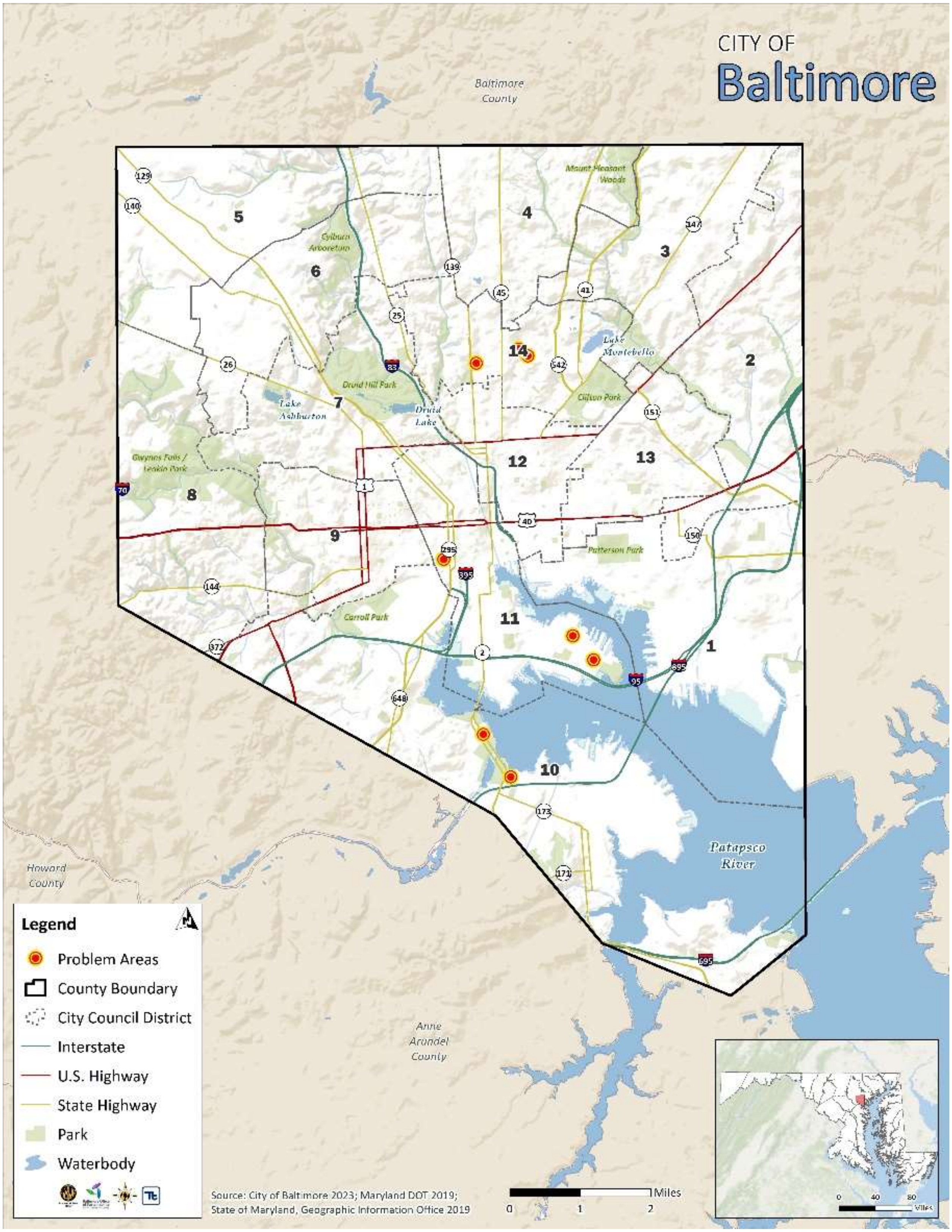
Source: BoS 2023

16.1.2 Recommendation 2: Use community resilience initiatives to address varying regional concerns.

This recommendation focuses on ensuring resilience initiatives are tailored to highly localized efforts, such as specific regions of Baltimore City or specific neighborhoods. Since the 2018 DP3, the Frederick Avenue Flood Mitigation Workgroup was formed to address community concerns and needs following catastrophic flooding in the Southwest Baltimore neighborhoods along Frederick Avenue. The workgroup consists of representatives from the neighborhoods, Stillmeadow Community Resiliency Hub, faith-based organizations, City staff, and additional stakeholders.

For the 2023 update, the outreach efforts included surveying neighboring jurisdictions (Anne Arundel, Baltimore, and Howard Counties) to identify regional hazard impacts and challenges and surveying the general public to identify areas of concern (see Figure 16-2). In combination with the results of the risk assessment, this information can be used to update the recommendation to specify specific regions and areas of concern to target resilience initiatives. This includes utilizing the best available data to identify geographic areas with heightened social vulnerability and areas with frequent hazard impacts.

Figure 16-2. Problem Areas Identified by General Public



16.1.3 Recommendation 3: Broaden public outreach and engagement efforts to include greater representation from all Baltimore neighborhoods and communities in planning efforts.

The focus for this recommendation was to promote outreach activities especially for key groups which may not have the resources to participate or provide feedback during the planning process. These groups could include those communities in economic distress (low-income, socioeconomically disadvantaged, etc.), housing-insecure citizens (individuals experiencing homelessness, displaced individuals, etc.), retirees, older adults, and those individuals living in historically underserved communities. Recommendations in the 2018 DP3 included targeted interviews and public survey methods to reach more members in the community. Other actions recommended convening population-specific interest focus groups, organizing large-scale community meetings at publicly accessible locations, and hosting interactive booths at common public events.

During the 2023 DP3 update, an Equity Subcommittee convened to discuss the planning process and provide feedback on the plan actions and strategies. The Equity Subcommittee included members from various neighborhoods and community organizations, who gave first-hand insight into the concerns and priorities for socially vulnerable individuals and underserved populations. Public outreach and engagement were broadened and spanned multiple community groups by incorporating feedback from the Equity Subcommittee into the 2023 update. This subcommittee strengthened Baltimore City's goal for equitable planning and ensures for a more inclusive plan to encompass all community members who live, work, and play in Baltimore City.

In addition to the Equity Subcommittee, outreach activities prioritized targeted outreach. Outreach to spread awareness about the surveys was conducted through meetings, emails, and in-person at several community-oriented facilities. The locations listed below were identified as focus areas to distribute in-person surveys to reach a wider representation of the community and provided dedicated engagement opportunities for neighborhoods and populations with increased vulnerability:

- Harlem Gardens: A senior center in the Harlem Park neighborhood in West Baltimore
- Bentalou Recreation Center: Located in the Lexington neighborhood in West Baltimore
- Edmondson Commons: A senior center in the Harlem Park neighborhood in West Baltimore
- Harvey Johnson Towers: An apartment complex in the Sandtown Winchester neighborhood in West Baltimore
- Plantation Park Heights: An urban farm in the Park Heights neighborhood in Northwest Baltimore
- MonteVerde Apartments: An apartment complex in the Park Circle neighborhood in Northwest Baltimore
- Oliver Senior Center-Home: A senior center, as well as an additional drop-off in its associated community center, in the Broadway East neighborhood in East Baltimore
- Herring Run Branch of the Enoch Pratt Free Library: In the Belair Edison neighborhood in East Baltimore

- Cherry Hill Branch of the Enoch Pratt Free Library: In the Cherry Hill neighborhood of South Baltimore

Additional engagement included:

- Hanging posters for the DP3 public survey at the West Baltimore Marc Station in Midtown Edmondson.
- Tabling at the following events: JFX Farmers Market in Downtown Baltimore, the Cherry Hill Farmers Market in the Cherry Hill neighborhood in South Baltimore, the Onyx Farmers' and Artisans' Market in the Old Goucher neighborhood in Central Baltimore, the Plantation Park Heights Food Giveaway in the Park Heights neighborhood in Northwest Baltimore during a Morgan State event at the farm and during their Senior Volunteer day, and the Liberty Grace Church of God GROW Center in Ashburton in West Baltimore.
- Presenting at the following meetings: local emergency planning committee, waste working group, and the Frederick Avenue Flood Mitigation community meeting.

It is recommended that the Equity Subcommittee is maintained throughout the implementation process of the DP3 to serve an in a community oversight role for the prioritization and implementation of the mitigation strategy. Public engagement can continue through plan adoption and implementation by continuing to identify existing community events to participate in and highlight the DP3.

16.1.4 Recommendation 4: Introduce solutions-oriented public engagement practices designed to solicit community-driven solutions.

This recommendation focuses on furthering the public engagement process by introducing new mechanisms, with the goal of collecting input on solutions to challenges and concerns identified by community members. This could aid with gathering sustainable solutions that align with the community's values and stays true to Baltimore City's commitment to promoting equity throughout the planning process.

The mitigation strategy was developed through a collaborative workshop consisting of stakeholders, community organizations, and City agencies. The workshop prioritized identifying opportunities to mitigate impacts to FEMA's community lifelines, which looks at essential community services from a systems perspective and ensures the interconnectedness of these services is considered.

The Equity Committee served as a forum to identify potential mitigations actions in collaboration with community members. In addition, part of the implementation process for the DP3 will be the development of a project portfolio of 5-10 high priority mitigation actions. The development of the project portfolio will include opportunities for community members and stakeholders to participate in prioritizing projects, refining projects, and assisting with developing an actionable implementation plan. This is a critical step in building community buy-in for successful implementation.

Moving forward it is recommended that City agency community liaisons continuously coordinate with BoS to uplift community concerns and needs as they arise. This will provide BoS the opportunity to identify mitigation opportunities outside of the DP3 planning process.

BoS will be able to use information coming directly from community members to guide and steer ongoing outreach during the implementation of the DP3.

16.1.5 Recommendation 5: Determine a strategy for incorporating information on vulnerable populations collected during the development of this plan. And Recommendation 6: Use public feedback to identify vulnerable populations and specify vulnerable populations to the greatest extent possible.

During the 2018 DP3, BoS mapped vulnerable populations and identified older adults and socially isolated individuals as two socially vulnerable populations requiring near-term attention.

At the commencement of the 2023 DP3 update process, FEMA released updated local hazard mitigation planning guidance, which called for the integration of considerations for socially vulnerable individuals and underserved populations. As a result, during the 2023 DP3 process multiple efforts were completed to integrate considerations for these populations and communities including the following:

- Surveying the public and stakeholders to identify what barriers and challenges exist in Baltimore City that may contribute to social vulnerability when faced with hazards.
- Targeted outreach to older adults and in geographic areas that may have heightened vulnerability to hazards.
- Establishing an Equity Subcommittee to participate in the planning process.
- Identifying and assessing socially vulnerable individuals and communities that may be disproportionately impacted by hazards in Baltimore. These groups included:
    - Children
    - Older adults
    - Persons with disabilities,
    - Economically disadvantaged individuals
    - Persons with limited access to transportation
    - Individuals with limited English proficiency
    - Black, Indigenous, and People of Color (BIPOC)
    - Individuals living in group quarters
    - Individuals experiencing sheltered and unsheltered homelessness
    - Lesbian, Gay, Bisexual, Transgender, Queer or Questioning, Intersex, Asexual or Ally, and Additional Identities (LGBTQIA+)

Moving forward it is recommended that BoS continue to identify challenges and barriers contributing to socially vulnerable groups within Baltimore City. By having communities self-identify the existing barriers and challenges it ensures that no groups are overlooked that may not be represented in quantitative data such as the census.

16.1.6 Recommendation 7: Develop criteria and a strategy for integrating human-caused hazards into the next DP3 with input from the public at the outset.

The 2018 DP3 included a recommendation to incorporate human-caused hazards into future DP3 plans, identified through public input (e.g., surveys). Baseline data was collected during the 2018 DP3 process to gather public feedback on public concerns of human-caused hazards.

There was a diverse understanding of human-caused hazard concerns, and what defines human-caused hazards, by community members within Baltimore City. It was suggested that including human-caused hazards into the DP3 would benefit from seeking public perspectives from the start of the development process, to identify best approaches and consensus related to this hazard.

During the 2023 DP3 update process, the surveys for stakeholders and the public assessed public perception of human-caused hazards. The results of the 2023 survey, 2018 survey, and other public outreach efforts informed the identification of human-caused hazards for inclusion in the 2023 DP3. The 2023 DP3 was scoped to include a limited number of new hazards.

Moving forward, the scope of the DP3 could be expanded to include additional hazards and to conduct additional analyses to identify human-caused and emerging hazards that could pose a moderate or high risk to Baltimore City.

16.2 Food Resilience

The 2018 DP3 focused on viewing food systems as critical infrastructure and identifying opportunities to build food resilience and security throughout the emergency management process. The April 2015 Baltimore Uprising was used as a case study to identify how crisis can disrupt food systems. Since the 2018 DP3, the COVID-19 pandemic has served as another opportunity for lessons learned regarding disruptions in food systems and how to overcome those disruptions.

To accomplish the goal of integrating food resilience and security into emergency management process the Baltimore Food Policy Initiative has undertaken the following projects:

Image from JFX Farmer's Market.

- Developed the Food Distribution Annex for Baltimore City's Emergency Operations Plan in partnership with OEM. This annex provides instruction as to how Baltimore City can distribute food during times of an emergency.
- Completed two projects totaling approximately $6 million to support the Farm Alliance of Baltimore farm incubator and produce box distribution. The farm incubator program provides hands-on training for new BIPOC farmers and provides

compensation for their participation. Produce grown at the site sold and distributed locally in partnership with Common Market, a regionally based and sourced produce distributor.

- Implemented an Online Supplemental Nutrition Assistance Program (SNAP) fruit and vegetable incentive program which improves the accessibility of online grocery shopping. This program provides $30.00/month to SNAP participants that can be used to procure fresh and frozen fruits and vegetables. This program is in progress and is being implemented by the Food Policy and Planning Division.
- The Food Policy and Planning Division joined a Mid-Atlantic supply chain network group to better understand the private sector's ability to respond to disasters and emergencies. The purpose of the group is to increase understanding of how to troubleshoot large grocery retail distribution issues during emergencies. This effort is funded through FEMA's Regional Catastrophic Preparedness Grant Program Initiative.

In addition to the initiatives listed above, the Food Policy and Planning Division continuously provides support to urban farms and community gardens through funding and assisting with infrastructure needs. This includes assistance in securing land tenure for urban farms and providing funding for water access and infrastructure through the Healthy Food Priority Area Funds.

Moving forward the Food Policy and Planning Division can continue to coordinate with BoS to identify mitigation actions and funding opportunities to support implementing mitigation at urban farms and community gardens to protect these resources against future hazard impacts. This includes continuing to identify opportunity to ensure food systems are resilient in Baltimore City.

16.3 Integration of Cultural and Historic Resources

The 2018 DP3 noted that DOP, BoS, and CHAP were engaging in an effort to develop a hazard mitigation planning strategy for Baltimore City's historic resources. The intent of the strategy was to determine resource-specific and neighborhood-specific adaptation strategies for the historic neighborhoods and areas most vulnerable to climate hazards.

Since the 2018 DP3, Baltimore City has developed and published the Fells Point Flood Mitigation Guidelines. The guidelines provide information to property owners and tenants to help with assessing their options to minimize flooding impacts on their historic properties. The guide is specific to the Fells Point Neighborhood area.

Moving forward continued support for similar efforts is recommended. Additional guidelines could be developed for other unique historic neighborhoods for or for a variety of uses of historic structure in Baltimore City, such as commercial and industrial.

16.4 Conclusion

Baltimore City 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 section. The recommendations outlined here represent important steps for Baltimore 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.

All mitigation planning practices present challenges and barriers for each community. The level of resources and staff available can have a substantial impact on the planning processes, and each community differs in these resources. Some barriers for Baltimore City during the 2023 DP3 update planning process included staff turnover throughout City agencies and time constraints to conduct the planning process.

As Baltimore City sets out to implement the 2023 DP3 and build upon the recommendations listed above, continuous stakeholder and public engagement will be paramount to the success of implementing the plan. The 2023 DP3 maintenance plan provides a strong foundation to maintain contact with stakeholders and community members over the course of the five-year performance of the DP3, ensuring that performance measures can be actively tracked and adjustments made as necessary.

The recommendations outlined above are not required but are important steps for Baltimore City to implement moving forward. Baltimore City recognizes that resilience is an ongoing and evolving process that requires consistent public engagement and continuous evaluation of mitigation resources.

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 — to moderate potential damage or cope with the consequences of those changes.

Asset: Any constructed 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 percent 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 BFE is used as the standard for the National Flood Insurance Program. BFE is the value that indicates the height of flood waters during a base flood; the BFE dictates the lowest level at which a living space can be built without being impacted by floods.

Body/Surface Waves: Cause the ground and buildings to vibrate.

Building Resilient Infrastructure and Communities (BRIC): FEMA grant program which supports communities through capability and capacity building. BRIC encourages and enables innovation, promotes partnerships, enables large-scale projects while maintaining flexibility and providing consistency (FEMA 2023).

Building: A structure that is walled and roofed, principally above ground, and permanently affixed to a site.

Coastal Flooding: When water inundates or covers normally dry coastal land because of high tides or storm surges.

Code Blue Cold Alert: Baltimore City Health Department official declaration of extreme freezing conditions.

Code Red Heat Alert: Baltimore City Health Department official declaration of extreme heat conditions.

Community Rating System (CRS): A program under the National Flood Insurance Program (NFIP) 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.

Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA): Authorizes the President to respond to releases or threatened releases of hazardous substances into the environment.

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 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.

Creep: The slow, steady, downward movement of slope-forming soil or rock. Creep is indicated by curved tree trunks, bent fences or retaining walls, tilted poles or fences, and small soil ripples or ridges.

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.

Cyber-Attack: An intentional effort to steal, expose, disrupt, disable, or destroy data, applications, or other assets through unauthorized access to a network, computer system, or digital device (NIST n.d.).

Cyberterrorism: The politically motivated use of computers and information technology to cause severe disruption or widespread fear in society.

Cyberwarfare: A series of cyber-attacks against a nation-state, causing significant harm. This harm could include disruption of vital computer systems up to the loss of life.

Dam: An artificial barrier allowing storage of water, wastewater, or liquid-borne materials for many reasons (flood control, human water supply, irrigation, livestock water supply, energy generation, containment of mine tailings, recreation, or pollution control) (Association of State Dam Safety Officials 2022).

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.

Debris Avalanche: This is a variety of very rapid to extremely rapid debris flow.

Debris Flow: A form of rapid mass movement in which a combination of loose soil, rock, organic matter, air, and water mobilize as a slurry that flows downslope. Debris flows are commonly caused by intense surface-water flow due to heavy precipitation or rapid snowmelt, which erodes and mobilizes loose soil or rock on steep slopes.

Denial-of-Service (DoS): A denial-of-service (DDoS) attacks flood a system's resources with fraudulent traffic. The difference between DoS attacks and DDoS attacks is simply that DoS attacks use a sole source to generate fraudulent traffic, while DDoS attacks use multiple sources. DDoS attacks are often conducted with a botnet, a network of internet-connected, malware-infected devices under a hacker's control.

Derecho: Widespread, long-lived windstorm that is associated with a band of rapidly moving showers and thunderstorms.

Domain Name System (DNS) Spoofing: Cyber-attackers will covertly edit DNS records to replace a website's real IP address with a fake one. When victims try to visit the real site, the malicious site steals data or spreads malware.

Duration: How long a hazard event lasts.

Earthquake: A trembling of the ground caused by the sudden movement of large sections of the Earth's outermost crust.

Earthflow: Have a characteristic "hourglass" shape. The slope material liquefies and runs out, forming a bowl or depression at the head.

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 life or health if people are exposed.

Extreme Heat: When the elevated temperature experienced by a region is severe enough to cause a substantial threat to life or health if people are exposed.

Extreme Wind Events: Include straight-line winds, downburst winds, micro-macro-burst winds, derechos, and more. Extreme wind events occur when there is a large pressure gradient in the atmosphere.

Falls: Abrupt movements of geologic materials, such as rocks and boulders, which become detached from steep slopes or cliffs. Falls are strongly influenced by gravity, weathering, and the presence of water in a mineral's pores.

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.

Flash Flood Watch: Issued generally when there is the possibility of flash flooding or urban flooding over an area within the next 36 hours.

Flash Flood Warning: Issued when flash flooding is imminent within the next 1 to 3 hours. Usually issued based on observed heavy rainfall (measured or radar estimated) but may also be issued for significant dam breaks that have occurred or are imminent.

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 collapse of shoreline land.

Flood Watch: Issued when there is the possibility of widespread general flooding over an area within the next 36 hours.

Flood Warning for River Forecast Point: Issued when a river gauge has exceeded, or is forecast to exceed, a predetermined flood stage.

Flood Advisory: Issued when flooding is imminent or occurring within the next 1 to 3 hours but is not expected to threaten life and property.

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): The official map of a community which defines the SFHAs and the flood zones applicable to a community. This map is used by the NFIP for floodplain management, mitigation, and insurance purposes. The flood map is the official source for determining flood risk within a community.

Floodplain: A floodplain is flat land adjacent to a river, creek, or stream that is subject to periodic inundation. The floodplain describes the area inundated by the "100-year" flood, or a flood that has a 1 percent chance in any given year of being equaled or exceeded. A floodplain is designated when floodwater exceeds the capacity of the main channel or water escapes the channel through bank erosion.

Flood Fringe: The area within the floodplain but outside the floodway; this area extends from the outer banks of a floodway to the river valley, where the elevation begins to rise.

Floodway: The channel of a river or other watercourse and the adjacent land areas that must be reserved to discharge the 1 percent-annual-chance flood without cumulatively increasing the water surface elevation by more than a designated height.

Flood Mitigation Assistance Grant Program (FMA): FEMA grant program that provides funding to communities and federally recognized tribes/territories for projects that eliminate the risk of repetitive flood damage to buildings insured by the NFIP (FEMA 2023).

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: Tornadoes 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.

Global Sea Level Rise: Refers to the increase currently observed in the average global sea level trend. This is primarily attributed to changes in ocean volume due to ice melting and thermal expansion.

Ground Motion (Shaking): Used to describe the vibration of the ground during an earthquake event. The severity of ground motion increases as magnitude increases and will decrease as one moves farther away from the fault line. Ground motion is caused by seismic waves.

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, tornadoes, 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.

Hazardous Materials: Considered severely harmful to human health and the environment, as defined by the United States Environmental Protection Agency (USEPA) CERCLA (Superfund Law).

Hazard Mitigation Grant Program (HMGP): FEMA grant program which provides funding to state, local, tribal, and territorial governments to develop hazard mitigation plans and rebuild to reduce future disaster losses in their communities (FEMA 2023).

Hazardous Substance Fixed Sites: These sites included abandoned warehouses, manufacturing facilities, processing plants, and landfills. In response to concerns regarding health and environmental risks, Congress established the Superfund program in 1980 to clean up these sites.

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.

High Hazard Potential Dam Grant Program: FEMA grant program which provides technical, planning, design, and construction assistance for the rehabilitation of high hazard potential dams (FEMA 2022).

High Hazard Potential: FEMA classification standard for any dam whose failure or misoperation can cause loss of life and significant property damage (FEMA 2022).

Hurricane: Tropical cyclones that have maximum surface winds exceeding 70 mph and form in the North Atlantic and Central/Eastern North Pacific.

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 transportation systems such as airports, highways, bridges, railways, waterways, dams, etc.

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.

Karst Aquifers: Vital groundwater resource in the United States. About 40 percent of the groundwater used for drinking comes from karst aquifers.

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.

Land Subsidence: Gradual settling or sinking of the Earth's surface.

Lateral Spreads: Distinctive because they usually occur on very gentle slopes or flat terrain. The failure is caused by liquefaction, the process whereby saturated, loose, sediments are transformed from a solid into a liquefied state. The failure starts suddenly in a small area and spreads rapidly (USGS 2004).

Liquefaction: When loose, water-logged, sediments are displaced due to ground surface movement.

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.

Major Flooding: Extensive inundation of structures and roads. Significant evacuations of people and/or transfer of property to higher elevations (NOAA 2021).

Minor Flooding: Minimal or no property damage, but possibly some public threat or inconvenience (NOAA 2021).

Moderate Flooding: Some inundation of structures and roads near streams. Some evacuations of people and/or transfer of property to higher elevations are necessary (NOAA 2021).

Mudflow: An earthflow consisting of material that is wet enough to flow rapidly and that contains at least 50 percent sand-, silt-, and clay-sized particles.

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: Storms that occur along the East Coast of North America. This hazard can take place at any time of the year but is most extreme during September and April.

Normal Fault: A vertical fracture with mostly vertical movement. Occurs when a hanging wall moves downward relative to the footwall. The fault surface dips steeply from 45 to 90 degrees.

Nuisance Flood: Also referred to as sunny day flooding or high-tide flooding. When sea level rise combines with local factors to influence water levels above normal high-tide mark (NOAA 2023).

Phishing: A socially engineered scam which uses fake emails or text messages to steal an individual's credentials, exfiltrate sensitive data, or spread malware. These messages are designed to look as though they were sent from a reputable source.

Planning: The act or process of making or conducting plans; the establishment of goals, policies, and procedures for a social or economic unit.

Pre-Disaster Mitigation Program (PDM): The 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.

P Waves: Propagate at a speed of 15 thousand miles per hour and are the first waves to cause vibrations in a building.

Ransomware: A form of malware that utilizes strong encryptions to hold data or systems storage. The individuals behind this type of attack will demand payment in exchange for releasing the system and restoring its functionality.

Rayleigh/Love Waves: The last waves, following S waves. These cause the ground to vibrate in a complex manner.

Recurrence Interval: The time between hazard events of comparable size in a given location. Based on the probability that the given event will be equaled or exceeded in any given year.

Relative (Local) Sea Level Rise: Refers to the height of the water as measured along the coast relative to a specific point on land. Tide stations measure local sea level rise.

Repetitive Loss Property: Property that is currently insured for which two or more NFIP losses (occurring more than 10 days apart) of at least $1,000 each have been paid within any 10-year period since 1978.

Replacement Value: The cost of rebuilding a structure. Usually expressed in terms of cost per square foot and reflecting 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 based on insurance estimates.

Resilience: 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: A building or set of buildings and neighboring outdoor space that will open to community members during the daytime and provide access to resources that may include food, water, ice, and 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.

Reverse (Thrust) Fault: Opposite of a normal fault. A vertical fracture with mostly vertical movement. Occurs when a hanging wall moves upward relative to the footwall. The fault surface dips steeply from 45 to 90 degrees.

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 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) impact assessment.

Riverine: Of or produced by a river.

Rotational Slide: This is a slide in which the surface of rupture is curved upward, and the slide movement rotates parallel to the ground surface.

Saffir-Simpson Scale: A 1 to 5 rating system based solely on a hurricane's maximum sustained wind speeds.

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.

Scareware: A form of malware that uses fake messages to frighten victims into passing sensitive information.

Sensitivity: Degree to which an asset is impaired by an impact.

Seiche: A standing wave oscillating in a body of water (NOAA 2023). Caused by strong winds and rapid changes in the atmospheric pressure pushing water from one end to the other.

Severe Repetitive Loss (SRL): FEMA-classified, NFIP-insured residential building that has incurred flood-related damage for which four or more separate claim payments have been made with the amount of each claim exceeding $5,000 and with the cumulative amount exceeding $20,000 or that has at least two separate claim payments with the cumulative amount exceeding the market value of the building (FEMA 2020).

Sinkhole: A depression in the ground that has no natural external surface drainage.

Slides: Translational or rotational movement of material downslope. Slides travel at a range of rates, displacing forests and infrastructure as they move.

Special Flood Hazard Area: The area that will be inundated by the flood event having a 1 percent chance of being equaled or exceeded in any given year. In this area, the NFIP's floodplain management regulations are enforced, and the purchase of flood insurance is mandatory.

Spyware: A form of malware that gathers usernames, passwords, and credit card numbers for the perpetrator to utilize.

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.

Storm Surge: The abnormal rise of water generated by a storm, over and above predicted astronomical tides.

Strike-Slip Fault: A vertical fracture with mostly horizontal movement. A right lateral strike-slip fault is when the hanging wall (block opposite an observer) moves right of the footwall. A left lateral strike-slip fault is when the hanging wall moves left of the footwall.

Structure: Something constructed (see also Building).

Structured Query Language (SQL) Injection: Occurs when an attacker inserts malicious code into a server that uses SQL and forces the server to reveal information it normally would not. An attacker could carry out an SQL injection simply by submitting malicious code into a vulnerable website search box.

Superfund: A US federal government program designed to fund the cleanup of toxic wastes.

Sustainability: Improving the quality of human life while balancing the need for environmental protection, societal progress, and economic growth to maintain the balance between meeting the needs of people today without diminishing the ecosystems upon which future generations rely.

Surface Faulting: The differential movement of a fault line.

S Waves: The second waves following P waves. They cause buildings to vibrate from side to side, causing the most damage to structures.

Tectonic Plates: A massive, irregularly shaped slab of solid rock composed of both continental and oceanic lithosphere (USGS 1999).

Tectonic (Crustal) Deformation: The changing of the Earth's surfaces caused by tectonic forces that accumulate in the crust and then cause earthquakes.

Thunderstorms: A localized storm produced by a cumulonimbus cloud and accompanied by lightning and thunder.

Tidal Flooding: Also referred to as high-tide flooding or nuisance flooding. Occurs when local sea levels temporarily rise above the threshold height for flooding. This hazard causes flooding in the absence of storm surge or riverine flooding.

Topographic: Characterizes maps that show natural features and indicate the physical shape of the land using contour lines. These maps may also include human-built features.

Toppling Failure: Distinguished by the forward rotation of a unit about some point under the actions of gravity and forces exerted by surrounding objects or by fluids in cracks.

Tornado: A violent rotating column of air extending from the base of a thunderstorm to the ground.

Translational Slide: In this type of slide, the landslide mass moves along a roughly flat surface with little rotation.

Trojan Horses: A form of malware that tricks users into installation by posing as a useful program or by hiding within legitimate software.

Tropical Cyclone: Rotating, organized systems of clouds and thunderstorms that originate over tropical or subtropical waters.

Tropical Storm: Tropical cyclones that have a maximum surface wind speed of 40–70 mph.

Tsunami: Large waves caused by undersea earthquakes. The height of a tsunami is about 3.3 feet (1 meter), with a distance between wave crests of more than 60 miles.

Undersea Earthquake: The vertical movement of the sea floor causing ground motion.

Urban Heat Island: A metropolitan area that is significantly warmer than its surrounding rural areas due to human activities.

Urban Karst: Used by ecologists to describe the dense, integrated underground water networks of highly developed areas; 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 damage, 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 effects.

Vulnerability Assessment: A process that further develops the risk assessment by examining current exposure (measures 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 brief period of time. Weather may describe current temperature, humidity, precipitation, wind, or other similar conditions. A weather forecast may predict conditions in the near future.

Worms: A form of malware that uses a self-replicating code to automatically spread between apps and devices without human action.

Winter Storms: A combination of heavy snow, blowing snow, and dangerous wind chills. Winter storms can be life-threatening.

Winter Storm Severity Index (WSSI): A national rating system by the NWS. The WSSI helps to inform the community on potential winter storm impacts, such as property and transportation damage and disruption to daily activities.

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